# The ecology of bottlenose dolphins (*Tursiops truncatus*) in the Hauraki Gulf, New Zealand

A thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Conservation Biology

**Blair R. Outhwaite**

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MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

# Abstract

Bottlenose dolphins (*Tursiops truncatus*) are one of the most studied cetacean species in the world. In New Zealand, this species is classified as *Nationally Endangered* and studies are generally limited to just a few known core areas. Herein, I examine the use of social media in citizen science as a means of collecting occurrence data of bottlenose dolphins in the inner Hauraki Gulf. A dedicated research vessel was employed to verify data collected by citizen scientists. This study also investigated the habitat selection of bottlenose dolphins at Great Barrier Island, an area only recently described for its importance to the north-eastern North Island population. Data collected for a behavioural budget and whistle repertoire were recorded on a dedicated research vessel with the aim of understanding habitat selection. Environmental variables were used to model behavioural states in order to determine how habitats were utilised by the dolphins. The whistle repertoire was assessed to understand how it correlated with behavioural states and group dynamics.

A total of 260 sightings of bottlenose dolphins were reported by citizen scientists between April 2015 and July 2016. Only 42 of these were independent reports. Of the total number of reports, 73.5% did not identify a dolphin species. Citizen scientists identified three species of cetacean. Killer whales (*Orcinus orca*) were often reported correctly, however all five reports of common dolphins (*Delphinus delphis*) were misidentified, and 33.3% (n=5) of the reports identifying bottlenose dolphin were either unconfirmed or misclassified. Researchers' verifying the identity of the species reported was the most useful method of confirming citizen science reports in this study (34.8%). Citizen scientists failed to detect dolphins on only three occasions that the research vessel or platform of opportunity did. Yet, citizen scientists were able to detect bottlenose dolphins more often than either the research vessel or platform of opportunity.

The number of independent citizen science reports, research vessel encounters and platform of opportunity encounters for bottlenose dolphins were similar over each austral season. Notably, only the platform of opportunity had encounters over summer, both of which were in deeper water, outside of the study area. Bottlenose dolphin group size was often underestimated by citizen scientists in this study, though rigid comparisons were not possible for group size or behavioural state due to small sample sizes. The proportion of total reports varied temporally between seasons, and was highest in the mornings for autumn and winter, but peaked during the afternoons in spring. Bottlenose dolphins did not appear to use the study area frequently and were usually recorded travelling.

The majority of behavioural observations at Great Barrier Island were made during winter and spring. Bottlenose dolphins were recorded between 13.5 and 24.1°C and in depths of 1.8 to 55.3m. The largest group sizes were recorded in autumn while the smallest group sizes were recorded most often in spring and summer. While the largest group sizes were recorded in the warmest sea surface temperatures and greatest depths, there was no significant difference between group size categories. Resting made up the largest proportion of the behavioural budget (32.1%), while foraging (8.2%) and socialising (9%) were rarely recorded. The models predicted that the behavioural budgets at Great Barrier Island were determined primarily by abiotic factors (e.g. depths and sea surface temperature).

The mean whistle rate, calculated as the number of whistles per minute per dolphin, recorded at Great Barrier Island for bottlenose dolphins was 0.50 (SD=0.53) and the highest whistle rate was recording during foraging (1.17, SD=0.98). There was no significant difference in whistle rates between group size categories. Whistles recorded lasted on average 0.84s (SD=0.52), with a mean frequency of 11.6kHz (SD=2.34). The parameters with the highest variation were the number of inflection points, length, and frequency range of whistles. The Ascending whistle type was the most commonly recorded, and particular whistle types were correlated to behavioural state and group size category.

This study represents the first instance that citizen science utilised social media in the Hauraki Gulf and suggests there is potential for continued monitoring of bottlenose dolphins with citizen science, if recommendations are applied. It also presents the first behavioural budget and whistle repertoire for bottlenose dolphins at Great Barrier Island. This study reported a unique behavioural budget and acoustic parameters that imply its importance for the north-eastern North Island population. Continued monitoring of this population is recommended to ensure this population is managed appropriately.

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# Table of contents

## Chapter 4 Whistle repertoire of bottlenose dolphins (*Tursiops truncatus*) at Great Barrier Island, New Zealand ............................ 86

## List of figures

# List of tables

# List of abbreviations

| | |
|---|---|
| ANOVA | Analysis of variance |
| BOI | Bay of Islands |
| ca. | Circa (approximately) |
| DE | Dolphin Explorer |
| df | Degrees of freedom |
| e.g. | Exempli gratia (for example) |
| etc. | Et cetera (and so forth) |
| GBI | Great Barrier Island |
| h | Hour |
| hp | Horse power |
| Hz | Hertz |
| i.e. | Id est (that is) |
| IHG | Inner Hauraki Gulf |
| IUCN | International Union for Conservation of Nature |
| kHz | Kilohertz |
| km | Kilometre |
| m | Metre |
| MMPR | Marine Mammals Protection Regulations |
| NA | Not applicable |
| NIWA | National Institute of Water and Atmospheric Research |
| p | P-value |
| POP | Platform of opportunity |
| RV | Research vessel |
| s | Second |
| SD | Standard deviation |
| SE | Standard error |
| SST | Sea surface temperature |
| USA | United States of America |
| WDWNS | Whale and Dolphin Watch - North Shore |
| WDWW | Whale and Dolphin Watch Whangaparaoa |
| $X^2$ | Chi-square statistic |

# Chapter 1

# General Introduction

A bottlenose dolphin (*Tursiops truncatus*) breaching at Great Barrier Island with the Coromandel Peninsula featured in the background.

## 1.1 Introduction

The field of ecology studies the interactions between organisms and their environment, supporting a wide range of species including: trees (Lindenmayer & Laurance 2016), beetles (Seibold et al. 2015), fish (Weng et al. 2015), birds (Powell et al. 2015), ungulates (Felton et al. 2017), and whales (Vikingsson et al. 2015). Understanding the distributional (Farhadinia et al. 2017; García Erize & Gómez Villafañe 2016; Stevenson et al. 2015; Subba et al. 2017), behavioural (Ghaskadbi et al. 2016; Li et al. 2015; Mekonnen et al. 2017) and acoustic (Nelson et al. 2016; Schmidt & Balakrishnan 2014; Templeton et al. 2016) parameters of a population can give insights into how a species interacts with its environment and the requirements for conservation. Recognising the environmental needs of such species is a crucial component of effective conservation management.

The ecology of bottlenose dolphins (*Tursiops* spp.) has been well documented internationally. The acoustic behaviour, behavioural state and distribution, have been reported to correlate with a number of environmental factors (Acevedo-Gutiérrez & Stienessen 2004; Allen et al. 2001; Baş et al. 2014; Gregory & Rowden 2001; Hastie et al. 2004; Jones & Sayigh 2002; López 2011; López & Shirai 2009; McHugh et al. 2011; Sini et al. 2005; Vermeulen et al. 2015). These studies provide an insight into which habitats and locations are important for bottlenose dolphins and have helped to improve the understanding of dolphin ecology for species conservation.

In New Zealand, studies of bottlenose dolphins have focused on the Bay of Islands (Constantine 2002; Constantine et al. 2004; Hartel et al. 2014; Peters & Stockin 2016; Snell 2000; Tezanos-Pinto et al. 2013), Fiordland (Boisseau 2004, 2005; Currey et al. 2009; Haase & Schneider 2001; Lusseau 2003a, 2003b; Lusseau et al. 2003; Schneider 1999; Williams et al. 1993) and to some extent, the Marlborough Sounds (Merriman et al. 2009; Merriman 2007). However, the north-eastern North Island population habitat extends well beyond the Bay of Islands. The waters surrounding Great Barrier Island (GBI) have recently been described as of overlooked importance for the *Nationally Endangered* bottlenose dolphins (Dwyer et al. 2014). Anecdotal reports also indicate that the coastlines of the inner Hauraki Gulf (IHG) may be of greater use to bottlenose dolphins than previously thought.

## 1.2 Taxonomy

Bottlenose dolphins belong to the delphinid subfamily Delphininae (LeDuc et al. 1999). Two species of bottlenose dolphins are currently recognised; common bottlenose dolphins (*T. truncatus*) and Indo-Pacific bottlenose dolphins (*T. aduncus*) by the Committee on Taxonomy (2016). Indo-Pacific bottlenose dolphins are genetically closer to the oceanic dolphins (*Stenella* and *Delphinus*) than to the common bottlenose dolphin. The *Tursiops* genus also varies geographically in distribution; common bottlenose dolphins occur throughout the North Atlantic, the Gulf of Mexico, the North Pacific, Chile, Argentina, southern Australia and New Zealand, while Indo-Pacific bottlenose dolphins occur around the east coast of Africa, through the Persian Gulf and south-east Asia and along the northern half of Australia (Rice 1998). Indo-Pacific bottlenose dolphins are generally smaller than common bottlenose dolphins and upon reaching maturity spots often develop on their ventral surface (Constantine 2002; LeDuc et al. 1999). Recently, a third species, Burrunan dolphins (*T. australis*), which is endemic to the southern and south-eastern regions of Australia, has been proposed (Charlton-Robb et al. 2011), but is still debated (Committee on Taxonomy, 2016).

Bottlenose dolphins in New Zealand have been recognised as common bottlenose dolphins (Tezanos-Pinto et al. 2009) although, two ‘ecotypes’ (coastal and oceanic) are known to occur (Baker et al. 2010; Zaeschmar 2014). The oceanic form has been distinguished based on gross morphology; their body size is comparatively larger and they are more robust, while typically displaying oval wounds and scars which are presumably inflicted by *Isistius* spp (Constantine 2002; Dwyer & Visser 2011; Visser et al. 2010). Generally, the oceanic ecotype is considered pelagic and is rarely observed in coastal waters (Visser et al. 2010; Zaeschmar 2014). The bottlenose dolphins in the north-eastern North Island population (including the Hauraki Gulf) have been considered as a coastal population of common bottlenose dolphins (Constantine 2002; Dwyer et al. 2014), hereafter referred to as bottlenose dolphins.

## 1.3 Morphology

*Tursiops* spp. demonstrates geographical variation in morphology. For example, adult lengths vary from 1.9 to 3.8m depending on population (Jefferson et al. 2008; Wells & Scott 2009, 2017). They tend to have a medium-sized, robust body with a tall and falcate dorsal fin set near the middle of their back (Jefferson et al. 2008; Wells & Scott 2009).

There is a crease that distinctly sets off the melon from the, short-to-moderate length, stocky rostrum (Jefferson et al. 2008).

The colour pattern varies from light grey to nearly black on the back and sides, fading to white (occasionally with a pinkish hue) on the belly (Jefferson et al. 2008; Wells & Scott 2017). Spots rarely occur and are usually small flecks on the belly and lower sides. Occasionally faint dorsal capes and/or spinal blazes may occur. Strips are present around the eyes and blowhole, but intensity varies and often brushings of grey occur over the body and face. A light patch on the side of the melon often occurs and they may display a throat chevron and/or genital patch (Jefferson et al. 2008). Male bottlenose dolphins tend to be larger than females, which is suggested to be consistent with the model of polygamous mating systems (Connor et al. 2000; Jefferson et al. 2008; Tolley et al. 1995).

**Figure 1.1** A bottlenose dolphin (*Tursiops truncatus*) porpoising from the water at Great Barrier Island, New Zealand. Note: the falcate dorsal fin located towards the middle of the dolphin, the dark to light grey pigmentation, the dark strip running over the eye to the pectoral fin and the robust rostrum, all traits indicative of a bottlenose dolphin (*T. truncatus*).

## 1.4 Social Organisation

Mammal societies are dynamic and complex (e.g. carnivores, primates, cetaceans) and form distinct assemblages, in which many of their members may interact and associate with other known or unknown individuals (Goodall 1986). Dolphin societies or communities are largely comprised of individuals that occupy the same general area and have frequent interactions with each other (Wells et al. 1987). Coastal bottlenose dolphin societies are characterised as fission-fusion, generally consisting of small assemblages that form a wide range of social bonds as individuals are exchanged between groups (Würsig & Pearson 2015). Bottlenose dolphins also form stable, long-lasting associations and individuals often show strong site fidelity (Wells 1991; Lusseau 2003b).

Affiliation between bottlenose dolphins is expressed through proximity, physical contact, and synchronous movement (Connor et al. 2000). Mothers and their young calves maintain close proximity and synchronise swimming (Connor et al. 2000; Mann & Smuts 1999). Females have been reported to form large networks of associates and are linked to the majority of other females, either through mutual association or occasional occurrence in the same group, though most have a strong association with a subset of other females (Connor et al. 2000; Smolker et al. 1992; Würsig & Pearson 2015). Calf survival is often related to group size and thus females may benefit from these associations through decreased predation risk, reduced male harassment and/or shared parental care (Connor et al. 2000; Gibson & Mann 2008).

Relationship parameters vary between populations, some populations show strong long-term associations between the same sex (Connor et al. 2000; Connor & Krützen 2015; Owen et al. 2002; Wells 2014). These sex-specific associations are generally characterised by differences in association patterns, as long-term bonds form between male-male alliances and looser associations form among female dolphin networks (Baker, O'Brien, McHugh, & Berrow 2017; Wiszniewski et al. 2012; Würsig & Pearson 2015). Though, in some populations strong associations occur between males and females (Baker, O'Brien, McHugh, & Berrow 2017) and in others, no sex-specific alliances are observed (Augusto et al. 2012; Wilson 1995).

Bottlenose dolphin group sizes typically range from 2 – 15 individuals, although groups of over 1,000 individuals have been reported (Shane et al. 1986; Shirihai 2006; Würsig & Pearson 2015). The bottlenose dolphins that inhabit pelagic waters tend to form larger groups (Connor et al. 2000; Lowther-Thieleking et al. 2015). Groups found in pelagic waters can often be found in mixed species aggregations with species such as pilot whales (*Globicephala* spp.) or false killer whales (*Pseudorca crassidens*; Connor et al. 2000; Zaeschmar et al. 2014).

The median group sizes for New Zealand bottlenose dolphins are usually between 8 – 12 individuals, up to a maximum of 60 animals (Brough et al. 2015; Constantine 2002; Merriman et al. 2009; Tezanos-Pinto 2009). Though, groups of more than 15 dolphins are not uncommon in New Zealand populations (Lusseau et al. 2003; Merriman et al. 2009). Furthermore, bottlenose dolphins at GBI have been reported to have median group sizes of 35 animals with a maximum of 80 individuals (Dwyer et al. 2014). Little work has been published on the social structure of bottlenose dolphins in New Zealand. However, in Doubtful Sound, sex-specific alliances have not been observed amongst bottlenose dolphins, but some male-female associations were stable over the course of several years (Lusseau et al. 2003).

## 1.5 Distribution

The distribution of *T. tursiops* is cosmopolitan (Figure 1.2) and they display great social and morphological variation geographically. Bottlenose dolphins can be found in the majority of the world's warm temperate to tropical seas, in both coastal and offshore waters (Wells & Scott 2009). They exhibit a full spectrum of movements which include seasonal migrations, year-round home ranges, periodic residency, as well as a combination of occasional long range movements and repeated local residency (Shane et al. 1986; Wells & Scott 2009).

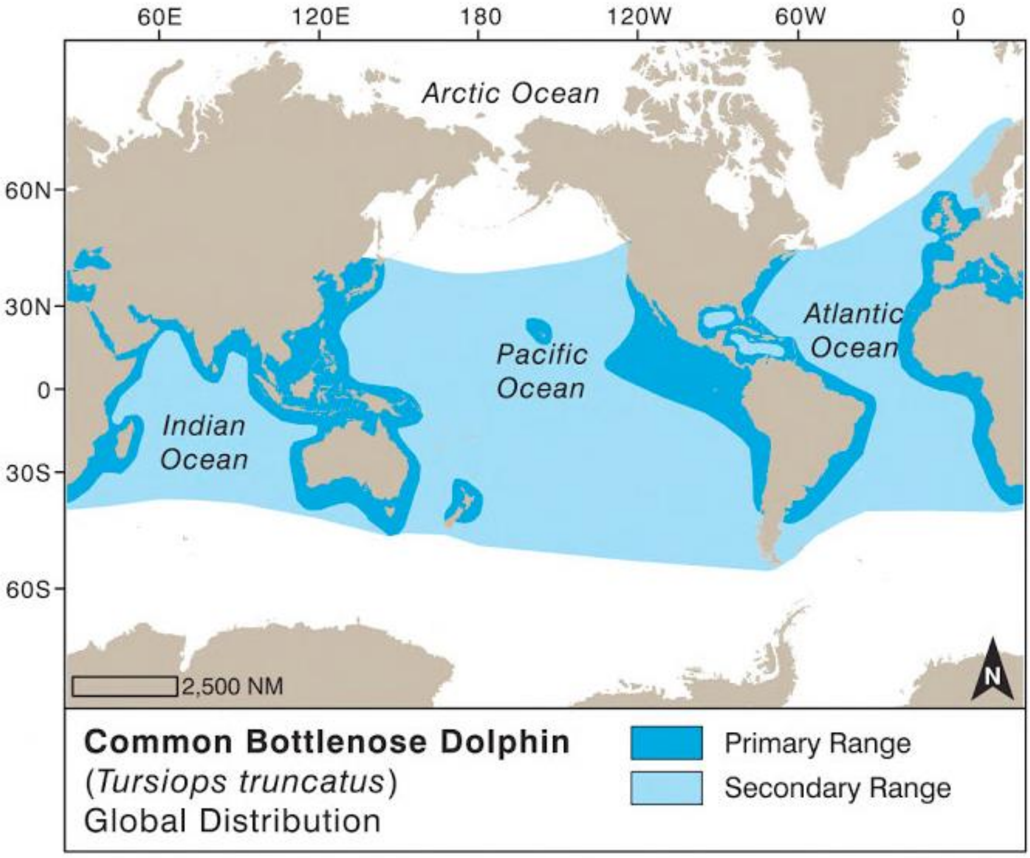


**Figure 1.2** Species range of common bottlenose dolphin (*Tursiops truncatus*). Modified from Würsig et al. (2017).

Bottlenose dolphins in New Zealand waters occur in both coastal and pelagic habitats (Constantine 2002), with three discontinuous coastal populations located in north-eastern North Island, Marlborough Sounds and Fiordland (Figure 1.3; Tezanos-Pinto et al. 2009). It has recently been reported that individuals from the Fiordland population have been identified in two previously unidentified areas for bottlenose dolphins, Stewart Island and Otago Harbour (Brough et al. 2015). Photo-identification and genetic results suggest there is little to none exchange of individuals between populations (Tezanos-Pinto et al. 2009).

Bottlenose dolphins in the Bay of Islands have been studied intensively and it appears there are no resident individuals, but instead a subset of regular users and infrequent visitors (Constantine 2002; Tezanos-Pinto 2009). Over half of the individuals identified in the Hauraki Gulf have been recorded in the Bay of Islands and there appears to be strong seasonality in the IHG (Berghan et al. 2008). GBI, located in the outer Hauraki Gulf, has been reported as a core area for the north-eastern North Island population and bottlenose dolphins were recorded there year round (Dwyer et al. 2014). Individuals known to frequent GBI waters have been recorded in the Bay of Islands (Tezanos-Pinto 2011) and the IHG (unpub. data).

**Figure 1.3** The presumed distributions of the three bottlenose dolphin populations (shaded) in New Zealand, based on live sightings, excluding the potentially extended range of the Fiordland population to Dunedin (Otago Harbour), recently reported by Brough et al. (2015; map retrieved from: http://www.teara.govt.nz/en/map/4681/new-zealand-distribution-of-bottlenose-dolphins).

## 1.6 Ecology & Life History

*Tursiops* inhabit a range of marine and estuarine habitats along shorelines in most warm temperate and tropical areas, occurring in primarily coastal waters which extend into harbours, bays, estuaries, rivers and fiords, but also occur in pelagic waters near oceanic islands and over the continental shelf (Leatherwood & Reeves 1990; Wells & Scott 2009). The diverse array of population structures reflects their ecological flexibility, from small resident groups (Augusto et al. 2012; Chabanne et al. 2012; Louis et al. 2017) and mobile coastal populations (Defran et al. 2017; Hwang et al. 2014; Morteo et al. 2017) to large pelagic schools (Lowther-Thieleking et al. 2015).

Female *Tursiops* can live to more than 67 years old, while males have shorter lifespans, reaching up to 52 years old (Wells & Scott 2017). In addition to differences in lifespan, most populations exhibit sexual dimorphism, where males tend to be slightly larger than females (Shirihai 2006). Bottlenose dolphins typically reach sexual maturity between the ages of 10 and 15 years old (Würsig et al. 2017), but as early as five years old (Robinson et al. 2017). They give birth to a calf between 0.84 – 1.4m in length, every two to six years, after a 12 month gestation period (Connor et al. 2000; Shirihai 2006; Wells & Scott 2017; Whitehead & Mann 2000). Calving tends to be diffusely seasonal with peaks during spring-summer, though births have been recorded from all seasons (Smith et al. 2016; Sprogis et al. 2016; Thayer et al. 2003; Wells & Scott 2009). *Tursiops* display significant parental investment through prolonged calf associations, typically ranging from 3 to 5 years (Connor et al. 2000; Wells & Scott 2017).

*Tursiops* calves are more prone to predation than adults (Fearnbach et al. 2011). Their natural predators include both killer whales (*Orcinus orca*) and sharks (Heithaus & Dill 2002; Wells & Scott 2017). While bottlenose dolphins generally predate on a large variety of squid and fish (Kiszka et al. 2014; Wells & Scott 2017), specialisation has been documented in some populations (Gannon & Waples 2004; Sargeant & Mann 2009).

Bottlenose dolphins in New Zealand have a varied diet of fish and squid. In the Bay of Islands, they have been observed preying on a wide range of fish species (Hartel 2010) and stomach content analysis in the Doubtful Sound revealed a varied diet of squid and fish, most of which were reef-associated fish or demersal (Lusseau & Wing 2006). They display seasonal trends in calving across New Zealand with most births occurring between autumn and spring (Constantine 2002; Henderson et al. 2014; Tezanos-Pinto 2009), and have been reported to give birth approximately every four years (Henderson et al. 2014; Tezanos-Pinto et al. 2015). The population structures of bottlenose dolphins in New Zealand include small resident groups (Currey et al. 2008), mobile coastal populations (Berghan et al. 2008; Brough et al. 2015; Constantine 2002; Merriman et al. 2009) and large pelagic schools (Zaeschmar 2014).

## 1.7 Habitat Use and Selection

Species occur in a higher abundance in certain habitats and are not uniformly nor randomly distributed, rather they are aggregated in patches, form gradients or occur within other spatial structures (Boulangeat et al. 2012; Legendre & Fortin 1989; Morris 1987). Managing anthropogenic impacts on a species requires knowledge of the factors driving their distribution and abundance (Boulangeat et al. 2012; Manly et al. 2002; Moe et al. 2007). The disproportionate use of a habitat relative to its availability is habitat selection, and it can operate at various spatial and temporal scales (Apps et al. 2004; Johnson 1980; Mysterud et al. 1999; Schooley 1994). Habitat selection studies are important to incorporate both habitat and demographic information into conservation planning, they demonstrate how factors, such as landscape structure, can influence precisely how animals navigate and select habitats (Allen et al. 2014; Caughley 1994; Jones 2001; Sánchez-Clavijo et al. 2016).

Bottlenose dolphins display great plasticity in habitat selection. Behavioural budgets vary between location, time of day, and population (Bearzi et al. 1999; Beddia 2007; Garcia et al. 2017; Gregory & Rowden 2001; Hanson & Defran 1993; Mattos et al. 2007; Sini et al. 2005; Vermeulen et al. 2015). Habitat selection has also been impacted by predation (Heithaus & Dill 2002, 2006; Mann et al. 2000), prey selection (Garcia et al. 2017; Heithaus & Dill 2002; Veneruso & Evans 2012), anthropogenic impacts (Bas et al. 2017; Bejder et al. 2006; Lusseau 2005) and environmental factors such as bottom topography (Allen et al. 2001), depth (Hastie et al. 2004; Wilson et al. 1997) and water temperature (Barco et al. 1999). Bottlenose dolphins are often reported to be engaged predominantly in foraging or travelling (Baker, O'Brien, McHugh, Ingram & Berrow 2017; Bearzi et al. 2009; Beddia 2007; Filby et al. 2017; Garcia et al. 2017; Inoue et al. 2017; Mattos et al. 2007; Sini et al. 2005; Veneruso & Evans 2012). Foraging has been reported to make up 0.04% to 61% of their behavioural budget (Ballance 1992; Bearzi et al. 2009; Sini et al. 2005) while travel has been reported from 19.6% to 65% (Bearzi et al. 1999; Filby et al. 2017). Behavioural state has been reported to be influenced by a number of factors, including: tidal state (Gregory & Rowden 2001; Inoue et al. 2017), time of day (Garcia et al. 2017; Hanson & Defran 1993; Sini et al. 2005; Vermeulen et al. 2015), group composition (Barco et al. 1999), season (Baş et al. 2014; Miller et al. 2010; Vermeulen et al. 2015) and/or habitat, such as topography (Hanson & Defran 1993; Hastie et al. 2004), algal blooms (McHugh et al. 2011), and vegetation (Allen et al. 2001).

Studies in behaviour and habitat selection of bottlenose dolphins in New Zealand have been focused on animals in the Bay of Islands (Constantine et al. 2004; Hartel et al.

2014), Fiordland (Lusseau 2003a, 2006; Schneider 1999) and the Marlborough Sounds (Merriman 2007) areas, which all have commercial whale and dolphin watching operations. Foraging and/or traveling also appear to make up the largest proportion of time spent in the dolphins' behavioural budget in New Zealand (Lusseau 2004; Merriman 2007; Peters & Stockin 2016; Schneider 1999). Differences in habitat use have been displayed between various locations within the distribution of the Marlborough Sounds population, with defined areas for socialising and travelling (Merriman 2007).

Similarly, the waters surrounding GBI may provide specific functions for the local bottlenose dolphin population. It has been hypothesised that the large average group sizes at GBI may relate to food availability due to large upwellings around the island (Dwyer et al. 2014), which has been suggested to produce high biological productivity (Black et al. 2000). The high number of neonates and calves at GBI may also influence the large average group sizes. Mann et al. (2000) suggests that large group sizes were associated with the presence of individuals less than 3 months old, which may reflect predator avoidance. Alternatively, GBI may represent a social hub where smaller groups fuse for socialising (Dwyer et al. 2014).

## 1.8 Acoustics

Communication is crucial for social behaviour (Janik 2009) and consists of associations between signals from one individual to another (Wiley 2006). It is a core part of animal behaviour, as all social interactions between individuals depend on exchanging information (Brumm 2013). Animals may convey information through means such as optical, acoustic, electrical, or chemical signals (Brumm 2013). Communication is dependent on a signal being encoded with information from a sender, which is then transmitted to a receiver (Shannon and Weaver 1949). Sound propagates much better than light in water and many marine animals have evolved ways to utilise sound as their primary distance sense to communicate and echolocate (Tyack and Janik 2013).

Mechanisms have evolved in marine mammals which allow them to use a wide range of frequencies of underwater sound (Tyack and Janik 2013). As lower frequency sounds travel further in the ocean, baleen whales (Mysticeti) have evolved mechanisms to produce and hear sound in the frequency range from less than 10 Hz to several hundred Hz which can be detected over hundreds of kilometres (Stafford et al. 1998; Tyack and Janik 2013). Delphinid signals are generally considered to belong to one of three categories: whistles, burst-pulsed sounds, and clicks. Clicks are most commonly used for echolocation (Janik 2009), but some species of toothed whales also use clicks for communication, such as sperm whales (*Physeter macrocephalus*; Weilgart & Whitehead 1993), harbour porpoises (*Phocoena phocoena*; Clausen et al. 2010), and Hector's dolphins (*Cephalorhynchus hectori*; Dawson 1991). Clicks are relatively broadband, short signals and often reach into the ultrasonic range (Janik 2009) while burst-pulsed signals consist of rapid click trains, and the term burst pulse sound is often used to describe all sounds that do not fall into the categories of whistles or clicks (Janik 2009). Most delphinids produce whistles which are frequency modulated, narrow band harmonic signals (Tyack and Janik 2013).

Whistles convey information about identity, relative position and emotional state (Caldwell and Caldwell 1972). They are thought to help maintain group cohesion and unite separated individuals/groups (Tyack and Janik 2013). It is thought that the effective range of these communication signals is several kilometres to tens of kilometres (Janik 2000; Miller 2006), which is consistent with the largest distance expected between conspecifics sharing strong social bonds (Tyack and Janik 2013). The fundamental frequency of their whistles generally ranges from 2 kHz to 25 kHz (Boisseau 2004; Janik 2009) and lasts from 0.1 to 4 seconds (Janik 2009; Tyack and Janik 2013). The complexity of frequency modulations that dolphins produce in their acoustic signals varies between populations and species (Janik 2009).

Bottlenose dolphins are extremely vocal (Boisseau 2005). The whistle rates and parameters recorded for bottlenose dolphins have indicated that whistle features are often dependent on group size and/or behaviour (Cook et al. 2004; Hawkins & Gartside 2010; Janik et al. 1994; Jones & Sayigh 2002; Quick & Janik 2008). In New Zealand, little acoustic research has been undertaken on bottlenose dolphin whistles. The acoustic repertoire of bottlenose dolphins in Fiordland described 12 individual signal types (Boisseau 2004, 2005) and the whistle repertoire has been partly described for the north-eastern North Island population, in the Bay of Islands (Snell 2000).

### 1.8.1 Luscinia

Luscinia is software that was written and maintained by the Department of Biological and Experimental Psychology, in the School of Biological and Chemical Sciences at Queen Mary University of London for bioacoustic measurement, analysis and archiving (Lachlan 2007; http://rflachlan.github.io/Luscinia/). Acoustic recordings are stored together with metadata about the location of the recording, who made them, and their measurements. The purpose of Luscinia is to provide a fast, flexible and reliable way to semi-automatically measure acoustic signals.

Signals are measured using 15 acoustic parameters as contours and hierarchical information of how complex signals are structured. It also implements a wide array of analytical methods, from exporting summary statistics to the implementation of a dynamic time warping algorithm, which allows for the comparison of disparate and complex signals (Lachlan 2007).

To this date, Luscinia has primarily been used in ornithology (e.g. Geberzahn et al. 2009; Greig et al. 2013; Halfwerk et al. 2012; Holveck et al. 2008; Lachlan et al. 2016; Prather et al. 2010; Schwabl et al. 2015; Yorzinski 2014), but it has also been utilised during studies of cichlids (Cichlidae; Verzijden et al. 2010) and dwarf mongoose (*Helogale parvula*; Rubow et al. 2017a, 2017b). These studies assessed a range of bioacoustics, such as song learning, vocal intersexual competition, environmental impacts on vocal production, natural and sexual selection on vocal complexity and identification of individuals (Geberzahn et al. 2009; Greig et al. 2013; Halfwerk et al. 2012; Holveck et al. 2008; Rubow et al. 2017b). The present study will utilise Luscinia as a method to take measurements from bottlenose dolphin whistles and to semi-automatically classify whistle types.

## 1.9 Citizen Science

The method of collecting data through citizen science is being utilised over an expanding range of scientific disciplines (Bhattacharjee 2005; Bonney et al. 2009; Conrad & Hilchey 2011; Cooper et al. 2014; Silvertown 2009). Citizen science involves collecting data for scientific research by non-specialist volunteers (Bhattacharjee 2005; Silvertown 2009). The benefits of utilising citizen science include; the integration of public outreach and the collection of simultaneous observations over large spatial and temporal scales (Bhattacharjee 2005; Bonney et al. 2009; Conrad & Hilchey 2011; Cooper et al. 2007, 2014; Silvertown 2009).

The increased utilisation of citizen science has been facilitated by: easily accessable technology (e.g. the internet and smartphones), the recognisation of free labour, skills, computational power and finance, and in some cases, the requirement by funding agencies to include public outreach related to the project (Cohn 2008; Silvertown 2009). Concerns over the legitamcy of citizen science have risen, but many studies have demonstrated that citizen science can collect data equal to that of experts when provided with protocols, training and over sight (Bonney et al. 2014; Danielsen et al. 2014; Davies et al. 2013; Delaney et al. 2008; Edgar & Stuart-smith 2009; Fore et al. 2001; Foster-smith & Evans 2003; Newman et al. 2003). Other studies have demonstrated that data quality and spatial issues may be offset by improving sampling protocols (Edgar & Stuart-smith 2009), data management (Crall et al. 2011), modifying project design (Cooper 2014; Engel & Voshell 2002; Tregidgo et al. 2013) and filtering or subsampling data to deal with error and uneven effort (Fink et al. 2010; Sullivan et al. 2014; Wiggins & Crowston 2011; Wiggins et al. 2011).

Citizen science appears to be particularly suited to ecological research, which is is often labour intensive, but techically straight-forward (Foster-smith & Evans 2003). Studies of cetaceans using citizen science (or at least the term ‘citizen science’) are lacking in published literature even though there are numerous websites dedicated to it (Appendix 1.1). However, in 1973 citizen science was utilised by enlisting a large network of observers to review the cetaceans using Brittish waters (Evans 1980). Since then, a number of theses and scientific papers have employed citizen science to monitor the recovery of an injured bottlenose dolphin (*Tursiops* spp.; Bossley & Woolfall 2014), investigate the the distribution of humpback whales (*Megaptera novaeangliae*; Bruce et al. 2014) and delphinids (Giovos et al. 2016), monitor the occurrence of multiple coastal cetacean species (Embling et al. 2015; Lodi & Tardin 2018), and catagorise vocalisations from killer (*Orinus orca*) and pilot whales (*Globicephala* spp.; Shamir et al. 2014). Citizen science could prove a key resource for the conservation of bottlenose dolphins in New Zealand.

## 1.10 Conservation Status

Determining the global threat status of bottlenose dolphins has been hindered by their extensive geographic range and historically unclear taxonomic status (Currey 2008; Reeves & Leatherwood 1994; Reeves et al. 2003). Bottlenose dolphins were assessed as *Least Concern* in 2008 on the IUCN Red List while Indo-Pacific bottlenose dolphins have remained *Data deficient* (IUCN 2016). Presently no evidence suggests bottlenose dolphins are threatened globally, however many regional populations are threatened with anthropogenic impacts (Reeves et al. 2003). The bottlenose dolphins in New Zealand were upgraded from *Range Restricted* to *Nationally Endangered* in 2009 due to the apparent decline of two populations (Baker et al. 2010, 2016).

## 1.11 Anthropogenic impacts

Cetaceans are faced with a wide range of anthropogenic threats. The increased use of motorised transportation frequently brings humans and wildlife into contact, either through direct physical contact or indirectly by posing greater anthropogenic noise. Evidence suggests that the noise or presence of motorised water vessels causes cetaceans to elicit avoidance behaviours such as: increased swimming speed (Marley et al. 2017; Nowacek et al. 2001), longer dive durations (Janik & Thompson 1996; Ng & Leung 2003; Nowacek et al. 2001), heading changes (Au & Perryman 1982; Baş et al. 2017; Nowacek et al. 2001; Schaffar et al. 2013), decreased inter-animal distance (Bejder et al. 1999; Nowacek et al. 2001), and increased breathing synchrony (Hastie et al. 2003).

Increased anthropogenic noise in the oceans is a growing concern as it can have an impact on cetacean communication, disrupt behaviour, and even cause temporary hearing loss (Hatch & Wright 2007; Shannon et al. 2016). Cetaceans often alter their acoustic rates before, during or after exposure to anthropogenic noises, such as drilling, military sonar or boat traffic (Blackwell et al. 2017; Buckstaff 2004; Rendell & Gordon 1999; Van Parijs & Corkeron 2001) which may serve to improve information transmission and/or facilitate group cohesion to a perceived threat (Tyack and Janik 2013). Acoustic structures may also be modified when the noise level is not changing quickly enough or the individual cannot wait to transmit the signal. Cetaceans have been reported to increase the level of their call or alter frequency parameters of their acoustic signals in response to anthropogenic noise (Gospić & Picciulin 2016; Heiler et al. 2016; Lesage et al. 1999; Papale et al. 2015; Parks et al. 2011; Scheifele et al. 2005). Furthermore, signals may be altered to extend the length of calls (Wieland et al. 2010) or increase the number of repetitions (Fristrup et al. 2003; Miller et al. 2000) during periods of increased noise.

Recreational vessels are perhaps the source of the greatest anthropogenic noise in coastal waters, as boat noises range between 0.1 and 10kHz (Buckstaff 2004). This range overlaps an important mode of dolphin communication; whistles, which generally range from 2 to 25kHz (Boisseau 2004; Buckstaff 2004; Janik 2009). Animals will often modify their behaviour in response to fluctuations in environmental noise by changing the amplitude, call type, duration, repetition rate, and/or frequency of sounds produced (Brumm & Slabbekoorn 2005; Buckstaff 2004; Holt et al. 2009, 2015; Lesage et al. 1999; Scarpaci et al. 2000; Van Parijs & Corkeron 2001). The direction and type of acoustic behavioural responses vary between species, but typical responses may enhance signal detectability and group cohesion in a noisy environment. These acoustic responses could have biological costs which may include increased detection by predators or competitors, degraded signal efficacy or function in social contexts as well as direct individual costs such as increased energetic costs and altered metabolic demands (Holt et al. 2015). For bottlenose dolphins living in coastal waters, the greatest source of anthropogenic noise may originate from watercraft (Buckstaff 2004).

Bottlenose dolphins face a range of anthropogenic threats including entanglement in or ingestion of fishing gear (Félix et al. 2017; Miketa et al. 2017; Powell & Wells 2011), pollution (Balmer et al. 2018; Jepson et al. 2016), boat collisions (Dwyer et al. 2014; Félix et al. 2017), and drive or harpoon fisheries (Butterworth et al. 2013; Oremus et al. 2015). Additionally, the impact that tourism has on cetaceans has also raised concerns (Baş et al. 2017; Constantine et al. 2004; Filby et al. 2017; Lusseau et al. 2006; New et al. 2013; Parsons & Scarpaci 2016).

Declines in two populations of bottlenose dolphins in New Zealand are considered to be contributed to largely by tourism and habitat change (Currey et al. 2009; Tezanos-Pinto et al. 2013). The decline in Bay of Islands could be due to an increased mortality and/or low recruitment or increased emigration (Tezanos-Pinto et al. 2013). GBI appears to be an important area for the north-eastern North Island population, with large average group sizes and high numbers of calves (Dwyer et al. 2014), it also lacks commercial whale and dolphin watching tourism and has a perceived low level of disturbance.

## 1.12 Thesis Rationale and Structure

GBI has been identified as an important area for the north-eastern North Island population, due to the year round use, larger than average group sizes and groups that predominantly contain calves (Dwyer et al. 2014). It is vital to understand why GBI's waters are important to the bottlenose dolphins in order to avoid further decline to the north-eastern North Island population through any anthropogenic impacts. Additionally, recent advances in social media led this study to address how it may play a role in citizen science. Citizen science was utilised to investigate the occurrence of bottlenose dolphins in the IHG, an area which previously had little dedicated research.

This research aims to investigate the importance of GBI to the north-eastern North Island population of bottlenose dolphins. Behavioural and acoustic sampling was undertaken on a dedicated research vessel to provide an understanding of habitat selection. Improving knowledge of habitat selection is crucial in the conservation efforts of the *Nationally Endangered* bottlenose dolphins so that areas of importance can be recognised and protected accordingly. Social media pages were monitored for reports, combined with dedicated research surveys along the Whangaparaoa and North Shore coastlines, in order to assess the usefulness of citizen science in this area and the habitat use by bottlenose dolphins in these waters. The use of social media in citizen science may provide a cost effective means of collecting cetacean data within the Hauraki Gulf. Additionally, examining the habitat use of the north-eastern North Island population of bottlenose dolphins provides further understanding of their utilisation of waters outside of areas previously assessed. Together, this research provides a better comprehension of the ecology of the bottlenose dolphins that inhabit the waters of the Hauraki Gulf. The information provided within this thesis may provide useful information for policy makers and management agencies (e.g. Department of Conservation) to improve conservation efforts directed towards the north-eastern North Island population of bottlenose dolphins inhabiting GBI waters and the IHG.

# Chapter 2

# Application of citizen science via social media: a case study on bottlenose dolphins (*Tursiops truncatus*) in the Hauraki Gulf, New Zealand.

A bottlenose dolphin being watched by members of the public that gathered at the beach following citizen science reports of their presence.

## 2.1 Introduction

The utilisation of citizen science is expanding across a wide range of scientific disciplines, including ecology and environmental science (Ballard et al. 2017; Bhattacharjee 2005; Bonney et al. 2009; Conrad & Hilchey 2011; Cooper et al. 2014; McKinley et al. 2017; Silvertown 2009). Citizen science is the collection of data for scientific enquiry by non-specialist volunteers (Bhattacharjee 2005; Silvertown 2009). It enlists the help of the public to collect large quantities of data across an array of habitats and locations over large spatial and temporal scales (Bhattacharjee 2005; Bonney et al. 2009; Cooper et al. 2007). Citizen science data can be collected through various means, such as paper (Spurr 2012) and digital website data forms (Gardiner et al. 2012), mobile phone applications (Sequeira et al. 2014) or social media (Stafford et al. 2010). Contributions from citizen scientists now provide a vast quantity of data, and projects utilising citizen science have been remarkably successful in advancing scientific knowledge (Bonney et al. 2009). However, citizen science is not a universally accepted method for scientific investigation (Bonney et al. 2014), so the involvement of volunteers in science is often poorly documented within the published literature (Fore et al. 2001).

The validation of citizen science data is required to ensure it is utilised appropriately, as volunteer environmental monitoring has become a widespread and global activity (Harvey 2006). The inadequate/incomplete data and monitoring by dedicated scientists and government often impedes a comprehensive understanding of ecosystems. This void is increasingly filled using citizen science and could supplement scarce resources (Conrad & Hilchey 2011; Delaney et al. 2008). Citizen science can also bring publicity and discourse to conservation issues (Bird et al. 2014; Pattengill-Semmens & Semmens 1990). For example, thousands of volunteers throughout the 20th century have participated in a wide range of projects including; climate change, invasive species, conservation biology, ecological restoration, water quality monitoring, and population ecology (Bonney et al. 2009; Silvertown 2009). Citizen science has been used in ecology to; measure air and light pollution (Kyba et al. 2013; Tregidgo et al. 2013), inspect ecosystem rehabilitation (Gollan et al. 2012), map invasive species (Delaney et al. 2008; Jordan et al. 2012) and monitor lady beetle (Coccinellidae), moth (Lepidoptera) and bee (Apoidea) communities (Bates et al. 2013; Gardiner et al. 2012; Kremen et al. 2011). Furthermore, citizen science has been applied specifically to marine mammal populations to monitor distribution patterns of migrating humpback whales (*Megaptera novaeangliae*; Bruce et al. 2014), measure the abundance of humpback whales (Tonachella et al. 2012), classify acoustic data sets from pilot whales (*Globicephala* spp.) and killer whales (*Orcinus orca*; Shamir et al. 2014), monitor an injured individual *Tursiops* spp. (Bossley

& Woolfall 2014), measure spatial trends of harbour porpoises (*Phocoena phoceona*; Camphuysen 2011) and monitor the occurrence of bottlenose dolphins (*Tursiops truncatus*; Bristow et al. 2001; Embling et al. 2015).

Citizen science studies could be utilised as a cost effective means of collecting data on coastal cetaceans in shore based studies. Shore based surveys are limited spatially to areas close to land but they can be a cost effective means to gather occurrence data of cetaceans at coastal locations (Evans & Hammond 2004; Pierpoint et al. 2009). These surveys are also less invasive and do not disturb the behaviour of the study animals, and because of their cost effectiveness they can allow for long-term monitoring (Embling et al. 2015). Shore based surveys have been employed previously in different *Tursiops* spp. studies to quantify the effects of boat disturbance on foraging activity (Pirotta et al. 2015), investigate habitat use and the effects of boat traffic (Sini et al. 2005), determine movement patterns and foraging areas (Bailey & Thompson 2006), and in photo-identification studies to determine site fidelity and habitat use (Levesque et al. 2016; Vermeulen et al. 2016). Citizen science has also begun to utilise land based surveys to identify habitat use (Bristow et al. 2001) and occurrence (Embling et al. 2015) of bottlenose dolphins.

Data collected during shore based observations could be collected and shared through social media platforms as a tool of citizen science. With the advantage of geo-tagging on most social media platforms, scientists could take advantage of information uploaded to these platforms (Bonney et al. 2009). Indeed, there is the potential for these platforms to report cetacean distribution data (Giovos et al. 2016). Studies collecting conservation data through social media have utilised photographs taken by locals and tourists to estimate the supply and demand of ecosystem services, particularly with regards to tourism (Gliozzo et al. 2016; Keeler et al. 2015; Martínez Pastur et al. 2016; Sonter et al. 2016; Tenerelli et al. 2016; Tieskens et al. 2017; Wood et al. 2013; Yoshimura & Hiura 2017).

The social media website and smart phone application, Facebook, had over 1.28 billion daily active users on average for March 2017 (Facebook, 2017) and it was reported in 2015 that on average, over 2 million New Zealanders used Facebook daily (Pelea 2015). A Facebook group was initially established by a member of the public in 2014, with the primary purpose of reporting live sightings of marine mammals, particularly dolphins, around the Whangaparaoa coastline, North Island, New Zealand. These sightings were primarily reported and shared by observers who typically have no access to boats, but could view cetaceans from land. This group started reporting semi-consistent sightings of dolphins in an area not previously considered important, since dedicated research on cetaceans within the area concentrated on the deeper waters of the Hauraki Gulf. A second group, also established in 2014, covers the area south of Whangaparaoa, along the North Shore of Auckland City. Although these groups were not established for the specific purpose of citizen science, this study assesses their usefulness as a citizen science platform by determining what data can be reliably extracted from reported sightings. This was undertaken via a comparison with data collected from a dedicated research vessel and a platform of opportunity to determine how representative citizen science reports may be and thus, how useful social media can be in areas for which otherwise are not subject to any dedicated study or surveys.

The inner Hauraki Gulf (IHG), on the north-east coast of the North Island, has received no dedicated research focused on bottlenose dolphins, though two studies based on a platform of opportunity (Berghan et al. 2008; Martinez et al. 2010) and one dedicated spatial study focused on a range of cetaceans in the area (Dwyer 2014; Dwyer et al. 2014, 2016), did offer the first insights into the potential use of the region by bottlenose dolphins. Sightings of bottlenose dolphins within the region appear more prevalent in winter (Berghan et al. 2008; Dwyer et al. 2016; Martinez et al. 2010), with at least 70% of bottlenose individuals resighted at least once in the Hauraki Gulf (Berghan et al. 2008). Nonetheless, it remains unclear to what extent bottlenose dolphins utilise the IHG. As former studies in the Hauraki Gulf have been limited to small portions of the gulf per day (Dwyer 2014), citizen science may assist in addressing the spatial paucity of coverage in this region (Hann 2015). The Hauraki Gulf also supports two other delphinid species; common dolphins (*Delphinus* sp.) and killer whales (Dwyer et al. 2016; Hupman et al. 2014; Stockin, Pierce et al. 2008, 2009; Visser 1999). Though the focus of this study was bottlenose dolphins, data provided by citizen science on these other two species were collected and further used to assess the ability of citizen scientists to identify species accurately.

The aim of this study was to assess the usefulness of citizen science data collected via social media in cetacean research and to utilise this data to determine the occurrence and minimal range of bottlenose dolphins along the western coastline of the Hauraki Gulf, New Zealand. Specifically, the objectives were to:

1) Examine the usefulness of citizen science data by assessing the accuracy of species identification and the degree of additional data reported with each sighting.

2) Assess the quality of data collected via Facebook groups by comparison of sightings data collected via opportunistic and systematic boat surveys operating in the same region concurrently.

3) Identify inherent biases that occur in non-effort related citizen science data by assessing reports temporally and spatially.

4) Determine the use of coastal inner gulf waters by bottlenose dolphins along the Whangaparaoa and North Shore coastline via a combination of citizen science reports and systematic surveys.

## 2.2 Methods

### 2.2.1 Study area

The Whangaparaoa and North Shore coastlines are located in the western Hauraki Gulf, New Zealand. All waters up to 2km offshore between Hatfields Beach (36°33’51S 174°42’45) to North Head (36°39’48S 174°48’49E) made up the primary study area (Figure 2.1) and encompass ca. 97km$^2$. This study area consisted of relatively shallow water, whereby the maximum depth did not exceed 30m (Chart NZ 5321, Land Information New Zealand).

The Whangaparaoa and North Shore areas surveyed have an urban or suburban periphery, with coastlines characterised by a number of sandy shallow embayments which are interrupted by rocky shoreline. The Whangaparaoa and North Shore coastlines fall into two Local Board Areas (“Hibiscus Coast and Bays” and “Devonport-Takapuna”) for which the 2013 census reported a total population of 145,299 individuals (Statistics New Zealand 2013). The suburbs that make up make the Whangaparaoa survey area have a population of 40,380 individuals with a median age of 41, while the North Shore suburbs along the survey area have a population of 61,998 and a median age of 42.

### 2.2.2 Data collection

#### *2.2.2.1 Citizen science*

Members of the public reported their sightings on the Facebook groups in ‘posts’ (hereafter referred to as reports). A Facebook group is a page created within the social media network for people to share their common interests and express opinions. Two Facebook pages, Whale & Dolphin Watch Whangaparaoa (WDWW) and Whale and Dolphin Watch – North Shore (WDWNS) were used in this study. WDWW currently has over 2800 members while the WDWNS group has over 1300 members. Figure 2.1 displays the approximate reporting range for the target of each group, based on the reports previously posted, which determined the study area mentioned above. The reports posted to these Facebook groups may be in the form of a written message and/or contain photographs or videos that other members of the group can see and make ‘comments’ on. These reports are conveniently time stamped when they are posted to the group.

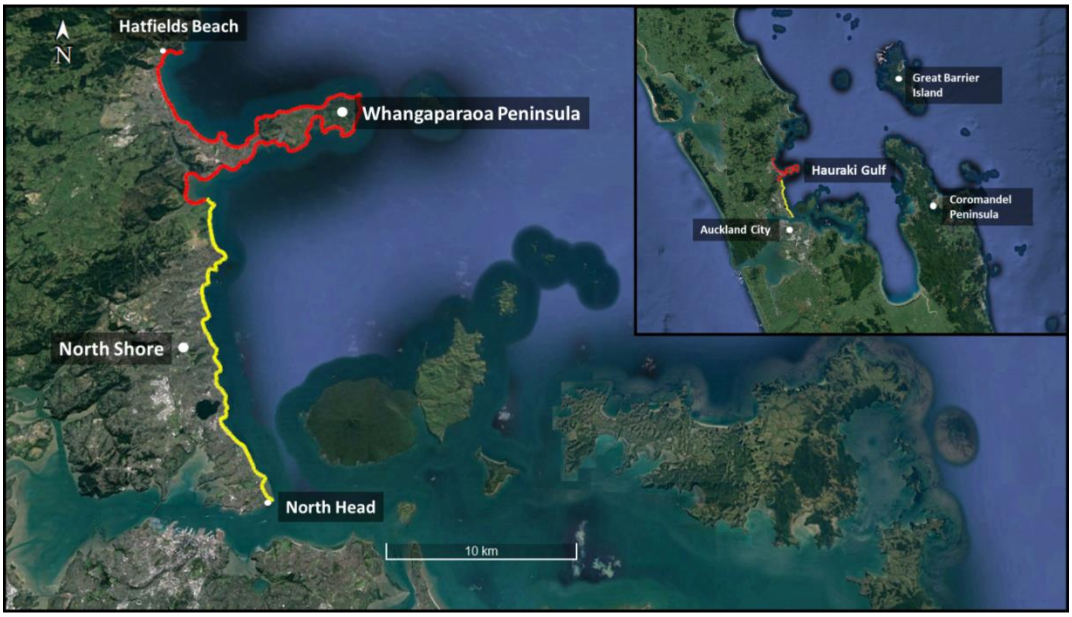


**Figure 2.1** The approximate target area for the Facebook groups along the Whangaparaoa and North Shore Coastline, New Zealand. The red outline indicates the target coastline for WDWW and yellow line indicates the target coastline for WDWNS.

Data from the reports between April 2015 to July 2016 were manually entered into an excel spreadsheet. The information recorded from reports lodged by the public include: date, time, location, species, description of dolphins, group size, group composition, behaviour and direction of travel. The Facebook group that the report was logged in and the species identity as determined by the researcher were also recorded. Researchers were employed as volunteers to assist in recording and assessing details reported by citizen scientists. Each researcher was required to have a minimum qualification of a Bachelor of Science degree majoring in marine sciences (or other relevant degree) and received training on data collection.

Species confirmation in the field by researchers was often not possible and thus was determined by the following methods;

1. Photographic or video evidence
2. An observer rating system to assess the reliability of the individual's capacity to correctly identify species based on their expected experience and/or education given their occupation (Table 2.1)
3. A description provided by the observer of the dolphins' behaviour and appearance assessed against the criteria for each species (Table 2.2)
4. Identification validated by nearby reports of confirmed sightings (based on direction of travel reported and on the temporal and spatial scale is it reasonable to assume that it is the same group of animals being tracked)

It is expected that observers considered *Expert* required a certain level of education and/or experience to perform their role in their given occupation (Table 2.2). For example, it was expected that a Department of Conservation marine ranger would have the ability to identify common species of cetacean in their given area to adequately perform their duties. Observers rated as *Naturalist* were not expected to have the ability to identify common species of cetacean in their local waters as a requirement for their profession, but instead it arises from a high level of personal interest or experience with the animals. For example, a professional boat skipper who has spent many hours working in the Hauraki Gulf would likely have had numerous encounters with the cetaceans inhabiting those waters and know the difference between key species. The *General Public* were observers who had little experience or education identifying different species of cetaceans and were therefore, less likely to be able to correctly classify the species observed. An observer's experience information was obtained either through a review of their biography section on their Facebook profile or via personal contact. If an observer's personal information could not be verified, they were given a rating of three.

**Table 2.1** Observer rating based on their experience with cetaceans. Only observers with a rating of 2 or above were considered to reliably identify species.

| | | |
|---|---|---|
| 1 | *Expert* | Someone whose professional career has required detailed identification knowledge of cetacean species (e.g. a marine scientist, marine ranger) |
| 2 | *Naturalist* | A person experienced with cetacean recognition whose career does not require detailed identification knowledge (e.g. professional boat skippers, amateur wildlife photographer) |
| 3 | *General Public* | Untrained with little or no experience in cetacean identification |

When a citizen scientist provided a description of the animals observed, a combination of features was often used to identify the species (Table 2.2). Given that bottlenose dolphins are frequently performers of aerial behavioural events such as breaching, side slaps, etc. (Shirihai 2006), this was an identifying feature that was used with high confidence. Other species of delphinid known to occur within the region (common dolphins and killer whales) rarely exhibit this behaviour. The known distribution of bottlenose dolphins usually means they can be found inhabiting shallow waters close to the shoreline (Würsig & Würsig 1979). This is contrasted with the known distribution of common dolphins in the Hauraki Gulf, which typically occur in deep waters further from shore (Dwyer et al. 2016; Stockin, Pierce et al. 2008).

The identifying features that held the least confidence were the pigmentation and size descriptions of the dolphins. Nonetheless, it could be reasonably assumed that a dolphin described with a dark dorsum and white ventrum that was large and robust relative to human beings, was a bottlenose dolphin (Shirihai 2006). This was assumed since; 1) killer whales are especially identifiable given their distinct pigmentation and pronounced sexually dimorphic dorsal fin and rounded pectoral fin (Shirihai 2006) and; 2) common dolphins are notably shorter and more slender than bottlenose dolphins, featuring a yellow hour glass pattern (Perrin 2002; Shirihai 2006).

**Table 2.2** Species identification and features used by citizen scientists in descriptions provided in reports of sightings from the Whangaparaoa and North Shore coastline, New Zealand.

| Species | Identifying Features |
|---|---|
| Bottlenose dolphin<br>(*Tursiops truncatus*) | - Often observed side slapping and breaching<br>- Often located close to shore in shallow waters<br>- Large body size<br>- Light/dark grey pigmentation on dorsum fading to a white ventrum |
| Common dolphin<br>(*Delphinus* sp.) | - Often located further from shore in deeper waters<br>- Black, grey, yellow and white ‘hourglass’ pigmentation<br>- Small body size |
| Killer whale<br>(*Orcinus orca*) | - Contrasting black and white pigmentation with white ‘saddle’ and eye patch<br>- Pronounced sexually dimorphic male dorsal fin<br>- Circular pectoral fin |

Only sightings within the study area were selected for this study (Figure 2.1). Reports were recorded from April 2015 to July 2016. A ‘post’ was pinned to the top of the Facebook pages by the group administrators for all members to read, whereby members were asked to provide the details listed above in each report. If a member reported a sighting without a photo or description, they were prompted to provide this additional information where available in the comments section.

To assess the accuracy of data entered into Facebook groups, data collected (as described below) during a systematic survey on a dedicated research vessel (Aihe II) and opportunistically from a non-systematic tour vessel (Dolphin Explorer) were used for comparison. Only data collected from Aihe II and Dolphin Explorer during the same time period of the citizen science reports were used in this comparative assessment.

#### *2.2.2.2 Research Vessel*

Systematic surveys were conducted between April 2015 to July 2016, to assess the effectiveness of citizen science in identifying species and detecting the occurrence, group size, and behaviour of bottlenose dolphins. Surveys were conducted on research vessel (RV) Aihe II, a 4.8m aluminium boat powered by a 120hp four-stroke outboard engine (Figure 2.2). Each survey occurred twice monthly when conditions allowed; a northern survey, which included the coastline from Whangaparaoa Peninsula (36°37S 174°44E) north to Hatfield's Beach, and a southern survey, targeting the North Shore coastline from Gulf Harbour Marina (36°37'39S 174°47'28E) to North Head (36°39'48S 174°48'49E).

**Figure 2.2** Research vessel; *Aihe II*. Photo: Dr K. Hupman

Systematic surveys were focused ca. 1km from the coastline, as this was considered the distance cetaceans could be reliably identified with binoculars (Karczmarski et al. 2000; Stockin et al. 2006). Each survey consisted of two search lines (hereafter referred to as 'transects') which ran parallel to the shoreline at a distance of approximately 0.5km and 1.5km, while the RV maintained a speed between 5 to 10kts while on-effort. These distances were chosen to achieve adequate coverage of the predicted area that can be surveyed from shore and includes areas that are commonly overlooked by the local tour boat (Hupman et al. 2014). The distance from shore for the first transect of each survey was randomly selected using a random number generator in Microsoft Excel, to generate either a 1 or 2. If a 1 was generated, then the 0.5km transect was surveyed first and subsequently the 1.5km transect was surveyed upon completion of the first, and vice versa if a 2 was generated.

Environmental data were collected throughout the survey every 15 minutes (Peters & Stockin 2016), with parameters adapted from Neumann (2001b) to include weather conditions, Beaufort Sea State, visibility (glare), sea surface temperature (SST; ±0.1°C), swell (m) and depth (±0.1m). An on-board thermometer and depth sounder was used to record SST and depth.

Once a group of animals was located, the RV departed the survey route to begin focal follows. Dolphins located within a 100m radius, observed moving in the same direction, and (usually) engaged in the same behaviour, were deemed to be part of the same group (Stockin et al. 2009). This methodology included the decision rule to remain with the largest group when one or more individuals departed the original focal group (Stockin et al. 2009). Once a focal group or animal was sighted, the RV approached the animal(s) in accordance to the Marine Mammal Protection Regulations (1992), i.e. maintaining a speed below 10kts within 300m of a dolphin. Once within 400m of an animal, the vessel speed was reduced to ~5kt. Once the focal group were within ca. 100m of the vessel, an ‘encounter’ was commenced. The research boat was carefully manoeuvred to minimise its potential effects on the behaviour of the dolphins during data collection (Constantine et al. 2004). This involved approaching the pod from the side or behind and driving the boat to match the speed of the focal group. During periods where the pod had no overall movement, the engine was switched into neutral or switched off.

Once an encounter was commenced, initial parameters were recorded. The latitude and longitude were recorded using a Samsung Galaxy Mini Smartphone every 30 seconds with CyberTracker software (Version 3.440 CyberTracker Conservation 2013). Behavioural state was recorded every 3 minutes using focal-group scan sampling (Altmann 1974). All individuals of the focal group were scanned left-to-right to determine the behavioural state that >50% of the animals were engaged in. Ensuring the inclusion of all the animals in the group reduces potential bias caused by the observer being drawn to specific individuals or behaviours (Mann 1999). Behaviour occurring at the surface is assumed to be representative of subsurface behaviour (Baird & Dill 1996). All represented behaviours were recorded if an equal percentage of individuals are engaged in different behaviours within a group (Stockin et al. 2009). Behavioural state definitions are adapted from Constantine (2002), Constantine et al. (2004) and Peters & Stockin (2016) to allow direct comparisons (Table 2.3). The research boat was not included as a vessel interacting with the focal group as the changes in behavioural state that were measured occurred over and above the effect of the research boat (Constantine et al. 2004; Nowacek et al. 2001).

**Table 2.3** Behavioural states of bottlenose dolphin (*Tursiops truncatus*) groups, defined from Constantine 2002; Constantine et al. 2004; Peter & Stockin 2016.

| Behavioural state | Definition |
|---|---|
| *Foraging* | 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 observed. |
| *Milling* | 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. |
| *Resting* | 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. |
| *Socialising* | 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 frequently observed. |
| *Travelling* | Dolphins engaged in persistent, directional movement making noticeable headway along a specific compass bearing. |

Group size, dispersal, group heading and the number and type of vessels present were also recorded every 3 minutes. Group sizes were recorded by the absolute *minimum* number of individuals counted, the *maximum* number of animals believed could be in the group, and the *best* estimate for the most likely number in the group (Dwyer et al. 2014).

Group dispersal was defined as:

- State 1: dolphins 0 - 2 dolphin body lengths apart
- State 2: dolphins >2-5 dolphin body lengths apart
- State 3: dolphins >5-10 dolphin body lengths apart
- State 4: dolphins >10 dolphin body lengths apart

Group composition (Table 2.4) was determined by listing the absolute minimum number of individuals belonging to each age class defined by Constantine (2002) for *Tursiops* and adapted by Dwyer (2016) and Peters & Stockin (2016).

**Table 2.4** Definitions of age classes for bottlenose dolphin (*Tursiops truncatus*) New Zealand (defined from Cockcroft & Ross 1989; Mann et al. 2000; Mann & Smuts 1999)**.**

| **Age classes** | **Definition** |
|---|---|
| *Neonate* | Classified by the presence of obvious dorso-ventral foetal folds down their sides. They also displayed poor motor skills and were often uncoordinated upon surfacing to breathe. The neonate stage usually lasts up to 3 months of age. |
| *Calf* | Defined as individuals that were approximately one-half or less (i.e., 1.5m) the size of an adult and were closely associated with an adult, often swimming in 'infant position' (i.e., in contact under the mother). Calves were thought to be up to 3 - 4 years of age. |
| *Juvenile* | Approximately two-thirds (i.e., 2.0 - 2.5 m) 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), suggesting they had been weaned. Upon reaching sexual maturity (for females this was often indicated by close association with a calf), individuals were no longer classed as juveniles. |
| *Adult* | All individuals (including assumed mothers) that were fully grown, i.e., equal or greater than 3m in total body length |

An encounter (and subsequent data collection) was terminated when the decision was made to leave the group of animals. The choice to depart was prompted by; changes in the animals behaviour (e.g. predator avoidance type behaviours), deteriorating weather conditions, low fuel reserves, dusk was approaching or contact with focal group was lost (Hupman 2016). The end time and GPS location was noted for each encounter. Once the encounter was terminated, the RV continued the systematic survey from the location it departed the transect. Additionally, the RV responded opportunistically to reports of bottlenose dolphins on independent days and during systematic surveys in the coastal region to confirm species identity and collect data.

### *2.2.2.3 Platform of Opportunity*

Auckland Whale and Dolphin Safari's boat, Dolphin Explorer (DE), offered a platform of opportunity (POP) to collect bottlenose dolphin identification and occurrence data for comparison to the citizen science data. DE is a 20m catamaran powered by twin 350hp inboard engines (Figure 2.3). Their trips were based on previous sightings of cetaceans and usually targeted common dolphins and Bryde's whales (*Balaenoptera edeni*) in the deeper waters of the Hauraki Gulf. Nevertheless, DE had the potential to encounter bottlenose dolphins in areas neighbouring the study area as they travelled to deeper waters, such as; Auckland Harbour (south of the North Shore survey area), the Rangitoto Channel (parallel to the North Shore survey area) or around Tiritiri Matangi Island (adjacent to the tip of the Whangaparaoa Peninsula). Furthermore, DE would follow reports through the citizen science group within the study area. Trips departed from Auckland Viaduct at 1230h to 1700h from April 1st to September 30th and 1330h to 1800h from October 1st to March 31st. This commercial whale and dolphin watching boat records encounter data (including species, location, group and composition) which was used to assist with the bottlenose dolphins' verification within the reported vicinity of unconfirmed citizen science reports from April 2015 to July 2016. The distance that dolphins travelled from a citizen science report, that it was considered reasonable to assume was the same group encountered by DE, was approximately 1.2km, within an hour of the report (based on a minimum travelling speed of 1.2km/h; Mate et al. 1995).

**Figure 2.3** Platform of opportunity; *Dolphin Explorer*. Photo: Dr K. Hupman.

### 2.2.3 Data Analysis

Due to the limited nature of the data collected, only descriptive statistics and summaries are provided in this chapter. All sightings reported via Facebook were examined as a source of citizen science. The delphinid species identified on Facebook was assessed against RV and POP encounters and the description also provided in the report based on the criteria in Table 2.2. This assessment provided means to evaluate the accuracy of the observer’s species classification. Independent reports were plotted on a map using Google Earth Pro (V7.1.7.2600) and compared to RV encounters to identify if detection varies within any regions of the study area. To avoid pseudo replication, independent reports were considered as the first confirmed sighting within a 24h period and duplicate sightings thereafter were removed from analysis. The frequency of each type of species confirmation method was also examined to identify which ones were the most useful.

Dolphin group size estimates reported by citizen scientists were presumed to be comparable to the *best* estimates, described above, made by the researchers. Direct comparisons between citizen scientist and researcher estimates were often not possible as estimates were rarely synchronous. Behavioural state and group composition were often not reported by citizens and thus could not be compared to data collected by researchers.

The total number of bottlenose dolphin reports was assessed by season and time of day to examine any temporal bias in effort that may occur as a consequence of using citizen science. Austral seasons were defined as: spring (September to November), summer (December to February), autumn (March to May) and winter (June to August). The time for each confirmed report was put into a time period; either morning (0500h to 1159h), afternoon (1200h to 1659h), or evening (1700h to 2100h). Each time period was assessed per season, seven reports were not used as precise time was not reported. The number of reports was also plotted per location to assess spatial observer bias.

To examine how often bottlenose dolphins occurred within the study area, the number of days with confirmed sightings was calculated for independent reports from the citizen science reports. Using all confirmed reports, the mean number of sightings per day was calculated to gain an idea of how often dolphins were sighted in the study area. The behavioural data recorded by the RV was plotted in a behavioural budget to complement the data collected by citizen scientists to aid understanding of how bottlenose dolphins use the Whangaparaoa and North Shore coastlines.

## 2.3 Results

### 2.3.1 Effort

A total of 260 sightings of bottlenose dolphins were reported during April 2015 to July 2016 by citizen scientists in the Facebook groups, 42 of which were independent. The RV travelled over 3,900km in total around the western coastline of the Hauraki Gulf in

273.8h, during 58 days from April 2015 to July 2016. A total of 93 transects were conducted during systematic surveys on 47 days, covering 2,390km in 107h (Figure 2.4). Transects often had to be altered to avoid other boat traffic.

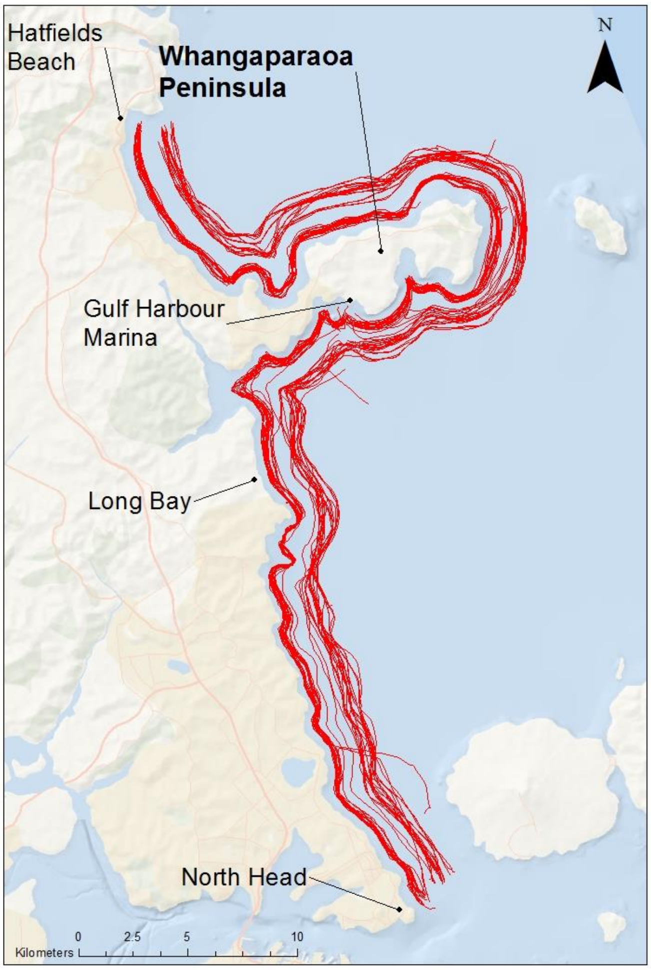


**Figure 2.4** Search effort of the research vessel along the Whangaparaoa and North Shore coastline, New Zealand.

### 2.3.2 Usefulness of Social Media

During the study period there were a mean number of confirmed bottlenose dolphin reports of 0.28 (SD=1.26) per day. Observer's identification of species was only considered valid if the observer's rating was above two, due to the public's general unfamiliarity with each species. A total of 191 (73.5%) reports did not identify a species and often only reported "dolphins". In approximately a third of the reports (n=65) whereby the species was not reported, the identity of the species was unable to be determined. For citizen science reports, exact GPS coordinates were not reported, only the general location names were given with the approximate location of the animals within the named bay. Given the lack of specific coordinates, the reports were plotted on the map in the central point of each bay area for comparison (Figure 2.6; 2.7).

Citizen scientists reported all three of the species commonly observed in the Hauraki Gulf. Killer whales were the species most identified by citizen scientists, while common dolphins were only identified in five reports (Table 2.5). Each common dolphin classification was a misidentification by the citizen scientists. Bottlenose dolphins were not frequently identified but occurred in the highest number of reports as classified by researchers.

**Table 2.5** Species identified by citizen scientists; Reported = the number of observations reported as the identified species, Confirmed = the number of reports confirmed as the identified species, Misidentified = the number of reports that classified that species but were incorrect, and Not Classified =the number of reports where the species was not classified but later identified by researchers.

| Species | Reported | Confirmed | Misidentified | Not Classified |
|---|---|---|---|---|
| Bottlenose dolphin (Tursiops truncatus) | 15 | 10 | 2 | 123 |
| Common dolphin (Delphinus sp.) | 5 | 0 | 5 | 0 |
| Killer whale (Orcinus orca) | 49 | 42 | 0 | 0 |

Researcher confirmation was the highest method of species validation (34.8%), closely followed by Nearby Reports (27.4%) and then Photo/Video evidence (23.7%; Figure 2.5). Observers who were deemed experienced enough (Table 2.1) to verify species identity reported very few sightings (3.7%).

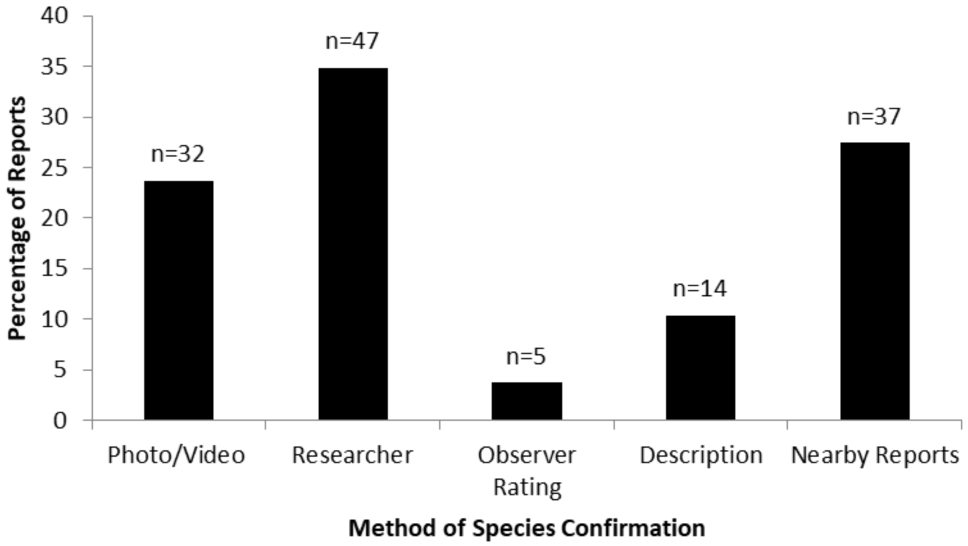


**Figure 2.5** Confirmation methods used to verify social media reports of bottlenose dolphin (*Tursiops truncatus*) along the Whangaparaoa and North Shore coastline, New Zealand.

### 2.3.3 Citizen Science Data Quality

Reports determined to be bottlenose dolphins were reported over 42 days. The RV had a total of 13 sightings of bottlenose dolphins (Table 2.6), eight of which were following reports from the citizen science group. Only two sightings from the RV were not detected by the citizen science groups and both of these sightings were detected close to the 500m transect. The POP encountered bottlenose dolphins on 18 trips out of total of 246 from April 2015 to July 2016 (Table 2.6), and only two were not reported by the citizen science groups (one of which was detected by the RV).

**Table 2.6** The number of days with encounters of bottlenose dolphins between April 2015 and July 2016 along the western Hauraki Gulf coastline, New Zealand, for the research vessel and platform of opportunity when compared to independent citizen science reports. Detected = the number of encounters on days that citizen science reported bottlenose dolphins, Undetected = the number of days with encounters that were within the determined range for detection by citizen scientists, but were not reported, Too Distant = the number days with encounters that were considered too far from the coast to be detected by citizen scientists, No GPS = the number of days with encounters that were not detected by citizen scientists and lack GPS coordinates.

| | **Detected** | **Undetected** | **Too Distant** | **No GPS** | **Total** |
|---|---|---|---|---|---|
| ***RV*** | 11 | 2 | 0 | NA | 13 |
| ***POP*** | 7 | 2 | 7 | 2 | 18 |

There were fewer sightings in the North Shore area compared to the Whangaparaoa area (Figures 2.6 & 2.7). Sightings in the North Shore area were concentrated towards the northern area of coastline, with Browns Bay having the highest number of sightings (Figure 2.6). Arkles Bay had the highest number of sightings in the Whangaparaoa area but, sightings occurred almost throughout the entire area (Figure 2.7).

**Figure 2.6** Independent sightings of bottlenose dolphins in the estimated Whangaparaoa Facebook Group region, New Zealand, through citizen science and the research vessel. Yellow markers indicate citizen science sightings, blue marks indicate research vessel sightings whereby the animals were also reported through citizen science on the same day and red indicates sightings from the research vessel on days the dolphins were not reported by citizen science. The number represents the frequency count of independent sightings in that area.

**Figure 2.7** Independent sightings of bottlenose dolphins in the estimated North Shore Facebook Group region, New Zealand, through citizen science and the research vessel. Yellow markers indicate citizen science sightings and the blue marks indicate research boat sightings whereby the animals were also reported through citizen science on the same day. The number represents the frequency count of independent sightings in that area.

There were no reports over summer by citizen science and no encounters for the RV, however the POP had two encounters (Figure 2.8). It should be noted that these encounters occurred in depths greater than 25m, further from shore. The percentages of sightings were similar across all methods for autumn and spring, though it varied in winter. The number of citizen science reports ranged from 1 in a day to 16. Over 92% (n=39) of days had less than five reports. All of the days with over five reports occurred in spring.

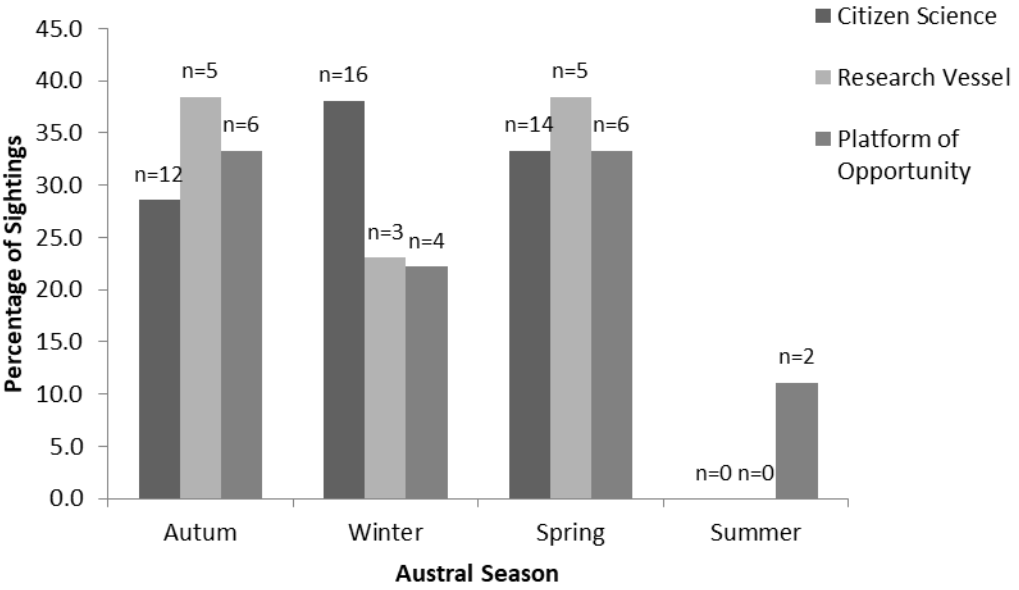


**Figure 2.8** Percentage of independent sightings reported by each data collection method for each season along the Whangaparaoa and North Shore coastlines, New Zealand.

Group size was often reported (n=89), with estimates ranging from 1 to 30 animals (median=6, mean=7.1, SD=5.4). Notably, 93.3% (n=83) of sightings reported contained less than 16 dolphins. It was only possible to compare 14 reports of group size with the estimates from the RV. Citizen scientists' estimates were often below those made by an independent researcher (78.5%, n=11), with a mean difference of 7.86 (SD = 8.0) animals. Group size estimates for the RV range from 2 to 35 (median=15, mean=13.8, SD=10.1) and 76.9% of groups contained less than 16 dolphins. Only three reports through citizen science listed the behaviour synchronously to the RV; two reported as milling while the RV observed resting. The third report matched the behaviour (travel) reported by the RV. The RV did not observe any bottlenose dolphin groups during the time that any citizen science groups reported calves, thus no comparisons can be made for group composition.

### 2.3.4 Citizen Science Biases

It appears there may be some bias in the total number of sightings by season and location. The total number of citizen science reports was higher during spring than any other season (Figure 2.9).

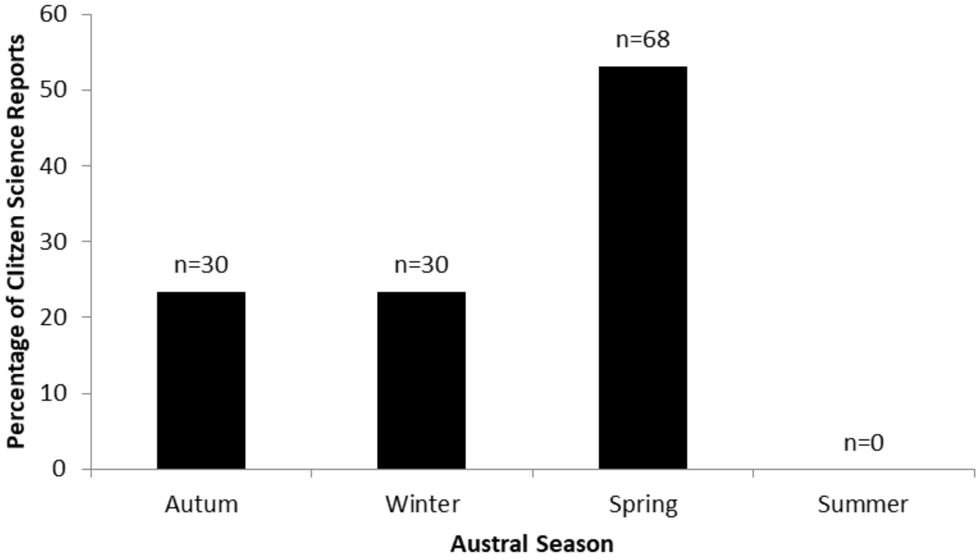


**Figure 2.9** The percentage of total bottlenose dolphin reports made by citizen scientists for each austral season.

There were less reports during the evening (n=19) than the morning (n=54) and afternoon (n=55). Spring had the highest proportion of afternoon sightings, followed by morning and evening while autumn and winter had the highest number of sightings in the morning, followed by afternoon and evening (Figure 2.10).

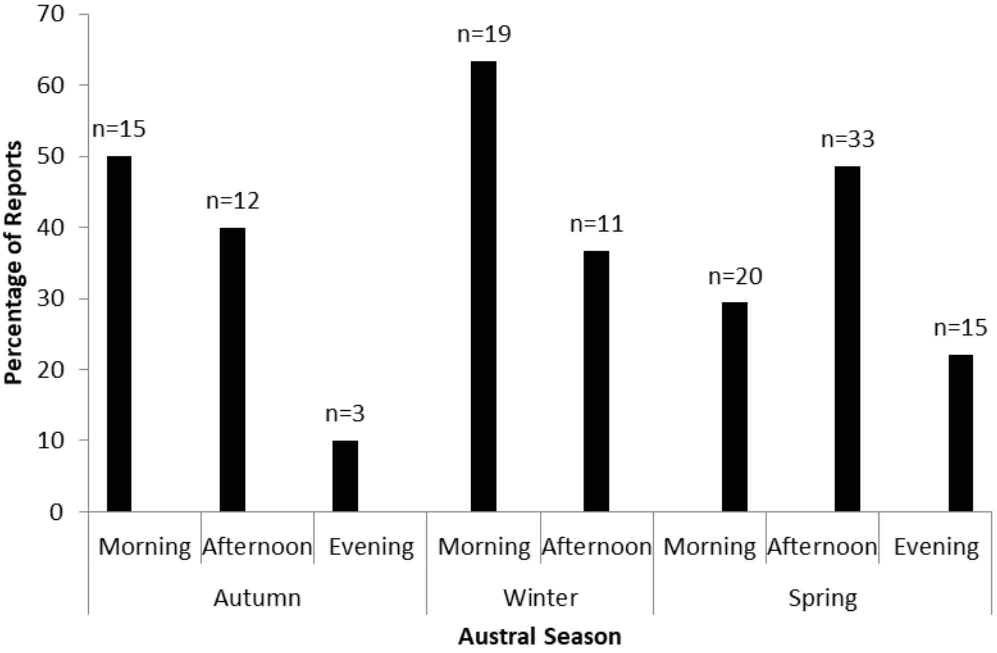


**Figure 2.10** The percentage of sightings of bottlenose dolphins (*Tursiops truncatus*) reported in the Facebook groups within each time period within each season along the Whangaparaoa and North Shore coastlines, New Zealand.

Stanmore Bay, Big Manly Beach, Tindalls Beach and Torbay identified high numbers of reports during spring (Figure 2.11). The number of sightings at Little Manly Beach was elevated during winter, while sightings at Arkles Bay were high during winter and autumn. It should be noted that during spring; in one day (20th of September 2015), the dolphins were reported 8 of the 10 times between Big Manly and Tindalls Bay (which are located less than 200m apart, figure 2.11) between 1136h and 1744h. On 3rd of October 2015, 12 reports occurred, six of these were from Tindalls Bay between 15:05h to 16:01h, where by the further six reports were recorded over five different locations, effectively tracking the animals north from 1648h to 1815h. During 6th of September 2015, 13 reports occurred, with dolphins observed at Torbay 12 times between 1207h to 1733h.

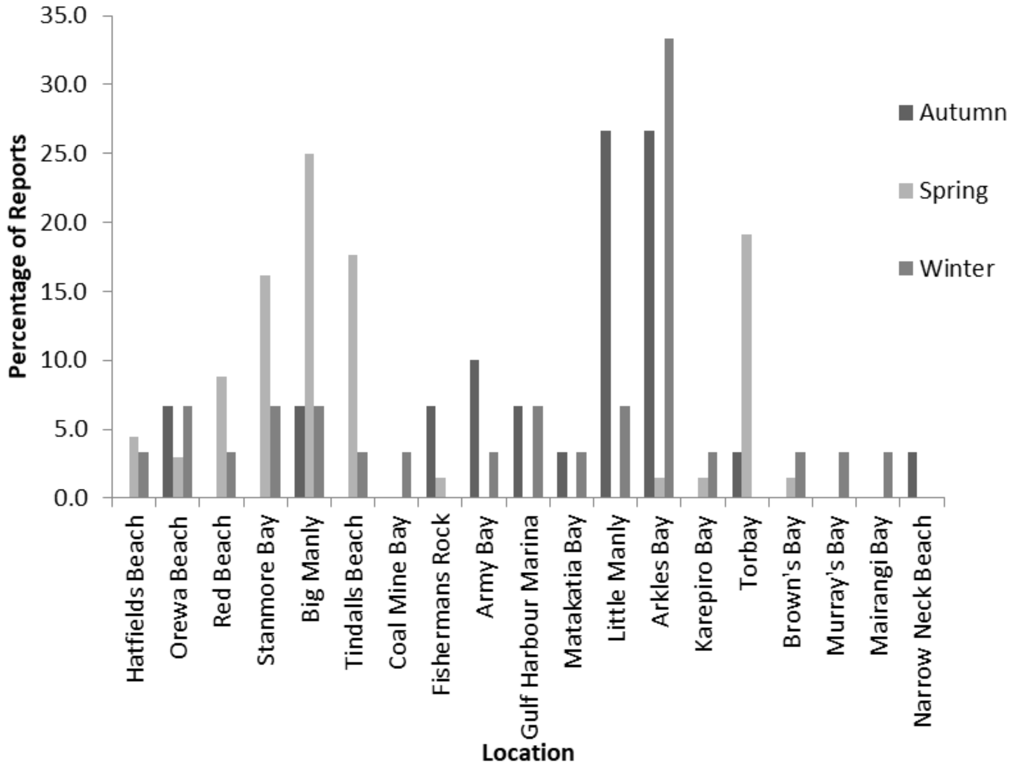


**Figure 2.11** Percentage of sightings at each location per season. Locations are in order they occur around the coastline, from Hatfield's Beach, running south to Narrow Neck Beach.

### 2.3.5 Habitat Use

Bottlenose dolphins were only sighted (by any method; citizen science, RV, and POP) on 11.5% of the total number of days in the survey period. Figure 2.8 indicates that the number of independent sightings were relatively even between autumn, winter and spring while bottlenose dolphins were rarely seen in summer. Bottlenose dolphins were often observed moving through the study area; on over half (66.7%) of the days that dolphins were sighted by citizen scientists, reports came from multiple locations and the mean number of locations reported per day was 1.98 (SD=0.98). Bottlenose dolphins spent an extended period of time in a single area on just three independent days (5.4%). These areas were Big Manly to Tindalls Beach, Tindalls Beach and Torbay. During encounters with the RV, bottlenose dolphins spent the most time engaged in travelling while foraging was the least recorded behavioural state (Figure 2.12).

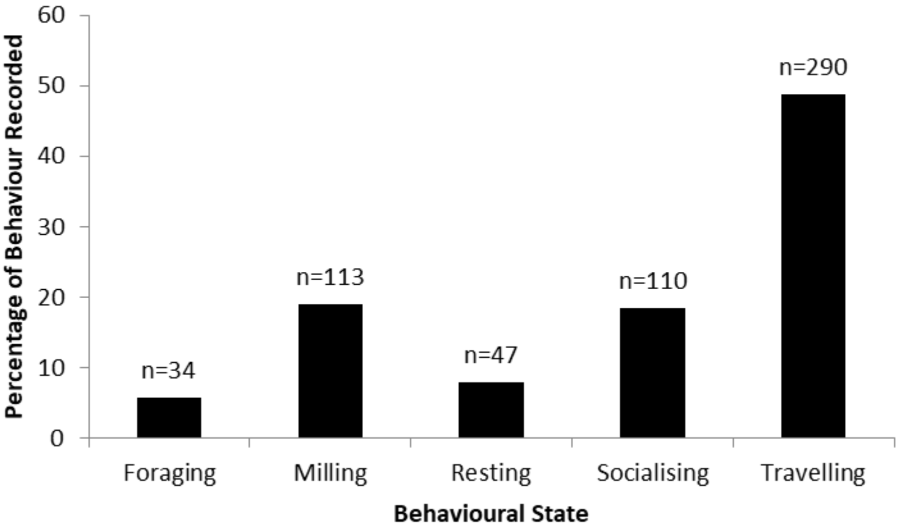


**Figure 2.12** Behavioural budget for bottlenose dolphins during focal follows by the research vessel around the Whangaparaoa and North Shore coastline, New Zealand.

## 2.4 Discussion

Citizen science is a growing method of data collection, especially over large spatial and temporal scales. It has been useful in advancing scientific knowledge, although it is not universally accepted (Bird et al. 2014; Bonney et al. 2014). Validating citizen science is crucial to cement its role in science as well as for ensuring data quality for each project. Citizen science supplements scarce resources and fills the void of incomplete/inadequate data sets. In this study, an opportunity arose to collect citizen science data through Facebook groups dedicated to sighting cetaceans around the Whangaparaoa and North

Shore coastline in the Hauraki Gulf. These groups have provided a large number of bottlenose dolphin reports in an area previously lacking dedicated surveys. This chapter assessed the quality of data collected through Facebook and compared it to that collected via a RV and POP. It also utilised that data to evaluate bottlenose dolphin occurrence in the area.

### 2.4.1 Quality and Bias

Citizen science often has multiple biases and this study attempted to acknowledge and minimise them during the analysis. Four main categories of bias have been identified from citizen scientist recording activity; 1) uneven recording intensity over time, 2) uneven spatial coverage, 3) uneven sampling effort per visit, 4) variability in detection skills among volunteers (Geldmann et al. 2016; Isaac et al. 2014; Xue et al. 2016). A problem using passive citizen scientists rather than active volunteers is that it was not possible to examine biases in uneven sampling effort or detection skills. These findings were similar to those of Lodi and Tardin (2018) who also used opportunistic citizen science reports of cetaceans through Facebook.

One obvious bias in the present study is the number of members in each Facebook group. The Whangaparaoa group had over double the number of members than the North Shore group at the time of writing this. This means there are more people that are reporting their sightings to the group in the Whangaparaoa area. This may account for the higher number of sightings in the Whangaparaoa area compared to the North Shore.

Overall, the number of confirmed sightings per day was low. This likely reflects the limited spatial scale of the study rather than a large number of undetected animals, as the study area makes up just a small portion of the Hauraki Gulf. The citizen science data collected through Facebook groups lead to more reports than were possible from the RV during the study period, this owing primarily to unfavourable weather conditions to operate the RV. This is consistent with another study that also used opportunistic data collected through a Facebook group, in which volunteers not only reported more encounters, but detected a higher number of species than the research vessel (Lodi & Tardin 2018). The identification of species was notably the largest issue in the data of the present study. Killer whales appear to be easily distinguished by citizen members of the group, with only a few reports remaining unconfirmed. Observers were generally more familiar with killer whales as a species, likely due to their distinctive appearance and elevated publicity via organizations such as the Orca Research Trust (http://www.orcaresearch.org/). Killer whale sightings also typically attracted a larger crowd compared with other smaller delphinids, leading to further reports and photographs that increased the chances of species verification. In contrast, citizen scientists were less capable of identifying bottlenose and common dolphins, with either species rarely identified. Instead, citizen scientists simply reported “dolphins”. Common dolphins were rarely reported which is expected given the known distribution of this species in the Hauraki Gulf (Dwyer et al. 2016; Stockin, Pierce et al. 2008), but each time they were reported it was later identified that they were bottlenose dolphins. In fact, there were no confirmed sightings of common dolphins during land based reports.

The number of experienced citizen scientists qualified to report verified species identity was very low and therefore this method was not reliable alone for confirmation (Figure 2.5). Photographic and video evidence was the most reliable method of verifying species, although on occasion, compromised quality of images still rendered species unconfirmed. Researcher confirmation was the most utilised form of species verification. This method did not always require good conditions, if the dolphins were located in a particular area for an extended period of time, researchers were able to reach the location of the report and confirm species from land. Reports that had been confirmed as bottlenose dolphins via; photographic/video evidence, researcher confirmation, expert confirmation and/or clear descriptions, were used to verify the species from other reports within a reasonable spatial and temporal scale as they were assumed to be the same group of animals. Often citizen scientists reported a direction of travel which also increased confidence in this assumption. The features described in Table 2.2 allowed reasonable assumptions to be made about species identity, although species’ descriptions observed at distance without binoculars were often not reported. It is reasonable to assume in future that citizen scientists provided with some training and/or using an identification chart could identify bottlenose dolphins around the coastline with confidence given the distinct characteristics of the three common delphinid species occurring within region.

Seasonal effort was a concern with this type of citizen science, as it would be expected that more people would be near the coastline during summer (Maguire et al. 2011), as people spend more time at the beach in hot weather and this coincides with school holidays. Contrary to this, the results of this study revealed no sightings during summer. Instead, double the number of total reports occurred in spring than during autumn and winter. This unlikely represents a bias in search effort however, given 55.9% (n=38) of these reports in spring were concentrated to just three days in which the dolphins spent an extended period of time in a small area. These reports were dispersed temporally over the day, and thus likely that these concentrations of reports are representative of the dolphins’ movement (or lack of) patterns rather than bias in effort. As dolphins stayed within a small area, multiple observers travelled to the reported location to view the dolphins with confidence that they would not miss them. It is suggested that this is comparable to the ‘off effort’ section of a survey in which an encounter with the RV takes place. The number of independent days with confirmed reports of bottlenose dolphins was similar between autumn, winter and spring. It is reasonable to suggest that there is sufficient baseline effort during all seasons in this area given that many observers reside on or near the coastline covered by the Facebook groups, especially given the large number of members.

Sightings were highest in the morning for both autumn and winter. Winter had no sightings during the evenings, which may be due to fewer daylight hours. Spring had a higher number of sightings during the afternoons than morning and fewest in the evenings. The high numbers of sightings during the afternoon in spring is again contributed to the days whereby dolphins spent a long period of time in a small area whereby the majority of reports were concentrated in the afternoon. When these days are removed, the majority of sightings occur in the morning in spring, following the sighting pattern of autumn and winter. This pattern is unlikely to be a bias in search effort for two reasons; firstly, it would be expected that participants would spend more time around the coastline during the afternoon as the temperature increases. Secondly, a sighting during the morning tended to put citizen scientists on higher alert that dolphins were in the area and would result in an increased vigilance during the rest of the day. Additionally, diurnal movements of dolphins into deeper waters in the afternoon have been noted in various species and locations (Cipriano 1992; Norris et al. 1994; Henderson et al. 2011) and may account for the pattern of citizen science reported here.

Citizen science is often limited to areas of urbanisation or tourist hotspots where people are concentrated; this non-random distribution of effort is a common bias in citizen science data sets (Bird et al. 2014; Giovos et al. 2016; McCaffrey 2005). As much of the coastline in this study is urbanised and many of the reports come from locals (hence they spend substantial time in the study area) there is likely to be good spatial and temporal coverage of the area. There were a relatively even number of independent sightings over much of the coastline. The southern half of the North Shore area had a very low number of sightings; however this was also reflected by the RV. This suggests that this reflects the dolphins’ movement patterns rather than spatial bias in effort. This study is unlikely to suffer significantly from spatial bias due to the relatively small scale, excluding a small stretch of coastline around the end of Whangaparaoa Peninsula which is a regional park and partly utilised by the Ministry of Defence, thus un-urbanised (Quadling 2006). This is evident in Figure 2.7 from the lack of reports in this area. If the current study area is expanded in future to cover more of the Hauraki Gulf, it should be considered that this bias would greatly increase as citizen science is likely to be concentrated around population centres (Bird et al. 2014; Giovos et al. 2016; McCaffrey 2005), which may exclude areas such as the western Coromandel Peninsula or many of the IHG islands.

### 2.4.2 Citizen Science versus RV and POP

Citizen science only missed three potential sightings that were detected by the RV and POP within the study area, yet provided more independent sightings than either. Due to the large number of participants involved in the Facebook groups (which continue to increase), the probability of missing sightings are reduced (Higby et al. 2012). This indicates that citizen science has the potential to provide useful occurrence information about bottlenose dolphins along the Hauraki Gulf coastline by covering a large area. A recent study found that most of the data collected from the research vessel and citizen scientists were similar for cetacean occurrence and distribution (Lodi & Tardin 2018). Additionally, citizen scientists expanded the database further than the research vessel, including the occurrence of an additional four species (Lodi & Tardin 2018). As residents live on or close to the coastline on the Whangaparaoa Peninsula and North Shore areas, they observe or visit beaches and coastal areas every day, at different times of the day, and thus the probability of sighting dolphins may be much greater than that of surveys (Lodi & Tardin 2018).

The majority of group size estimates were similar to the RV, although observers often underestimated the number of animals. However, during only two of the reports was the RV with the animals during the exact period that group size was reported by citizen scientists. Thus, it is possible that changes in group size occurred between the time of the report and the RV encounter. Nonetheless, given observers do not have experience; it is likely that their estimates were less accurate than those from trained researchers. When untrained observers estimate group size, they may only count the number of dolphins surfaced at a single point in time and thus, not account for submerged animals. Despite this, group size estimates from citizen science reports were reasonable. Citizen scientists can provide accurate data (Delaney et al. 2008), but training for group size estimates should be provided in future and these estimates of group size by citizen scientists should be validated (Newman et al. 2003). Citizen scientists rarely reported behaviour and thus no direct comparisons could be made between citizen science and the RV.

### 2.4.3 Developing Citizen Science in the Hauraki Gulf

This citizen science data were collected opportunistically via Facebook and was limited by a lack of rigidity in the type of data collected. Two other studies were successful in collecting opportunistic data through social media, however both of these studies utilised photographs and video footage (Giovos et al. 2016; Lodi & Tardin 2018), which means they were less reliant on the identification skills of citizen scientists. Additionally, the location was usually automatically stamped to each photograph or video during the upload process to social media. Photographs and video footage were rare in this study, as the overwhelming majority of citizen scientists were land based and thus could not get close enough to record the animals in high quality. Previous land based citizen science studies conducted more rigorous data collection, but were focused on core areas for bottlenose dolphins (Bristow et al. 2001; Embling et al. 2015). This type of data collection heavily limits the number of citizen scientists due to the extensive time commitment, and reduces the spatial scale of data collection. Extending the spatial scale in this type of study was estimated to have considerable financial costs (Embling et al. 2015). Given the low concentrations of sightings in any particular location within the Hauraki Gulf, it would also be difficult to maintain the volunteer interest that would be required to conduct the constant scans required. Additionally, it would be impractical to use this type of survey in such a protracted coastline. Instead it would be more appropriate to improve the current ad-hoc presence-only methodology which has been shown to still be useful in building predictive models with cetaceans, especially with large volumes of data and the inclusion of explanatory factors, such as time of day or behaviour (Bruce et al. 2014; Giovos et al. 2016; Higby et al. 2012). The appropriate models can account for the bias in effort (Bird et al. 2014), but as the bottlenose dolphins may be widely dispersed within the Hauraki Gulf, it is recommended that large data sets are collected to better utilise citizen science (Hann 2015).

Data collection in this study was not designed or standardised specifically for citizen science, but more to assess the usefulness of a mainstream social media platform to inform dolphin occurrence. However, future citizen science based research should consider design and standardisation in order to extract the most value from the dataset acquired (Delaney et al. 2008; Silvertown 2009). It is also clear that sufficient training is necessary to achieve the most useful data (Newman et al. 2003), particularly with reference to species identity, behaviour and group composition. The use of a Facebook groups makes it difficult to ensure every member is getting the correct information and/or that they are using it. Two reasons are suggested for this; firstly, when materials such as descriptions and photographs are posted on the group page, it is easy for many members to miss it and it is difficult to find later for reference. Secondly, members aren't interested in identifying the species; they simply wish to report the sighting to the group so other members can view the animals.

The Facebook groups used for this study only cover a small portion of the Hauraki Gulf. Further groups have since been established by other members of the public on Facebook for Waiheke Island and the south-east coast of Auckland, though these groups have not been as successful in gathering members or reporting sightings. Even with these groups, there remain significant gaps in the Hauraki Gulf coastline, such as the entire western Coromandel coastline (mostly uninhabited) as well as the Thames region and the many other islands of the Hauraki Gulf. Promoting the Facebook groups and involving regular boat users of the Hauraki Gulf (such as ferry crew or fishing charters) would improve coverage of the centre of the HG and its islands, and may be of benefit in non-urbanised areas.

Citizen science should continue to be used in the Hauraki Gulf to supplement data, but not independently of a dedicated RV. Further citizen science research in the Hauraki Gulf should employ a different platform to collect observer data for citizen science while continuing to utilise the Facebook groups for promotion and sharing results (Sequeira et al. 2014). While Lodi and Tardin (2018) were successful in collecting citizen science data through Facebook, their study allowed their analysis to be based on photographs and video footage. Thus, they were less reliant on the citizen scientists' skills for details such as the type of species. Reporting sightings specifically for citizen science may make volunteers more active and effective at data collection as they feel they are contributing to authentic science and conservation (Evans et al. 2005). It is suggested that the creation of a mobile phone application and website would be highly useful here, such as Whale mAPP which has been developed to ensure high data quality without excluding any observers (Stelle & King 2015). This would allow large groups of people to be trained (e.g. through videos) as well as providing a platform to provide feedback and assistance to citizen scientists. This would also give citizen scientists references for local species identification and behavioural states, which is important to avoid confusion for novice observers (Silvertown 2009). It would also prompt citizen scientists to enter all of the details required (e.g. through dropdown menus) when they are entering data.

Mobile applications and websites are already currently in use to track citizen sightings of cetaceans. These include the; Maui dolphin sightings application (http://www.wwf.org.nz/take_action/maui_s_campaign_/) and Hector's dolphin sightings application (https://www.facebook.com/hectorsdolphinsightingsapp/) for reporting sightings of their respective species, Whale Alert (http://www.whalealert.org/) to reduce ship strikes around USA waters, Whale mAPP (http://www.whalemapp.org/; Hann 2015; Stelle & King 2015) which is used to report sightings of cetaceans globally and Coastal Walkabout (http://mucru.org/our-research/research-projects/citizen-science-coastal-walkabout/) to record marine animal species sightings around Australian coastlines.

Developing citizen science further to monitor bottlenose dolphins in the Hauraki Gulf is recommended as the commercial whale and dolphin watching operation targets the inner Hauraki Gulf and has recently been prevented by the Department of Conservation from opportunistically viewing bottlenose dolphins. This means the only platform to date which was able to acquire scientific information on this endangered population is no longer permitted to engage this species in order to collect data. Even historically with the context of this study the operating procedure of DE limits bottlenose dolphin encounters, as reported here given the number of days with sightings they had (n=18) compared to the Facebook groups (n=42). As such, a dedicated RV should be used alongside citizen science, in particular to cover coastal areas that have limited citizen science coverage and to collect further information beyond the capability of citizen science (e.g. acoustic and behavioural data). Citizen science may reduce the cost of data collection (i.e. through direct data collection, and indirectly by allowing the RV to expend less time and fuel searching for bottlenose dolphin groups). Additionally, citizen science can engage the public and inform them of scientific findings and conservation issues (Conrad & Hilchey 2011) within the Hauraki Gulf.

It is interesting to note that while Facebook was impractical for many forms of data collection, it served other purposes. The number of reports was likely higher than other citizen science data collecting platforms due to the sense of community within the groups and the ability of members of see dolphins based on reports of other group members. This is a positive effect for shore based dolphin watching, but could cause a negative impact in areas with a higher number of recreational boat users. Members of this group also promoted responsible behaviour when encountering cetaceans and their conservation. It also informed the Department of Conservation when large groups of people began to gather to view the animals or of those who were violating the Marine Mammal Protection Act (1978). As such, while social media isn't specifically designed for data collection and may have its limits for citizen science, it has in this case still proven an invaluable tool from a monitoring and compliance perspective.

### 2.4.4 Bottlenose dolphin occurrence

Within limited home ranges, bottlenose dolphins around the world are known to have seasonal distributions (Elliott et al. 2011; Scott et al. 1990). It should be noted that an El Niño system occurred during this study period and thus, results presented here may vary from La Niña and Neutral conditions (NIWA National Climate Centre 2015;2016). Previous studies have found that bottlenose dolphins were encountered most frequently in winter and autumn within the IHG, and the least in summer (Berghan et al. 2008; Dwyer et al. 2016; Martinez et al. 2010). The Facebook groups' data detected a similar trend as most independent reports occurred in winter followed by spring and autumn, while the research boat and platform of opportunity had a majority of encounters in autumn and spring, followed by winter. It is possible that bottlenose dolphins are using the IHG more frequently than what has been reported during autumn, winter and spring, but are not concentrated in a particular area and thus, difficult to locate.

Bottlenose dolphins occur in deeper waters in the Hauraki Gulf when they are encountered during summer (Dwyer et al. 2016; Martinez et al. 2010), with a similar trend occurring in the Bay of Islands (Constantine 2002; Hartel et al. 2014). The absence of bottlenose dolphins from the study area during summer is expected given these results, as sightings are largely limited to land based observations. The distribution of bottlenose dolphins during summer appears to be concentrated towards the middle and northern areas of the IHG, and absent from the western coastline during summer (Martinez et al. 2010). It is apparent that bottlenose dolphins are rarely using the IHG during summer, and this likely relates to their expanded use of Great Barrier Island (Dwyer 2014), the Bay of Islands (Tezanos-Pinto 2009) and Northland (Peters 2018) waters during the summer. As the distribution of bottlenose dolphins is often thought to relate to prey movements (Barco et al. 1999; Bearzi et al. 2008; Hastie et al. 2004) it has been suggested that as the warm waters of the East Auckland Current, flowing in the northerly entrance of the Hauraki Gulf during summer and autumn, bring with it an influx of prey which may explain the absence of sightings during summer in the IHG (Dwyer 2014).

Travelling was the most recorded behavioural state, which is similar to other populations in New Zealand (Constantine 2002; Lusseau 2004; Merriman 2007; Schneider 1999; Peters & Stockin 2016). Travelling is often reported in high proportions for *Tursiops sp.* (Baker, O'Brien, McHugh, Ingram & Berrow 2017; Bas et al. 2017; Bearzi et al. 2009; Beddia 2007; Filby et al. 2017; Inoue et al. 2017) and it has been suggested that one of the primary functions of travel is to locate food, as it has been associated with foraging (Beddia 2007; Garcia et al. 2017; Karniski et al. 2015; Mattos et al. 2007). Very little foraging was observed during the present study. Instead, it is possible that bottlenose dolphins use Whangaparaoa and North Shore coastlines as a corridor to other foraging areas either within, or outside the IHG, given the low detection rate. Bottlenose dolphins have also been reported to spend the majority of their time moving through their favourite 'corridors' within 50m from shore (Bearzi et al. 2009; Defran & Weller 1999), which is consistent with observations and reports in the present study. Furthermore, Ballance (1992) reported travelling as the most predominant behaviour outside of foraging areas. A possible explanation for the high rates of travel and seasonality is that the north-eastern North Island bottlenose dolphin population disperse throughout their home range (including the IHG) during winter as prey is more dispersed and less concentrated than in summer, when the East Auckland Current moves into the outer Hauraki Gulf (Dwyer 2014) and Bay of Islands (Hartel 2010).

It does appear that bottlenose dolphins utilise the Whangaparaoa coastline more than the North Shore. Fewer sightings were reported in this area by citizen science and the RV. The bays in the Whangaparaoa area are more sheltered than the North Shore and may provide a more suitable habitat for travelling through the Hauraki Gulf. Upon reaching the North Shore section of the survey area (between Long Bay and Browns Bay) dolphins may move away from the coastline. Dolphins may depart the coastline to travel to deeper waters or to the nearby IHG islands. In the Whangaparaoa coastline, the waters around Little Manly Beach and Arkles Bay were used more frequently by the dolphins (Figure 2.7), though with low sample sizes it is difficult to infer significance. While there were a few days where dolphins also spent an extended period of time in certain areas, behavioural states were not reported by observers and so use of these areas cannot be determined. On one of these occasions however, it was observed by the RV that two adult dolphins split from the rest of the pod and spent the day socialising in a sheltered bay and interacting with swimmers and kayakers. Sub-areas have been identified to have particular uses for bottlenose dolphins, such as foraging (Ballance 1992; Mattos et al. 2007a) or resting (Hartel et al. 2014). In this case it may be that sheltered areas around the Whangaparaoa coastline occasionally provide an area to socialise amidst bouts of travel.

It should be noted that the Whangaparaoa and North Shore coastline make up only a very small part of the IHG's coastline and further study off the coast of the Coromandel Peninsula, Firth of Thames and many islands may be warranted, as effort has previously been concentrated towards the western area of the Hauraki Gulf (Dwyer 2014; Martinez et al. 2010). Transects by Dwyer (2014) covered the entire IHG, but were usually greater than 1km from the coastline in many areas around the Hauraki Gulf, making it possible to miss bottlenose dolphins which were frequently observed in very close proximity to shore in this study. Additionally, Dwyer (2014) could also only cover small portions of the Hauraki Gulf during a single trip which would decrease the likelihood of encountering bottlenose dolphins.

### 2.4.5 Summary

This chapter reveals that cetacean data collected through citizen science should account for biases in effort based on concentrations of citizen scientists. Season and time of day likely did not cause any bias in the present study; however this should be accounted for in less densely populated areas. Citizen science was able to detect the presence of bottlenose dolphins more often than the RV as it was not restricted by unfavourable weather conditions. Yet, training citizen scientists is important to accurately identify species and behaviours. Additionally, Facebook was not an ideal platform for collecting citizen science data due to the informal nature of the groups, although the number of reports is likely higher due to a sense of community and potential of dolphin sightings based on other shared reports. This group, combined with a dedicated research vessel and platform of opportunity, have revealed that this small length of coastline is likely a corridor for bottlenose dolphins within the Hauraki Gulf. With training and a rigid data collecting platform, citizen science could aid in conservation by helping to collect large scale data sets for coastal cetaceans while social media platforms, such as Facebook, provide an ideal tool for spreading conservation messages.

# Chapter 3

# The use of Great Barrier Island waters by bottlenose dolphins

A bottlenose dolphin calf next to its presumed mother, off the western coast of Great Barrier Island, New Zealand

## 3.1 Introduction

The interaction between an animal and its environment is often examined in relation to evolution (Barros et al. 2011; Rosenzweig 1974), habitat use (Best et al. 1995; Lind & Welsh 1994) and residency patterns (Chin et al. 2013). Habitat use patterns describe the distributions of individuals across habitat types, while habitat selection is a hierarchical process of behavioural responses that may result in the disproportionate use of habitats to influence the fitness and survival of individuals (Block & Brennan 1993; Hutto 1985). Habitat selection can be majorly determined by factors such as reproduction, predator avoidance and food distribution (Alcock 2001). Distribution and behavioural patterns are often examined to determine how an organism utilises its environment (Burns et al. 2008; Phillips 1987; Whitehead 2001). Understanding how an animal uses its environment is important for monitoring and protecting core areas in conservation and management (Carvell 2001; Fellers & Kleeman 2007; Lefebvre et al. 1999).

Behavioural ecology studies lead to a more comprehensive understanding of habitat use and the potential impacts of habitat degradation and incidental mortality (Mattos et al. 2007). With an ever changing marine environment, determining the cause of habitat selection and examining the behavioural ecology of marine mammals is often difficult (Mann 2000). Habitat use is influenced by a highly dynamic ecosystem resulting from shifting factors such as prey availability, turbidity and sea surface temperature (Bräger et al. 2003). Abiotic factors have been related to the distribution of delphinids and are often measured spatially (e.g. water depth) or by the properties of the surrounding water (e.g. temperature; Bräger et al. 2003; Viddi et al. 2011). These factors may influence distribution directly or indirectly (i.e. by influencing prey distribution; Bräger et al. 2003).

Habitat use studies have been able to identify areas that are important for a range of crucial delphinid behaviours. For instance key foraging habitats have been identified for a variety of species, including: shallow rocky reefs for Indo-Pacific humpback dolphins (*Sousa chinensis*; Karczmarski et al. 2000), kelp beds for Peale’s dolphins (*Lagenorhynchus australis*; Viddi & Lescrauwaet 2005), shallow areas around river mouths, dredged channels and breaker waters for the Australian snubfin (*Orcaella heinsohni*) and Indo-Pacific humpback dolphins (Parra 2006). Resting behaviour is often reported in shallow areas, examples include; dusky dolphins (*Lagenorhynchus obscurus*; Garaffo et al. 2007) and spinner dolphins (*Stenella longirostris*; Thorne et al. 2012). It has also been reported that tucuxis (*Sotalia guianensis*) in Guanabara Bay, south-eastern Brazil, avoided areas degraded by anthropogenic impacts (Azevedo et al. 2007).

Bottlenose dolphins (*Tursiops truncatus*) demonstrate great behavioural and ecological plasticity, illustrated by the diversity of foraging specialisations noted in different populations (Sargeant et al. 2005; Smolker et al. 1997; Torres & Read 2009), which allows them to exploit an array of habitats. Considerable variation in patterns of habitat use between populations has been recorded through extensive habitat use studies (Ballance 1992; Torres & Read 2009; Wilson et al. 1997). Bottlenose dolphin populations exhibit a range of movement patterns, including seasonal migrations, year-round home ranges, periodic residency, and a combination of occasional long range movements and repeated residency (Wells & Scott 2009).

Factors such as prey distribution (Allen et al. 2001; Bearzi et al. 2008; Hastie et al. 2003; Scott et al. 1990; Wilson et al. 1997), predation risk (Heithaus & Dill 2002; Scott et al. 1990), environmental characteristics (Hastie et al. 2003; Shane 1990; Wilson et al. 1997), group size and composition (Grigg & Markowitz 1997; Hartel 2010; Mann et al. 2000; Scott et al. 1990) have all been observed to influence habitat use for bottlenose dolphins. The duration and frequency of behavioural states are influenced by environmental factors such as season, habitat, time of day, and tidal state, and by physiological factors such as reproductive seasonality (Wells & Scott 2009). Behavioural observations enable a better understanding of the function behind habitat use. Furthermore, anthropogenic disturbance can also influence behavioural states, with certain states more susceptible to disturbance than others (Christiansen et al. 2010; Stensland & Berggren 2007).

The impacts of tourism have been noted in New Zealand's bottlenose dolphins (Constantine et al. 2004; Guerra et al. 2014; Lusseau 2004, 2006; Peters & Stockin 2016). A decrease in resting and socialising behaviour has been observed in the presence of boats in Fiordland (Lusseau 2003a) and in the Bay of Islands (Constantine et al. 2004). Great Barrier Island (GBI) has been identified as an important area for the north-eastern North Island population of bottlenose dolphins, where there are no commercial whale and dolphin watching activities. The area's importance is highlighted by high site fidelity, large average group sizes and high year-round groups that predominantly contain neonates and calves (Dwyer et al. 2014).

It has been hypothesised that due to large upwellings that occur at GBI, higher prey availability may relate to larger average group sizes (Dwyer et al. 2014). Alternatively, GBI may represent a social hub where smaller groups fuse for socialising (Dwyer et al. 2014). The high numbers of calves and neonates may also influence group size at GBI, as larger group sizes have been associated with groups containing infants (Mann et al. 2000). The aim of this study was to identify why GBI waters in the Hauraki Gulf, New

Zealand, are important to the north-eastern North Island population of bottlenose dolphins in New Zealand. Specifically, the objectives were to;

1) Provide detailed insight into the habitat use of bottlenose dolphins at GBI by assessing group size categories relative to environmental parameters
2) Determine the importance of GBI waters via habitat selection by utilising behavioural budgets
3) Model behavioural states to determine the variables that influence habitat selection

## 3.2 Methods

### 3.2.1 Study area

GBI is located in the Hauraki Gulf, New Zealand, ca. 80km northeast of Auckland City (Figure 3.1). The west coast of GBI is characterised by a number of shallow embayments and consists predominantly of rocky shoreline (Dwyer et al. 2014) which occurs adjacent to Cradock Channel in the north (36°12’S 175°11’E) and Colville Channel to the south (36°23’S 175°25’E). Research focused on the western coast of GBI, in line with previous research (Dwyer et al. 2014). All waters up to 10km offshore between Miners Head (36°04’S 175°20’E) in the north and Ross Bay (36°19’S 175°28’E) in the south made up the primary study site (Figure 3.1) and encompassed ca. 500km$^2$ (Dwyer et al. 2014). This study area consisted of relatively shallow water, reaching a maximum depth of 90 m (Chart NZ 522, Land Information New Zealand). GBI is New Zealand’s largest northern offshore island at 285km$^2$, but the human population density is low and 68% of the land is administered by the Department of Conservation (DOC; Dwyer et al. 2014; Norgrove & Jordan 2006). The west coast of GBI remains largely uninhabited and no commercial marine mammal tourism operations are currently based or operating within GBI waters (Dwyer et al. 2014).

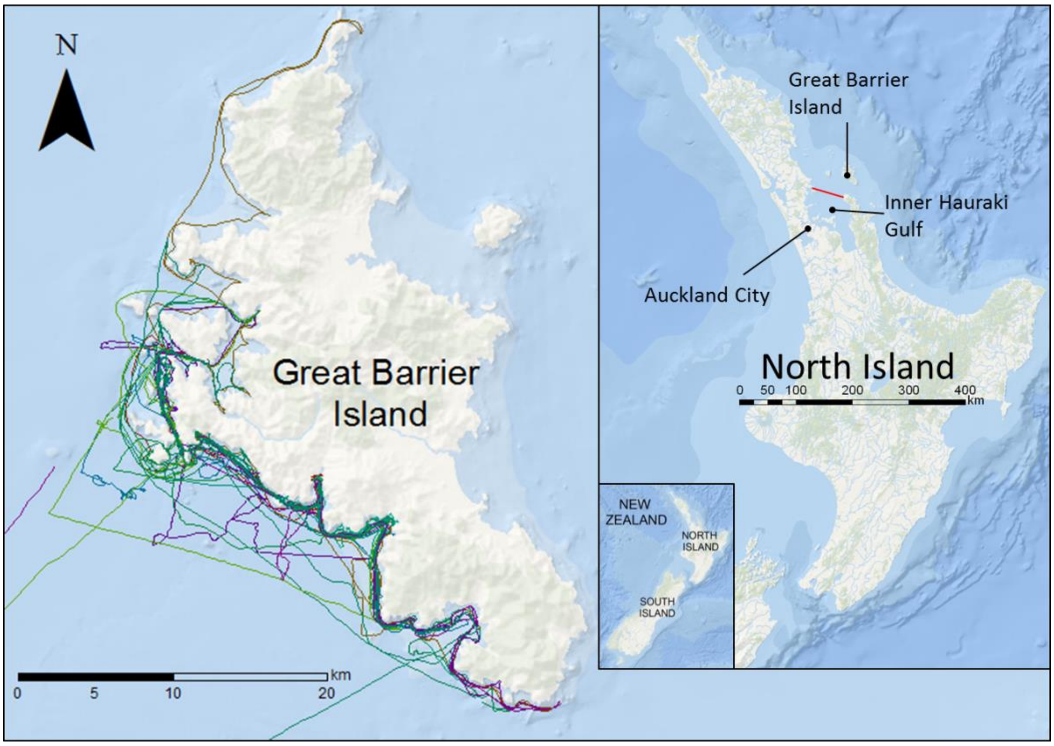


**Figure 3.1** Survey tracks off the western cost of Great Barrier Island (GBI), New Zealand, between July 2015 and March 2016. Each colour represents a survey, including on and off effort. Bathymetry is depicted with darker shades of blue representing deeper waters. Inset: Location of GBI in relation to the North Island of New Zealand, the solid red line (from Takatu Point to Kaiiti Point) indicates the boundary between the inner and out Hauraki Gulf. Source: GIS Arcmaps.

### 3.2.2 Data collection

Between July 2015 and March 2016, monthly research trips averaging 4 days in duration were undertaken to GBI when feasible (i.e. when weather and sea conditions permitted). Boat-based surveys at GBI were conducted on the research vessel *AUT Sciences*, an 8.5m aluminium boat powered by two, four-stroke 150hp outboard engines (Figure 3.2).

Non-systematic surveys were conducted to locate bottlenose dolphins and were governed by weather conditions (e.g. swell and prevailing winds). Additionally, animals were searched for based on previously known locations and sightings reported over the marine radio. Four experienced observers continuously scanned the horizon in a 270° arc in front of and to the sides of the vessel. Observers were employed as volunteers to assist in field data collection. Each observer was required to have a minimum qualification of a Bachelor of Science degree majoring in marine sciences (or other relevant degree) and received training on field data collection. Animals were detected using the naked eye and/or binoculars (10 x 50 magnification). Visual cues that indicated the presence of bottlenose dolphins included splashing, sightings of blows, or detection of dorsal fins or bodies (Dwyer et al. 2014; Stockin et al. 2009). Environmental data were collected continuously throughout the survey every 15 minutes, as detailed in Chapter 2 (Section 2.1.2.2).

**Figure 3.2** Research vessel; *AUT Sciences*. Photo: Evan Brown.

Once a group of animals was located the research vessel (RV) approached the animal(s) in accordance to the Marine Mammal Protection Regulations (1992). Once the focal group were within ca. 100m of the vessel, an 'encounter' was commenced and the group was approached as detailed in Chapter 2 (Section 2.2.2.2).

Once an encounter started, initial parameters were recorded. The latitude and longitude were recorded every 30 seconds with CyberTracker software (Version 3.440 CyberTracker Conservation 2013) and behavioural states were recorded every three minutes as detailed in Chapter 2 (Section 2.2.2.2). The decision to maintain three categories of travel was based on evidence from Bearzi et al. (1999) that suggested travel - slow in their study was similar to resting behaviour described in a number of previous studies.

**Table 3.1** Behavioural states of bottlenose dolphin (*Tursiops truncatus*) groups, defined from Constantine et al. 2004; Peter & Stockin 2016.

| Behavioural State | Definition |
|---|---|
| *Foraging* | 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 observed. |
| *Milling* | 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. |
| *Resting* | 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. |
| *Socialising* | 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 frequently observed. |
| *Travel – Fast* | Dolphins engaged in persistent, directional movement making noticeable headway along a specific compass bearing at a speeds of >3 kts involving porpoising. Group spacing varies and individuals swim with short, relatively constant dive intervals. |

| **Behavioural State** | **Definition** |
|---|---|
| *Travel – Normal* | Dolphins engaged in persistent, directional movement making noticeable headway along a specific compass bearing at a speeds of >3 kts, but not involving porpoising. |
| *Travel - Slow* | Dolphins engaged in persistent, directional movement making noticeable headway along a specific compass bearing at a speeds of <3 kts often involving periods of other behaviours (foraging/socialising/milling). |

Group size, dispersal, group heading and the number and type of vessels present were also recorded every 3 minutes as detailed in Chapter 2 (Section 2.2.2.2). An encounter (and subsequent data collection) was terminated when the decision was made to leave the group of animals. The end time and GPS location was noted for each encounter.

### 3.2.3 Data analysis

Data were transferred from CyberTracker into excel spreadsheets. Statistical analysis was completed in R 3.3.2 (R Core Team 2016). A Partial Autocorrelation Function was run to test for independence between group sizes. If group size was not independent, then an autoregressive model was applied to the data to account for autocorrelation. An ANOVA was used to test if depth and sea surface temperature (SST) were significantly different between each group size category. If an ANOVA test showed significant differences between means, a Tukey's post hoc test was conducted to identify where significant differences occurred. The percentage of time bottlenose dolphins were observed in each group size category was plotted by season. Chi-squared tests were used to test for correlation between group size and season.

Any samples of behavioural states recorded during and 20 minutes after the focal group was within 200m of any vessels (excluding the research vessel) were excluded (adapted from Mattos et al. 2007). Initially all basic (foraging, milling, resting, travelling, socialising) and combined behavioural states (behaviours recorded if an equal percentage of individuals were engaged in different behaviours within a group) were plotted to give an activity budget. A second budget was created after removing all combined behaviours, to give a better overview of the time in each state. As combined behaviours comprised just 8.6% of the entire budget, the first activity budget was discarded. The five basic behavioural states were plotted using Arcmap GIS to give a better understanding of the latitude and longitude variables used in the models.

To test which ecological variables had an effect on behavioural state, each single state was turned into a binary variable, and a boosted regression tree (Ridgeway 2017) was used to explore which variables might have an influence in determining when the group was engaged in the particular behavioural state being tested. The autocorrelation function for the residuals of the fitted model suggested that the first, second and third neighbouring data points were autocorrelated, thus only every 4th data point was selected (i.e. every 12th minute) to avoid autocorrelation. The influence of each variable was displayed in a table and partial dependence plots were used to visualise the effect of a single variable on model response when holding all other variables constant. A confusion matrix was also generated to determine the accuracy of the model.

## 3.3 Results

### 3.3.1 Effort

Between July 2015 and March 2016, four dedicated boat-based surveys were made to GBI (one during each austral season), resulting in a total 1511.1km of track around the western coast of GBI in a total survey time of ca. 139h. During this time, 12 independent encounters with bottlenose dolphins occurred and a total of 1087 behavioural observations were recorded. This resulted in 535 behavioural observations after truncation for analyses when all observations potentially effected by disturbance were removed. After removing data points to avoid autocorrelation, 133 behavioural observations remained. The highest proportion of observations occurred during winter with the lowest recorded in autumn (Table 3.2).

**Table 3.2** The percentage of total behavioural observations recorded each season for bottlenose dolphins at Great Barrier Island, New Zealand.

| **Season** | **Percent of Observations** |
|---|---|
| *Autumn* | 9.2 |
| *Spring* | 34.9 |
| *Summer* | 16.0 |
| *Winter* | 40.0 |

Behavioural states were recorded in an SST range of 13.5 - 24.1°C (mean =18.0; SD=3.7) and from depths of 1.8 - 55.3m (mean=15.8m; SD=13.2). Summer observations had the warmest mean SST but it was very similar to autumn. Observations in summer were also recorded at the highest mean depth (Table 3.3). The lowest mean SST was recorded during winter, while the mean shallowest observations were recorded in spring.

**Table 3.3** The mean (SD) and range for seasonal water depth and SST for bottlenose dolphins encountered at Great Barrier Island, New Zealand.

| | **Autumn** | **Winter** | **Spring** | **Summer** |
|---|---|---|---|---|
| *Mean SST* | 21.6 (0.3) | 14.2 (0.6) | 15.0 (0.4) | 21.9 (0.6) |
| *SST Range* | 21.3-22.5 | 10.7-14.6 | 14-16 | 20.8-24.1 |
| | | | | |
| *Mean Depth* | 20.7 (8.6) | 11.2 (9.4) | 8.5 (8.7) | 23.4 (15.9) |
| *Depth Range* | 9.8-43 | 1.8-39.1 | 2-45.3 | 0.3-55.3 |

### 3.3.2 Group Size

Group size varied from 6 to 65 individuals (mean=33; median=35; SD=18.4). Most group sizes were between 21 and 50 animals (60.2%), with fewer groups of 1 to 20 animals (33.2%), and least often 50+ individuals (11.1%). All groups except one contained immature animals, with 85.7% (n=18), 95% (n=20) and 33.3% (n=7) containing juveniles, calves and neonates, respectively. There was a significant correlation between group size and season (X2=530.85, df=6, p=2.2e-16), with the largest groups encountered during autumn, while small groups were most often observed during summer (Figure 3.3). Small groups were rarely recorded during autumn and winter.

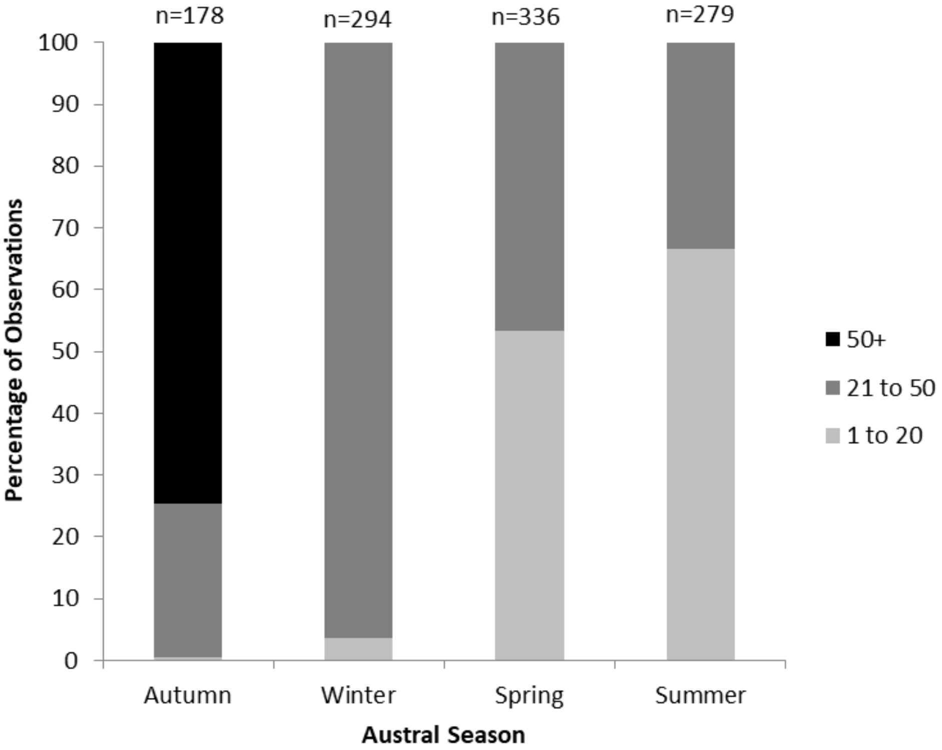


**Figure 3.3** The percentage of bottlenose dolphin groups observed in each group size category for each season; n=the number of 3 minute samples.

The largest group sizes were recorded in the deepest waters and at the highest SST (Table 3.4); however, there was no significant difference between group sizes and SST (p=0.9998) or depth (p=0.2038).

**Table 3.4** The mean (SD) and range for SST (°C) and Depth (m) for each group size category of bottlenose dolphins encountered at Great Barrier Island, New Zealand.

| | **1 to 20** | **21 to 50** | **50+** |
|---|---|---|---|
| *Mean (SD) SST* | 18.94 (3.53) | 16.54 (3.42) | 21.5 (0.11) |
| *SST Range* | 14 - 24.1 | 10.7 - 23.9 | 21.3 - 21.8 |
| | | | |
| *Mean (SD) Depth* | 14.95 (13.66) | 15.25 (13.5) | 20.55 (9.21) |
| *Depth Range* | 0.3 - 44.4 | 1.8 - 55.3 | 12.7 - 43 |

### 3.3.3 Behavioural budget for Great Barrier Island

All combined behaviours made up a total of 8.6% of the behavioural budget and thus were excluded from analysis (Appendix 3.1). Resting was the highest recorded behavioural state while foraging and socialising were rarely observed (Figure 3.4). Overall, travelling made up a total of 25.9% of the behavioural budget and of each of the travelling states, travel – slow was the most commonly observed while travel – fast was observed least.

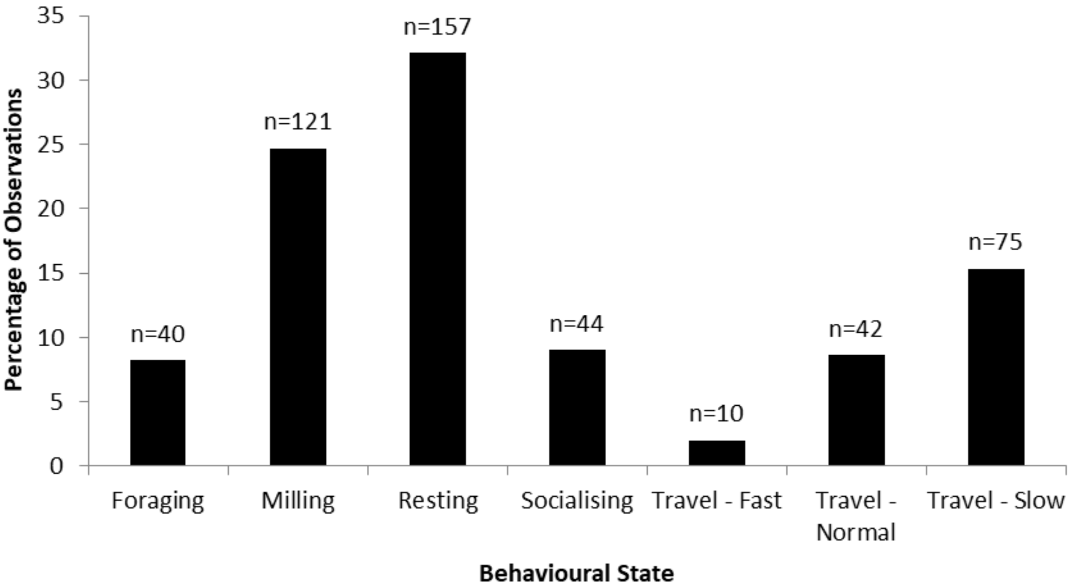


**Figure 3.4** The behavioural budget for bottlenose dolphins at Great Barrier Island, New Zealand.

### 3.3.4 Variables influencing behavioural state

With the exception of season, abiotic factors (e.g. depth, SST and location) appeared to have greater influences on behavioural state than biotic factors (e.g. group size and composition). Travelling was the most widespread behaviour, while socialising and resting groups were mostly concentrated in sheltered bay areas (Figure 3.5).

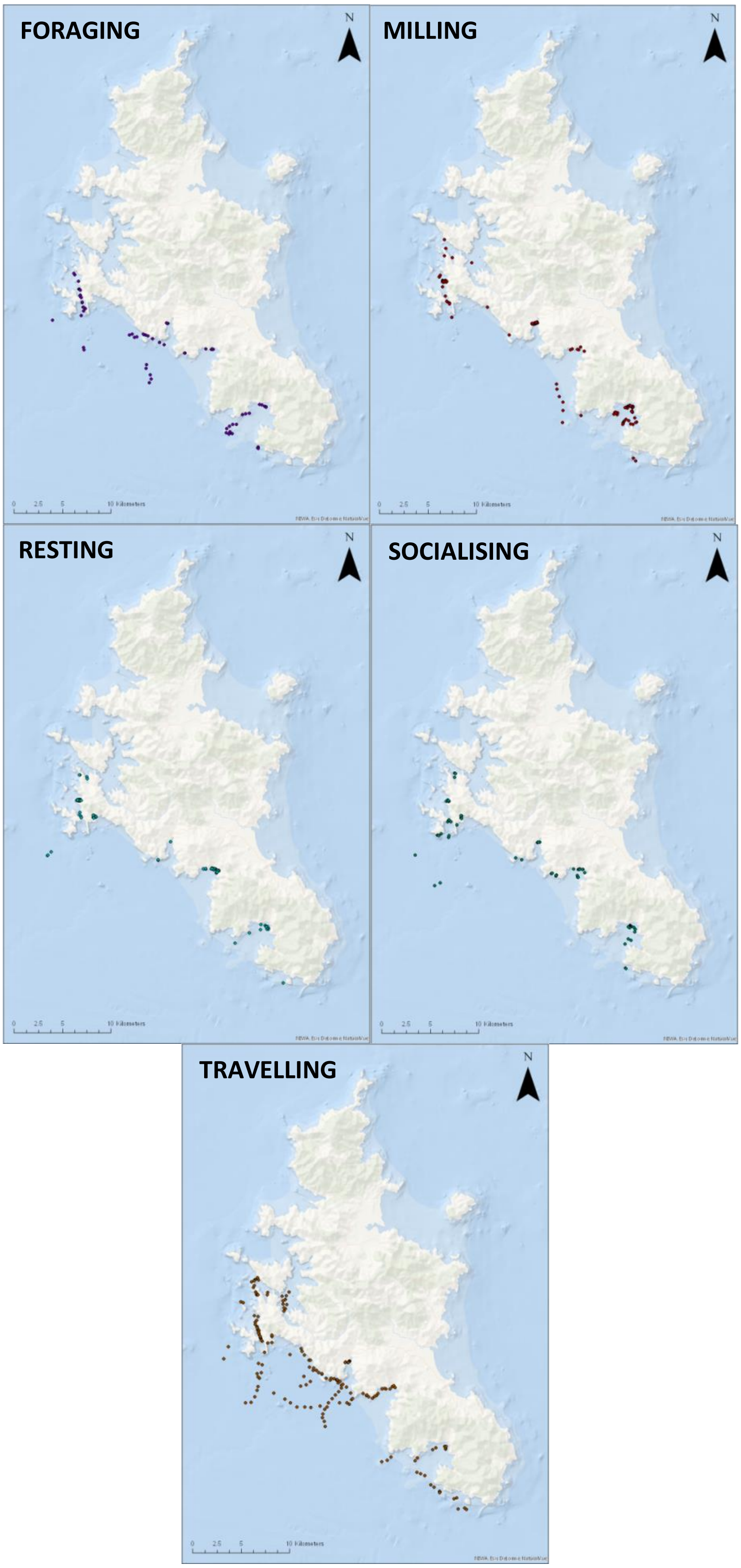


Figure 3.5 Each behavioural state plotted for bottlenose dolphins off western Great Barrier Island, New Zealand.

### *3.3.4.1 Resting*

Resting was the most commonly observed behavioural state (30.8%). The most important covariates for changing the probability of resting are SST and depth, followed by latitude and longitude (Table 3.8). As SST and latitude increased, the prevalence of resting also increased. Resting decreased with increased depth (Figure 3.8). The confusion model produced an error rate of 9% when predicting resting (Table 3.9).

**Table 3.5** The relative influence of each variable in the model to determine if the behavioural state is resting.

| Variable | Relative Influence (%) |
|---|---:|
| *SST* | 31.8 |
| *Depth* | 27 |
| *Latitude* | 19.5 |
| *Longitude* | 14.4 |
| *n. Juvenile* | 3.6 |
| *n. Neonate* | 2.8 |
| *Season* | 0.7 |
| *n. Calf* | 0.2 |
| *n. Adult* | 0.1 |

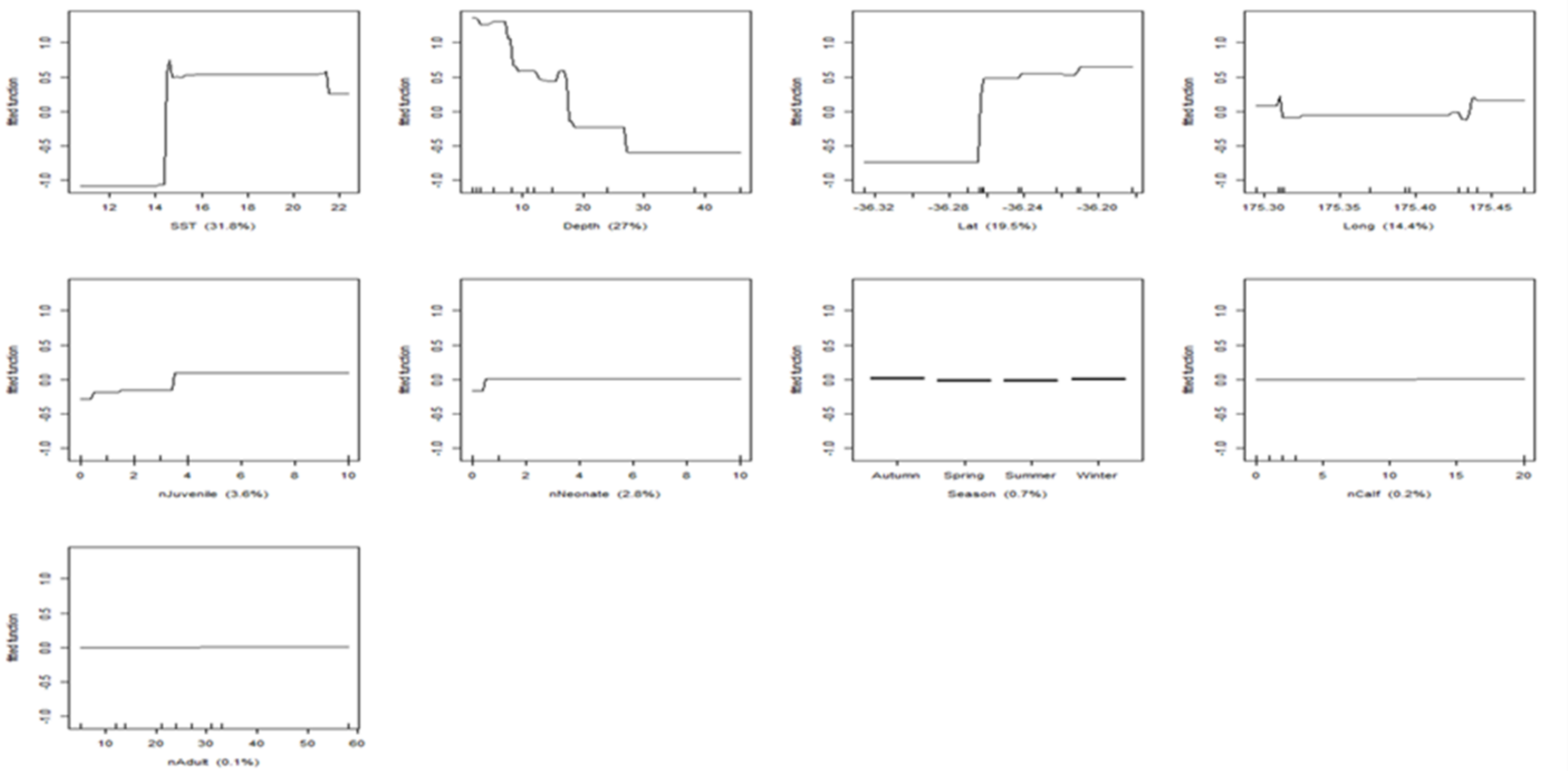


**Figure 3.6** Partial dependence plots that visualise the effect of each variable on the model response for the behavioural state resting.

**Table 3.6** Confusion matrix for boosted regression tree of resting.

| | **Predicted Resting** | |
|---|---|---|
| **Actual Resting** | *No* | *Yes* |
| *No* | 87 | 7 |
| *Yes* | 5 | 34 |

### *3.3.4.2 Foraging*

Foraging was rare (10.5% of observations modelled) and thus the final model prediction for all estimates was for the dolphins not to be foraging. Nevertheless, the model suggested the following covariates were important in changing the probability of foraging (in order of importance); foraging occurred more at greater depths and at lower latitudes and longitudes (Table 3.5; Figure 3.6).

**Table 3.7** The relative influence of each variable in the model to determine if the behavioural state is foraging.

| **Variable** | **Relative Influence (%)** |
|---|---|
| *Depth* | 32.6 |
| *Latitude* | 24.6 |
| *Longitude* | 20.4 |
| *SST* | 6.8 |
| *Group Dispersal* | 3.7 |
| *Group Size* | 3.2 |
| *n. Adults* | 2.5 |
| *n. Neonates* | 2.3 |
| *Time of Day* | 2.2 |
| *Season* | 1 |
| *n. Juvenile* | 0.6 |
| *n. Calf* | 0.2 |

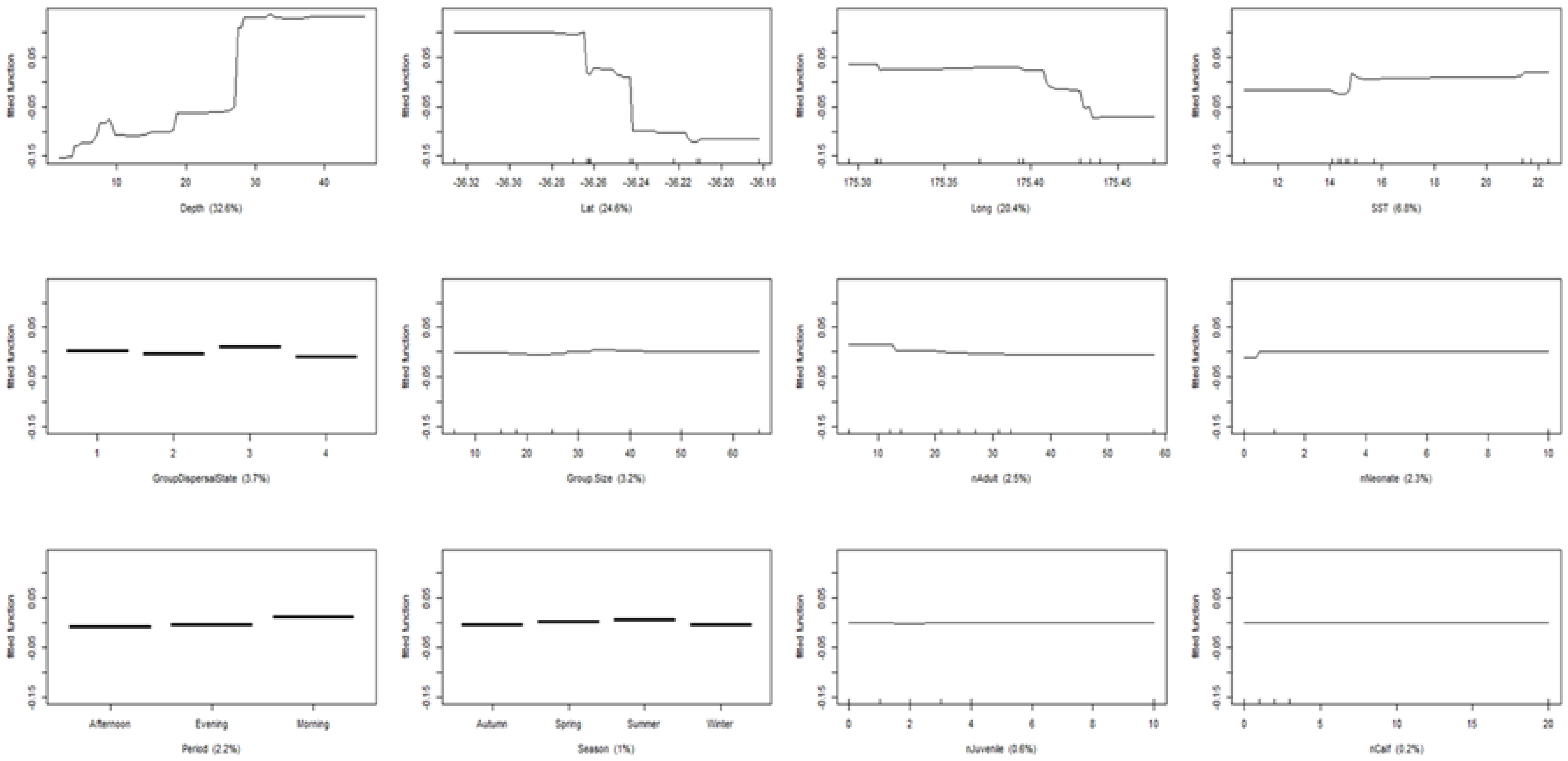


**Figure 3.7** Partial dependence plots that visualise the effect of each variable on the model response for the behavioural state foraging.

#### *3.3.4.3 Milling*

Milling comprised 27% of observations. The model suggests that SST is the most important factor influencing the probability of milling, the prevalence of milling decreases as SST increases (Table 3.6; Figure 3.7). The confusion matrix suggests that the model had an error rate of 7.5% when predicting milling (Table 3.7).

**Table 3.8** The relative influence of each variable in the model to determine if the behavioural state is milling.

| Variable | Relative Influence (%) |
|---|---:|
| *SST* | 57.6 |
| *Latitude* | 9.8 |
| *Group Dispersion* | 9.8 |
| *Depth* | 9.6 |
| *Longitude* | 7.2 |
| *Season* | 2.7 |
| *n. Juvenile* | 1.3 |
| *Group Size* | 0.9 |
| *n. Calf* | 0.5 |
| *Time of Day* | 0.4 |
| *n. Adults* | 0.2 |
| *n. Neonates* | 0 |

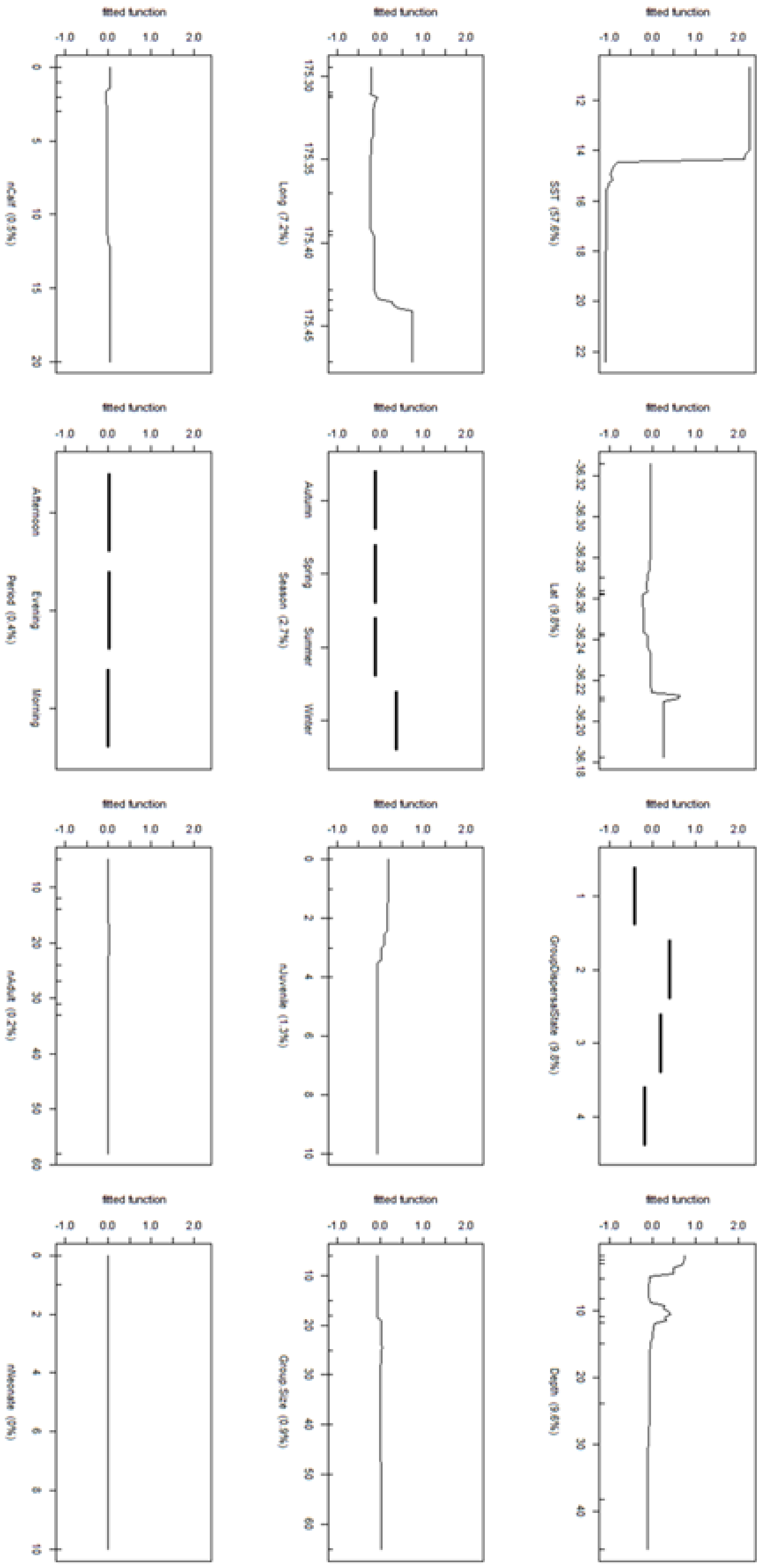


**Figure 3.8** Partial dependence plots that visualise the effect of each variable on the model response for the behavioural state milling.

**Table 3.9** Confusion matrix for boosted regression tree of milling.

| | **Predicted Milling** | |
|---|---|---|
| **Actual Milling** | *No* | *Yes* |
| *No* | 94 | 8 |
| *Yes* | 2 | 29 |

### *3.3.4.4 Socialising*

Socialising was never predicted as it was a rare event (6.7%), although the model suggested that longitude, SST and depth were the most important parameters likely to change the probability of socialising (Table 3.10). Socialising was predicted more at higher longitudes, SST and depth (Figure 3.9).

**Table 3.10** The relative influence of each variable in the model to determine if the behavioural state is socialising.

| **Variable** | **Relative Influence (%)** |
|---|---:|
| *Longitude* | 31.4 |
| *SST* | 24.5 |
| *Depth* | 14.3 |
| *Season* | 10.5 |
| *n. Adult* | 8.7 |
| *Latitude* | 7.1 |
| *Group Dispersal* | 1.3 |
| *n. Neonate* | 1.2 |
| *Group Size* | 0.5 |
| *n. Juvenile* | 0.3 |
| *n. Calf* | 0 |

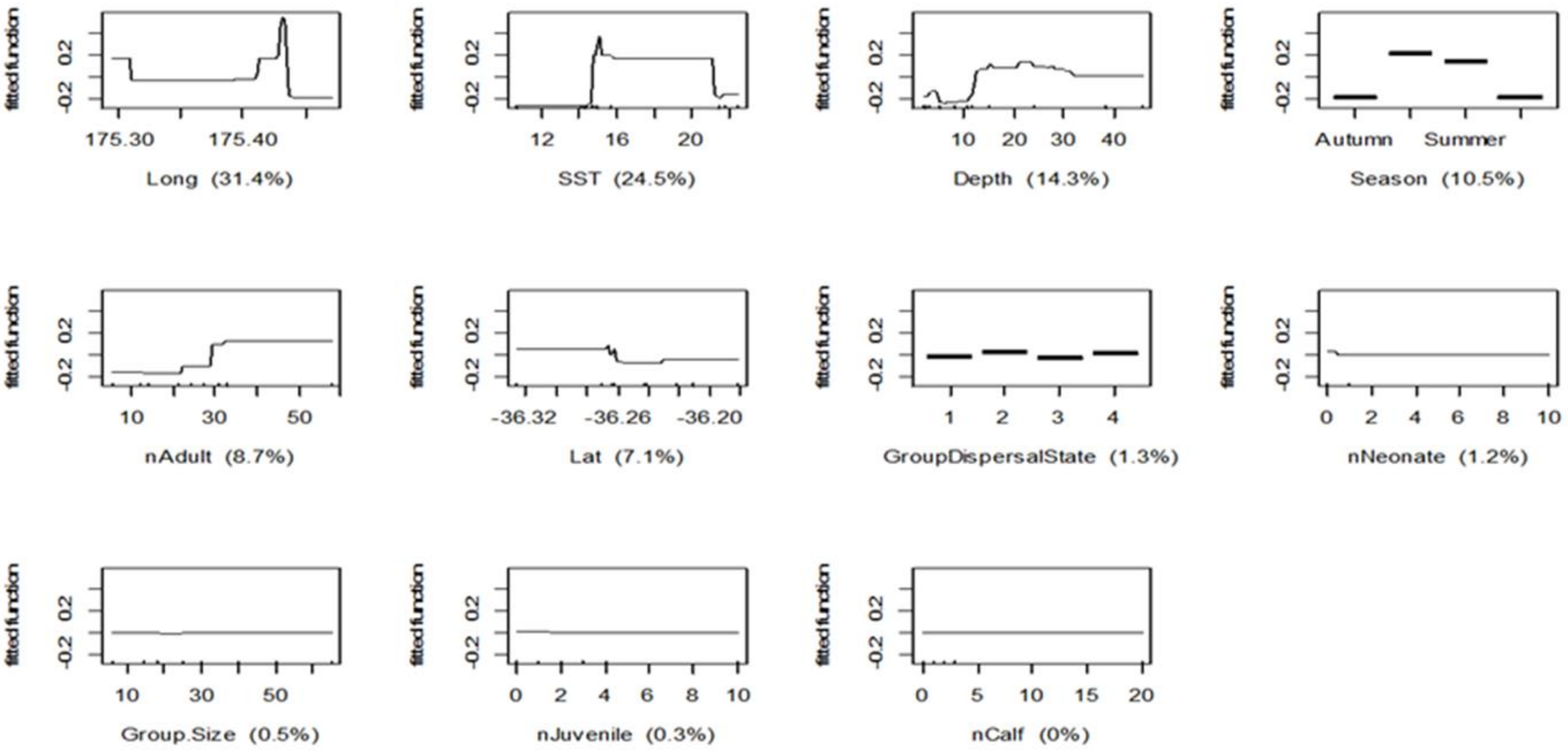


**Figure 3.9** Partial dependence plots that visualise the effect of each variable on the model response for the behavioural state Socialising.

### *3.3.4.5 Travelling*

Travelling was observed for 23.1% of observations. SST and depth were the most important variables for determining whether the behavioural state was travelling or not (Table 3.11). As SST and depth increased, the prevalence of travelling increased (Figure 3.10). The confusion model produced an error rate of 15.8% (Table 3.12).

**Table 3.11** The relative influence of each variable in the model to determine if the behavioural state is travelling.

| **Variable** | **Relative Influence (%)** |
|---|---:|
| *SST* | 37.7 |
| *Depth* | 36.5 |
| *Latitude* | 10.3 |
| *Longitude* | 5.5 |
| *Group Size* | 3.8 |
| *Group Dispersal* | 3.6 |
| *Season* | 1.1 |
| *n. Neonate* | 0.8 |
| *n. Adult* | 0.5 |
| *n. Juvenile* | 0.2 |
| *n. Calf* | 0 |

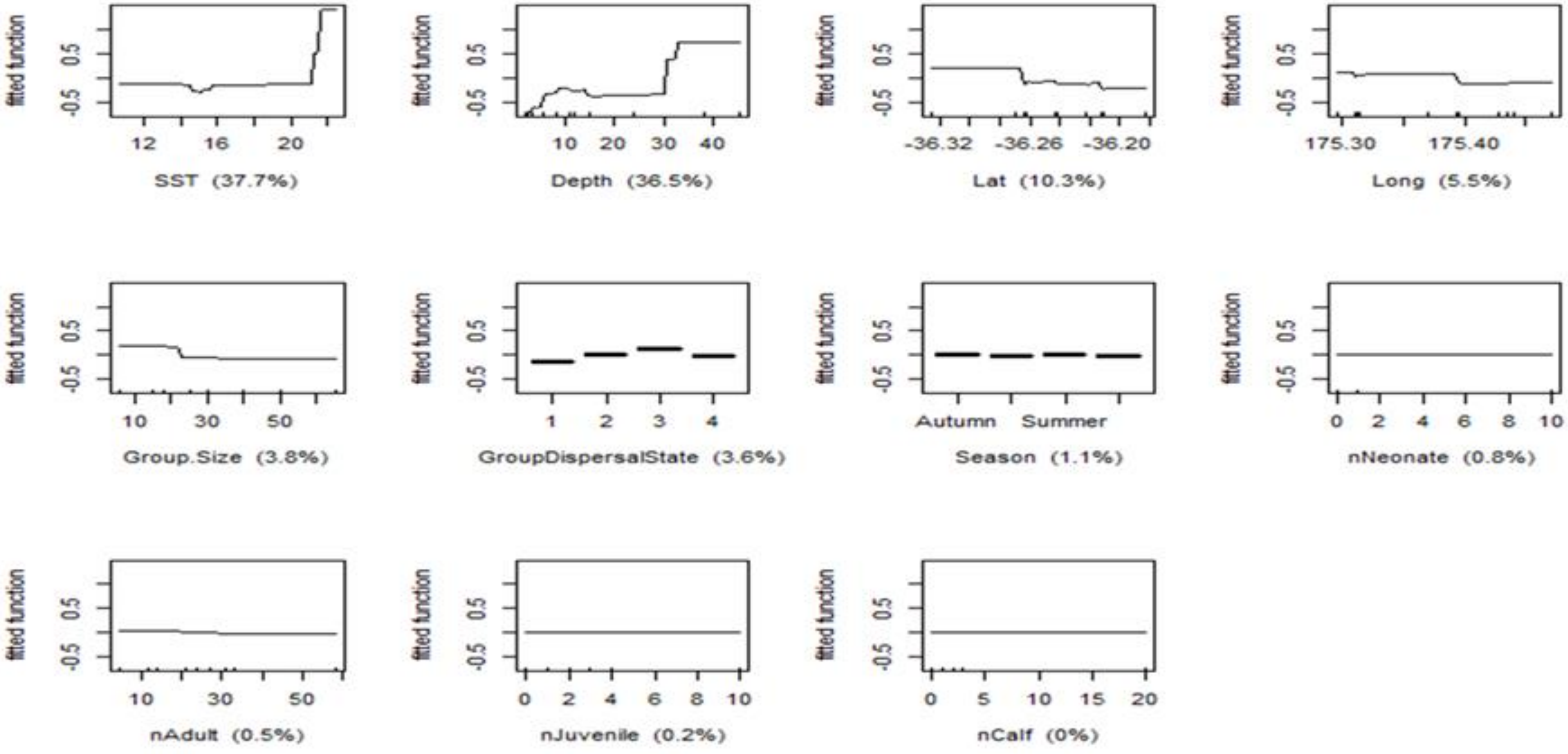


**Figure 3.10** Partial dependence plots that visualise the effect of each variable on the model response for the behavioural state travelling.

**Table 3.12** Confusion matrix for boosted regression tree of travelling.

| | **Predicted Travelling** | |
|---|---|---|
| **Actual Travelling** | *No* | *Yes* |
| *No* | 98 | 18 |
| *Yes* | 3 | 14 |

## 3.4 Discussion

### 3.4.1 Group Size

Group sizes remained consistent with previous studies (Dwyer 2014; Dwyer et al. 2014), though contrary to these studies, the largest group sizes recorded at GBI occurred during autumn while the smallest groups occurred most often during summer and spring. This is yet to be confirmed by photo-identification and could potentially be biased by the survey design (i.e. remaining with one focal group, concentrated survey effort towards the southern west coast) and small sample size. An alternative explanation is that seasonal changes in group size are evident, as is observed within and between populations elsewhere (Campbell et al. 2002; Barker & Berrow 2016). Season is unlikely to be a consistent variable for dolphin group size due to variations in SST and local oceanic currents occurring within each season. However, the largest groups were observed during periods with a higher mean SST. This is consistent with previous research which found the largest group sizes in summer, during periods of the warmest SST (Dwyer et al. 2014). Differences in group size by season may correspond with inter-annual variation in mean SST for each season between the present study and those reported by Dwyer (2014). Furthermore, these differences in mean temperature may be due to the weather variations caused by La Niña, Neutral and El Niño during the study by Dwyer et al. (2014) and the El Niño system that occurred between 2015 – 2016 (NIWA National Climate Centre 2015;2016) during the present study. Differences in SST may also occur due to differences in methodology, as Dwyer (2014) obtained SST from remote sensing satellite data.

While no significant relationship was found between group size and depth, the largest groups were recorded in the greatest mean depth (Table 3.4). Larger groups of bottlenose dolphins have previously been reported to occur more often in greater depths (Bearzi

2005; Sarabia et al. 2017; Shane 1990b), but the lack of significant variation in the present study may reflect the large average group sizes already present at GBI. Previously, large group size in deeper, open waters are thought to provide a higher chance of finding prey or increased predator protection (Bearzi 2005; Defran & Weller 1999), thus the consistently large groups at GBI may already provide these benefits.

Group size has previously been correlated with behavioural activity (Bearzi et al. 1999), yet in this study group size had little influence on behaviour. The formation of large group sizes at GBI may be explained by the high prevalence of calves. Studies have reported a positive correlation between group size and the number of calves (Merriman 2007; Moller & Harcourt 1998; Sinclair 2016; Vermeulen et al. 2015). Larger group sizes are thought to provide better calf protection and assistance, reduce individual maternal investment, and aid in learning (Dungan et al. 2016; Gibson & Mann 2008; Heithaus & Dill 2002).

### 3.4.2 Habitat Selection

Combined behaviours comprised just 8.6% of the entire budget and thus excluding them was assumed to cause little bias in further analysis (Appendix 3.1). Resting was the most prominent behavioural state recorded for bottlenose dolphins at GBI. Travelling and milling were also common behaviours. Other studies on *Tursiops* spp. generally report foraging (Garcia et al. 2017; Mattos et al. 2007; Sini et al. 2005; Veneruso & Evans 2012) or travelling (Baker, O'Brien, McHugh, Ingram & Berrow 2017; Bas et al. 2017; Bearzi et al. 2009; Beddia 2007; Filby et al. 2017; Inoue et al. 2017) to be the most prevalent behavioural states. Other studies in New Zealand have also reported travelling as the most prominent behavioural state (Lusseau 2004; Merriman 2007; Peters & Stockin 2016; Schneider 1999). The prominence of resting at GBI suggests something may be unique about this habitat or how this population uses the area. It should be noted that direct comparisons between regions and populations is complicated. Definitions of behavioural states are often different or overlap between studies. Methodology may also vary, while study sites likely only include a portion of the range of a population of bottlenose dolphins. For instance, the data collection for this study only included observations from GBI waters, while this population is known to inhabit a much larger area (Chapter 1; Figure 1.3).

Resting was the most recorded behaviour at GBI by bottlenose dolphins, and made up almost a third of their entire behavioural budget (Figure 3.4). Resting occurred at higher SST and lower depths. Warmer SST would result in lower energetic requirements to regulate body temperature, however this is difficult to conclude given the only behaviour to increase at lower SST was milling. Resting is considered the most vulnerable behavioural state as it requires reduced vigilance (Connor & Heithaus 1996; Heithaus 2001; Heithaus & Dill 2002). Thus, dolphins would be expected to select safe habitats for resting as the energetic costs of moving into safe habitats is low while the benefit of occupying safe habitats is high (Heithaus 2001; Williams et al. 1992). It is thought that shallower waters increase a dolphin's ability to detect predators and avoid sharks (Mann et al. 2000). Additionally, the perceived lower levels of human disturbance at GBI may facilitate resting behaviour, as resting behaviour is sensitive to vessel activity (Baş et al. 2017; Christiansen et al. 2010; Lusseau 2004; Stensland & Berggren 2007). This trend is reflected in part of the north-eastern North Island population in the BOI, as the proportion of resting significantly decreased in the presence of multiple vessels (Constantine et al. 2004). Yet, it should be noted that dolphins are not entirely sheltered from the impacts of boat traffic at GBI, as a number of recreational boats use these waters, particularly during summer.

The high proportion of resting at GBI may correlate to the high prevalence of calves. It was reported by Mann & Smuts (1999) that mothers in their study spent most of their time resting, while the calves remained in close proximity and also spent a considerable amount of time resting. The large proportion of time spent resting may aid to offset the large energetic cost of lactation (Kastelein et al. 2002). Furthermore, it is the main behavioural state in which female dolphins nurse their calves (Stensland & Berggren 2007).

Travel – slow was the most observed travel state and made up 60% of all travelling behaviour. This may be related to the high proportion of resting behaviour. Bearzi et al. (1999) reported that travel – slow in their study matched resting behaviour described in a number of previous studies and suggested it was a type of resting behaviour. An attempt was made to test travel – slow and travel – normal/fast as separate models, but problems with model convergence arose (Appendix 3.2). However, it did appear that there was a positive correlation between depth and travel – normal/fast (Appendix 3.2). This effect was present for travel – slow, yet it was much weaker. Additionally, a positive correlation with SST was important for predicting rest and travel – slow. This may support the idea that this state doubles as a form of rest. The correlation with depth may imply that Travel – slow may be a resting behaviour utilised in less sheltered waters. Travel – slow may be utilised to conserve energy while moving through habitats that require higher levels of vigilance than rest. Alternatively, as travelling is often associated with foraging (Beddia

2007), travel – slow may be a way to travel between locations while conserving energy, as less urgency is required than when the group is pursuing prey.

Milling was often observed and SST was the only factor presented by the model to significantly predict milling. As SST increased, the prevalence of milling decreased, which was the opposite trend for resting, socialising and travelling. The role that milling plays is difficult to assess and few attempts have been made to explain it (Neumann 2001b), though it is often associated with feeding, socialising or resting (Shane et al. 1986). It has been suggested that it may play multiple roles, e.g. investigating a potential foraging area, a brief rest between bouts of travelling, or a transitional stage between travelling and other behavioural states (Constantine 2001; Neumann 2001b; Stockin et al. 2009). Milling tends to occur in much lower proportions in other studies of *Tursiops* spp. (Filby et al. 2017; Hanson & Defran 1993; Lusseau 2004; Merriman 2007; Sini et al. 2005; Vermeulen et al. 2015). The large group sizes at GBI could explain the high prevalence of milling, as a positive correlation with group size has been reported during another study (Mattos et al. 2007). Perhaps part of the function of milling is to reorganise social units within a larger group. Alternatively, milling may be a result of dolphins searching for prey in their local vicinity. As SST increases, perhaps more prey is available and thus less milling behaviour is required to locate it. It has also been suggested that milling is used to conserve energy when the dolphins are unwilling to rest due to disturbance (Constantine 2002), though it is unlikely to be the cause of the high rates of milling in the present study given the perceived low levels of disturbance.

Foraging and socialising were not recorded often and made up only 8.2% and 9% of the behavioural budget, respectively. This is in contrast with the idea previously presented, that GBI is important for foraging or utilised as a social hub by bottlenose dolphins (Dwyer et al. 2014). Socialising was never predicted by the model as it was a rare event. It is not uncommon that socialising makes up a small percentage of *Tursiops* spp. behavioural budget (Baker, O'Brien, McHugh, Ingram & Berrow 2017; Bearzi et al. 1999; Beddia 2007; Filby et al. 2017; Garcia et al. 2017; Kiszka et al. 2011; Mattos et al. 2007). The model suggested that longitude and SST were the most important factors determining socialising, followed by depth and season. Longitude is a difficult variable to interpret in this instance. The two peaks in the partial dependence plot likely reflect the socialising distribution in figure 3.5. Socialising also increased with depth, but plateaued around 10 – 15m. The distribution and longitude suggest socialising still occurs within sheltered areas though the behaviour requires deeper water than resting. The reason for this may be because behavioural events often associated with socialising, such as chasing or breaching (Baker, O'Brien, McHugh, Ingram & Berrow 2017; Baş et al. 2017;

Karniski et al. 2015), require more space. Alternatively, the seabed substrate or vegetation may lend itself more favourably to social behaviours at that depth. For example, bottlenose dolphins have been recorded playing with seaweed (Kuczaj & Eskelinen 2014).

Warmer temperatures were important for determining if a behavioural state was socialising, which occurred most often during spring and summer. Seasonal trends in behaviour have previously been reported and are often thought to relate to prey movements (Baş et al. 2014; Miller et al. 2010; Vermeulen et al. 2015) or mating seasons (Miller et al. 2010). Socialising in the warmer temperatures of spring and summer have previously been associated with a mating season, as calves are often born in summer after a 12 month gestation period (Hanson & Defran 1993; Miller et al. 2010; Moller & Harcourt 1998; Smith et al. 2016; Sprogis et al. 2016). This is also a suspected pattern for the BOI, as higher numbers of neonates were sighted in warmer seasons (Hartel 2010). While socialising rarely occurred at GBI in this study, it is likely that dolphins there engaged in similar mating seasons. Observations from GBI support this, as 71.4% (n=5) of neonate sightings occurred during warmer temperatures (unpub. data) and the highest proportion of neonates previously reported was observed during summer (Dwyer et al. 2014).

The model was unable to predict foraging as this state was rarely observed, but it was able to provide insights into factors important for foraging. Foraging occurs at greater depths, which is expected given that foraging was often recorded further from the coastline (Figure 3.5). Movement into deeper waters has been reported previously for foraging bottlenose dolphins (Bearzi et al. 1999; Hastie et al. 2004). Higher latitude and lower longitude were also important to determine whether dolphins foraged or not. A lower longitude places the dolphins further away from the coastline and deeper waters and higher latitude places the dolphins closer to the Colville Channel. The strong currents and upwellings around the Colville Channel may result in increased biological activity (Black et al. 2000; Manighetti & Carter 1999), providing higher densities of prey species for bottlenose dolphins.

It should be noted that on multiple occasions, individuals or small groups of between one to five animals appeared to be foraging in shallow water while the majority of the group were engaged in other behavioural states (pers. obs). Thus, this type of solitary foraging strategy would have gone unreported during scan sampling. This is notable since cooperative foraging was rarely recorded in BOI, with solitary foraging techniques the primarily mechanism observed (Constantine 2002; Hartel 2010). This may indicate that the data shows an unrepresentative percentage of time foraging at both locations, as only a few individuals would be engaged in this activity it would not be recorded as a behavioural state. Alternatively, the presumption that there is an abundance of prey resulting from the upwellings around GBI may be incorrect. The low proportions of foraging observed may be indicative of low levels of prey in GBI waters, and this may vary annually with SST and/or be due to the La Niña/El Niño weather oscillations.

A considerable amount of time was spent travelling (Figure 3.4). However, if travel – slow is considered a resting behaviour and removed as mentioned previously, it makes up very little of the behavioural budget. It has been suggested that one of the primary functions of travel is to locate food and it has been associated with foraging (Beddia 2007; Garcia et al. 2017; Karniski et al. 2015; Mattos et al. 2007). The low proportion of travel – fast and travel – normal, combined with the large depths that both travel and foraging occurred in, could correlate to the low percentage of foraging behaviour recorded. Alternatively, if the proportion of foraging was low, the overall high rates of travel may be associated with potential shortages and/or patchy distributions of prey (Bearzi et al. 2009; Beddia 2007; Veneruso & Evans 2012).

Behavioural budgets varied greatly for GBI between the periods of 2011-2013 and 2015-2016. Travelling and milling were recorded in similar proportions; however in the period of 2011-2013 resting was rarely recorded while foraging and socialising was documented more often (Dwyer pers. comms.). Differences in behavioural budgets may be due to the different La Niña/El Niño weather patterns experienced during the studies. These weather patterns influence SST and ocean currents, which in turn may influence prey distributions (Miller et al. 2010; Neumann 2001a; Sprogis et al. 2018; Vermeulen et al. 2015). Methodology also differed between studies, as behavioural samples were taken every 15 minutes during 2011-2013 (Dwyer 2014).

In the BOI, travelling was the most observed behaviour with or without the presence of vessels, while resting was rarely observed (Peters & Stockin 2016; Constantine 2002). This is consistent with other studies of *Tursiops* spp. (Baker, O'Brien, McHugh, Ingram & Berrow 2017; Bas et al. 2017; Bearzi et al. 2009; Beddia 2007; Filby et al. 2017; Inoue et al. 2017). High rates of travel have previously been associated with potential shortages or patchy distributions of prey (Bearzi et al. 2009; Beddia 2007; Veneruso & Evans 2012), which may reflect the situation in the BOI and GBI, as the proportion of foraging was also low. Though, habitat use prior to tourism in the Bay of Islands is unknown as no data exists (Constantine 2002). Thus it is unknown if this high rate of travel is natural or a function of the high levels of boat traffic in the area and may reflect avoidance behaviour

(Constantine et al. 2004; Hartel et al. 2014). Perhaps the perceived lower levels of anthropogenic disturbance at GBI are reflected in the low rates of travel-normal/fast, which makes up a higher proportion of travel in the BOI. It is suggested that the BOI and GBI provide different habitat requirements for the population, given the differences in behavioural budgets.

### 3.4.3 Habitat Use

Groups containing females and calves are often larger than adult only groups and are referred to as ‘nursery’ groups (Wells 2003; Barker & Berrow 2016). Thus, it is suggested here that the large group sizes at GBI may be a function of the number of immature animals. Particular areas that appear to be used as nursery grounds for bottlenose dolphins have been previously identified (Barco et al. 1999; Estep 2012; Rossi et al. 2017; Scott et al. 1990; Toth et al. 2011). Certain geographic areas have been favoured as nursery areas, likely because they are protected, shallow and offer an abundance of prey. It has been reported that mother-calf pairs were sighted year-round in these nursery grounds as opposed to following any seasonal movements (Estep 2012). GBI has many small inlets and bays that are shallow and provide protection from predators and ocean waves. There are strong currents from the Colville Channel along the south-east coast of GBI, where upwellings occur under south-easterly winds (Black et al. 2000; Manighetti & Carter 1999). These upwellings may provide an abundance of prey in the waters surrounding GBI. These geographic characteristics are consistent with other areas considered to be nursery habitats (Barco et al. 1999; Estep 2012; Rossi et al. 2017; Scott et al. 1990). Additionally, perceived lower levels of anthropogenic disturbance have been considered to be a contributing factor to the selection of habitat as a nursery area for bottlenose dolphins (Rossi et al. 2017).

Particular study sites and habitats comprise only part of a population’s range. Specific areas provide functions for certain behaviours e.g. areas have been identified for foraging (Sini et al. 2005), socialising (Merriman 2007) or as refuges for resting (Vermeulen et al. 2015). Dwyer et al. (2014) suggested that GBI waters may be a used as a location for socialising or foraging, however the results of this study would suggest otherwise. It was also suggested that the shallow bays and harbours adjacent to the Colville Channel have consistent food availability, are suitable for breeding or calving, and lack high levels of anthropogenic pressures (Dwyer 2014). Very young neonates were observed at GBI and mother-calf pairs are sighted year round (Dwyer et al. 2014). The predominant behaviour observed during the present study was resting, which is the main behavioural state in which female dolphins nurse their calves (Stensland & Berggren 2007). Given the high rate of resting observed at GBI, the local bathymetry, perceived low anthropogenic impacts, and the large number of immature animals, it is possible that these waters may be important for nursery groups.

While little foraging was observed in the present study, dolphins may forage nocturnally at GBI. It is also possible that the waters surrounding GBI, particularly the Colville Channel, provide a foraging area that is able to sustain large groups as suggested by Dwyer et al. (2014). It has been predicted that the strong currents and upwellings around the Colville Channel may result in increased biological activity (Black et al.2000; Manighetti & Carter 1999). Few studies have surveyed the nocturnal activity of bottlenose dolphins, though nocturnal foraging has been reported (Bloom et al. 1995; Mann & Sargeant 2003; Klatsky et al. 2007). Species that engage in nocturnal foraging are often observed to engage in high proportions of resting behaviour during diurnal hours, such as spinner (*Stenella longirostris*; Karczmarski et al. 2005; Lammers 2004; Thorne et al. 2012; Tyne et al. 2017) and dusky dolphins (*Lagenorhynchus obscurus*; Markowitz 2012; Dahood et al. 2010). This could reflect the diurnal behavioural budget of bottlenose dolphins in the present study at GBI. Future research should attempt to expand the behavioural budget to include nocturnal activity.

It should be noted that these results may only reflect habitat use along the south-western coastline at GBI. Bottlenose dolphins have been reported along the north-western coastline, and often in small groups (Dwyer et al. 2014). Groups in these waters were not detected in the present study, likely due to the lower search effort in the area. Additionally, surveys along the eastern coast of GBI are yet to be conducted. Future studies should focus on gathering behavioural data from a wider range of bottlenose dolphins groups at GBI over a longer time frame.

### 3.4.4 Summary

Overall, group sizes remained consistent at GBI with Dwyer et al. (2014) which may correlate to the high number of immature animals observed in these waters. Group sizes were recorded to be larger during periods of higher SST. Bottlenose dolphins at GBI were primarily observed to be engaged in resting behaviour, though given the short time period and contradicting behavioural results to Dwyer (pers. comms.) it cannot be confirmed whether this is an artefact of this study or reflective of a real difference in behavioural budget. Additionally, travel – slow was the most prominent travelling speed and may indicate further resting behaviour. Contrary to Dwyer et al. (2014), foraging and socialising were rarely recorded. These differences between Dwyer et al. (2014) and the present study likely result from variations in weather patterns or methodology. Regardless, given the evidence presented in this study, it is hypothesised that the waters surrounding GBI are important for nursing groups of bottlenose dolphins in the north-eastern North Island population.

# Chapter 4

# Whistle repertoire of bottlenose dolphins (*Tursiops truncatus*) at Great Barrier Island, New Zealand

Bottlenose dolphins engaged in social behaviour at Great Barrier Island, New Zealand

## 4.1 Introduction

Animals actively utilise acoustics in a variety of different ways, including; echolocation (Norberg & Rayner 1987), prey capture (Versluis et al. 2000), searching for habitat (Simpson et al. 2004) and communication (Seyfarth & Cheney 2003). Communication is defined as consisting of the transfer of information between a sender and a receiver, using a code of specific signals that usually serve to meet common challenges (e.g. reproduction, foraging), and in group living species, to promote cohesiveness (Vauclair 1996). It is used by many animals to communicate specific messages complemented with additional information regarding their motivation, sex, age or even their identity (Halliday 1983). In social animals, vocal communication can be essential to mediate important social behaviours (McGregor & Peake 2000; Tyack 2003). It also allows members of a group to gain information about each other in the complex fission-fusion societies that animals, such as dolphins, often live within (Connor et al. 2000; Smolker et al. 1992).

To convey specific information within these societies, varying types of signals must be produced. It is essential to categorise vocalisations within a species' repertoire to facilitate insight into functionality, social relevance and geographical variation (Boisseau 2005; López & Shirai 2009). The close relationship between signals and specific social contexts has been identified for beluga whales (*Delphinapterus leucas*; Panova et al. 2012), killer whales (*Orcinus orca*; Foote et al. 2008; Van Opzeeland et al. 2005), tucuxi (*Sotalia fluviatilis*; Pivari & Rosso 2005) and *Tursiops* spp. (Cook et al. 2004; Díaz López 2011; Esch et al. 2009; Hawkins & Gartside 2009a, 2009b, 2010; Herzing 2000; Janik et al. 1994).

Bottlenose dolphins (*Tursiops truncatus*) are extremely vocal and this acoustic communication plays an important part in mediating social interactions (López 2011; López & Shirai 2009). It is considered that bottlenose dolphins produce three types of sounds: whistles, echolocation clicks and burst-pulse sounds (Boisseau 2005). Whistles and burst-pulse sounds are the two primary sounds thought to play a role in social interactions (Herzing 2000; López & Shirai 2009). Whistles are generally studied in dolphin acoustic research because they can be recorded in high numbers with good signal-to-noise ratios and they possess numerous characteristics that are easily measured from their frequency contours (Boisseau 2005; López 2011; Ralston & Herman 1995). It has been suggested working with captive animals, that bottlenose dolphins possess extremely fine-scale vocal classification abilities (Au et al. 2002; Brill et al. 2001; Helweg et al. 2003). Thus, along with whistle type, whistle parameters (e.g. duration or frequency) may also provide insight into the use of whistles by bottlenose dolphins. The acoustic features of whistles are thought to convey specific information about the behavioural context of the individuals involved (Hawkins & Gartside 2010; López 2011). Variation in the acoustic features of whistles demonstrates its integral role in social interactions of the complex fission-fusion societies of *Tursiops* spp. (Hawkins & Gartside 2009b; López 2011).

Dolphins produce a range of whistles, including signature whistles that are individually unique and appear to be used to communicate identity, location and possibly emotional state (Janik et al. 2006; Sayigh et al. 1990; Wells & Scott 2009). Whistles are a narrowband, frequency modulated and omnidirectional signal (Buck & Tyack 1993; Elliott 2010) and in the case of bottlenose dolphins, generally fall between 5 and 20kHz, although frequencies up to 27.3kHz have been reported (Esch et al. 2009). Acoustic features, such as frequency and duration, have been used to characterise whistles in the genus. This allows for comparisons among groups and populations (Azevedo et al. 2007; Bazúa-Durán & Au 2004; dos Santos et al. 2005; López 2011; Rendell et al. 1999).

Whistle rates can be dependent on behaviour, group size and/or group composition, but this varies between habitat and populations. Feeding and socialising tend to have the highest whistle rates, as reported in Costa Rica, Portugal, the Mediterranean and parts of the United States of America (Acevedo-Gutiérrez & Stienessen 2004; dos Santos et al. 2005; Jones & Sayigh 2002; López & Shirai 2009). Group size can influence whistle rate, positively (Cook et al. 2004; Jones & Sayigh 2002) or negatively (Hawkins & Gartside 2010; Jones & Sayigh 2002; Quick & Janik 2008). The group composition of *Tursiops* spp. can also influence whistle rates, as groups with calves often produce fewer whistles (Hawkins & Gartside 2010; Jones & Sayigh 2002).

Whistle types and characteristics can similarly be determined by behaviour (Hawkins & Gartside 2010; López 2011) and local environmental factors, such as high ambient noise (May-Collado 2010; Wang et al. 1995). Different environmental influences are likely to affect each population (Conner 1982) and differences in habitat, ecology, social group and contextual behaviour may influence whistle characteristics of different groups or populations (López 2011). Acoustic parameters, including peak frequency and number of inflection points, may be modulated by *Tursiops* spp. to carry additional information such as: behavioural activity, individual identity and stress levels (Azevedo et al. 2007; Díaz López 2011; Esch et al. 2009; Hawkins & Gartside 2010; Morisaka et al. 2005).

Great Barrier Island (GBI), New Zealand, presents a unique opportunity to study bottlenose dolphin whistle repertoire in the absence of commercial whale and dolphin watching vessels, and in an area with a perceived low level of anthropogenic impact. In a former study, Dwyer et al. (2014) reported GBI as overlooked in importance for the *Nationally Endangered* bottlenose dolphins. It has been identified that bottlenose dolphins utilising these waters have high levels of site fidelity, above average group size for coastal bottlenose dolphins and high year round use of this area by groups that contain calves (Dwyer et al. 2014). In order to assess the whistle repertoire of bottlenose dolphins at GBI, dedicated boat-based surveys were conducted along the western coast of GBI. The objectives of this chapter were specifically to:

- Describe the vocal repertoire of bottlenose dolphins at Great Barrier Island, New Zealand, via;
    - descriptive statistics of whistle characteristics
    - assessments of the types of whistles recorded
- Examine the social context in which specific whistles and their characteristics are recorded, via assessment in relation to group dynamics (group size and composition)
- Examine the behavioural context in which specific whistles and their characteristics are recorded, via assessment in relation to whistle rates and contours

## 4.2 Methods

### 4.2.1 Study Area

GBI is located in the Hauraki Gulf, New Zealand, ca. 80km northeast of Auckland City. The west coast of GBI is characterised by a number of shallow embayments and consists predominantly of rocky shoreline. Further information about GBI is provided in Chapter 3 (Section 3.2.1).

### 4.2.2 Data collection

Data were collected across all austral seasons between July 2015 and July 2016 during dedicated boat based surveys. Monthly boat based surveys at GBI were conducted on the research vessel *AUT Sciences* when weather permitted, as outlined in Chapter 3 (Section 3.2.2). Environmental parameters (adapted from Neumann 2001b) were recorded every 15 minutes as detailed in Chapter 2 (Section 2.2.2.2). Once a focal group or animal was sighted, the research vessel approached the animal(s) in accordance to the Marine

Mammal Protection Regulations (1992), detailed in Chapter 2 (Section 2.2.2.2). The research boat was carefully manoeuvred to minimise its potential effects on the dolphins' behaviour during data collection (Constantine et al. 2004). This involved approaching the pod from the side or behind and driving the boat to match the speed of the focal group. During periods where the pod had no overall movement, the boat was switched into neutral or switched off.

Once started, initial parameters were recorded. The latitude and longitude were recorded using a Samsung Galaxy Mini Smartphone every 30 seconds with CyberTracker software (Version 3.440 CyberTracker Conservation 2013). Group behavioural state (defined in Chapter 2; Table 2.3) was recorded every 3 minutes using focal-group scan sampling (Altmann 1974; Constantine et al. 2004; Stockin, Lusseau et al. 2008), in addition to group size, composition, dispersal, group heading and the number and type of vessels present following methods detailed in Chapter 2 (Section 2.2.2.2).

Upon approach of a focal group, dolphin behaviour was assessed to determine whether acoustic recording methods were permissible. The recording method required that the focal group were either moving slowly in a consistent direction or that the overall group location remains unchanged (within 100m of the hydrophone; adapted from Snell 2000). All recordings were made when the vessel was stationary with the engine off.

An encounter (and subsequent data collection) ended when the decision was made to leave the group of animals. The choice to depart was prompted by changes in the animals' behaviour (e.g. avoidance behaviours), deteriorating weather conditions, low fuel reserves, dusk was approaching or contact with focal group was lost (Hupman 2016). The end time and GPS location was noted for each encounter.

### 4.2.3 Acoustic data collection

If the group was travelling, a 'leap frog' method was employed by which the boat manoeuvred parallel to the dolphins predicted course and stopped ~100m a head of the focal group and recordings were commenced (Snell, 2000; Luís et al. 2014). The equipment was withdrawn from the water once the distance between the focal group and the hydrophone exceeded 100m, and the entire procedure was repeated. If the group of animals remained relatively stationary, the boat was stopped so that the focal group were within 100m of the hydrophone, which recorded continuously until the animals left the area (Acevedo-Gutiérrez & Stienessen 2004; Snell 2000). Acoustic recordings were monitored via headphones for quality assurance, e.g. to ensure no interference (Lopez & Shirai 2009; Lopez 2010). Recording ceased once the behaviour of the animals became unfavourable for acoustic collection or if an encounter was terminated (see above). The GPS location and time was recorded at the onset of recording.

Recordings were taken by a C55 hydrophone (Cetacean Research Technology Ltd) with an integral 20dB preamplifier. The hydrophone has a linear frequency range of 0.015 to 44kHz and a sensitivity of -185 dB (re 1V/µPa). Signals were digitised using a TASCAM DR-44WL 4-track Portable Digital Recorder with a frequency response up to 96kHz/24-bit.

### 4.2.4 Data analysis

All oral notes were transcribed onto a spread sheet using the marker indicated on the commentary track. Each acoustic track was cut into 1 minute segments in WavePad Sound Editor (Version 6.59; NCH 2016). Any recordings less than 1 minute or segments cut from the end of tracks that were less than one minute were removed from analysis. Segments that were recorded during or 20 minutes after the dolphins interacted with another vessel were also excluded from analysis following behavioural procedure (Chapter 3; Section 3.2.3). Each 1 minute segment was then imported into Luscinia (Version 2.16.10.29.01; Lachlan 2007) as a ‘song’. Each ‘song’ was viewed on a sonogram, displayed using a frame length of 4.2ms, 76.2% overlap and smoothed using a Hamming window.

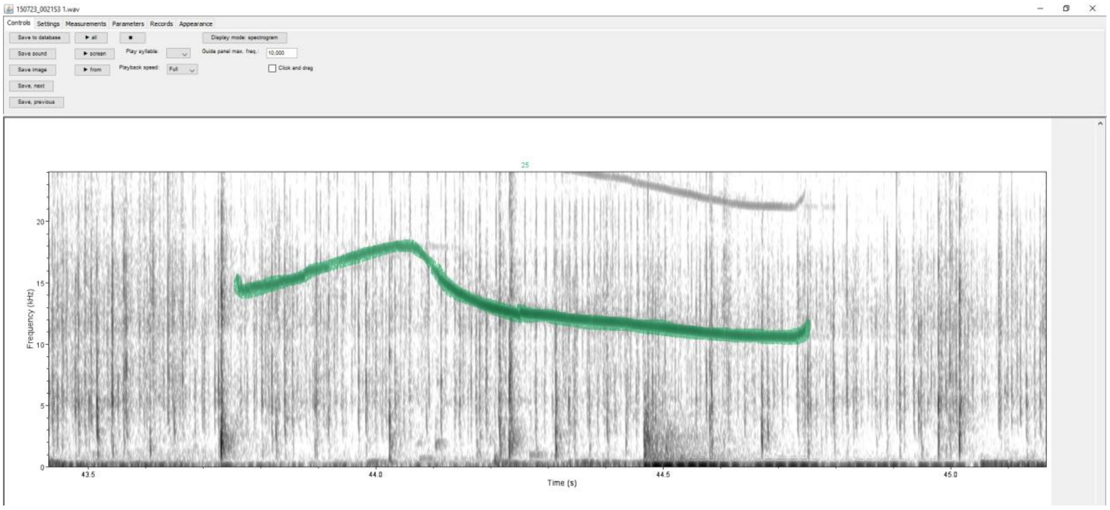
#### *4.2.4.1 Whistle rates*

A visual representation of the signal was observed as a spectrogram as the sound is played back to count the number of whistles and harmonics for each track. The number of whistles was determined by counting the number of whistles displayed in the spectrogram combined with faint whistles detected audibly. This allowed distant sounds to be picked up by ear that would be missed via inspection of the spectrogram alone. Analysis was restricted to the human audible range for reliability, only whistles with fundamental frequencies below 24kHz were used for analysis. Whistle fundamental frequencies rarely exceed 25kHz, and thus it was assumed that the omission of whistles exceeding this frequency would not overtly bias the dataset (Caldwell et al. 1990; Boisseau 2004). Whistle rates were calculated in two different ways; firstly, the mean number of whistles counted in each minute (mean number of whistles per minute); secondly, by dividing the mean of the number of whistles counted in each one minute segment by the number dolphins recorded in the focal group (mean number of whistles per minute per dolphin).

Group sizes were categorised into three groups (1-22, 21-50 and 50+ individuals). Whistles that occurred while two or more behavioural states were reported were removed from analysis as it could not be determined which behaviour was influencing the whistle repertoire. Statistical analysis was completed in R Studio (version 1.0.153). A partial autocorrelation function was used to check the data for independence. If whistle rate was not independent, then an autoregressive model was applied to the data to account for autocorrelation. An ANOVA was used to test if whistle rate was significantly different between each behavioural state and each group size category. If an ANOVA test showed significant differences between means, a Tukey's post hoc test was conducted to identify where significant differences occurred. The number of whistles per minute per dolphin was visualized by plotting the number of whistles recorded per dolphin for each minute of recording, for each behavioural state and group size category.

#### 4.2.4.2 Whistle parameters

Each whistle with a suitable signal-to-noise ratio was considered a "good" whistle, and manually marked in Luscinia by tracing around the whistle for further analysis as an 'element' (Edelaar et al. 2012; Figure 4.1). Harmonics were not included when marking whistles, as it was determined that this resulted in more accurate whistle parameter measurements.


150723_002153 1.wav

Display mode: spectrogram

Guide panel max. freq.: 10,000

Playback speed: Full

**Figure 4.1** Example of a traced (green) bottlenose dolphin whistle in Luscinia. Noted: Only the fundamental frequency is traced.

Parameters for each traced whistle were exported from Luscinia using the Analysis function, into an excel spreadsheet. The means, standard deviations and coefficients of variation were calculated for each whistle parameter to provide descriptive statistics of the whistle repertoire at GBI. Whistle parameters extracted by Luscinia (displayed in figure 4.2) include; duration (s), maximum frequency (kHz), minimum frequency (kHz), mean frequency (kHz), beginning frequency (kHz), and ending frequency (kHz). Additionally, the number of inflection points was manually counted from the spectrogram and the range was calculated as the difference between the minimum and the maximum frequencies (Azevedo et al. 2007). Tables displaying descriptive statistics were created to show if and how parameters vary by whistle type, behaviour and group size.

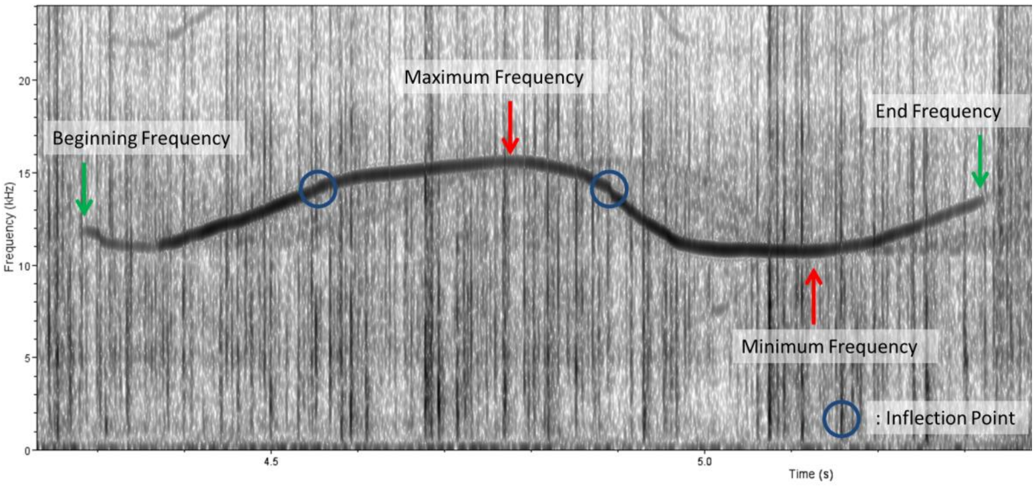
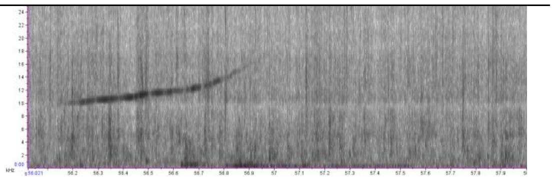
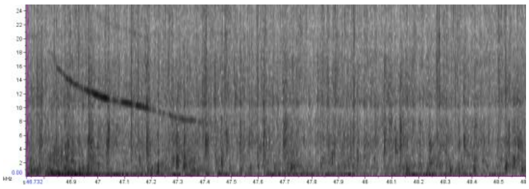
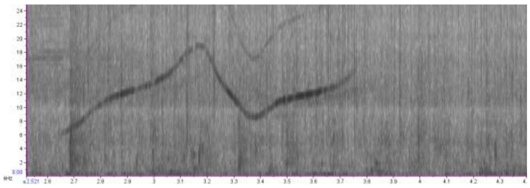
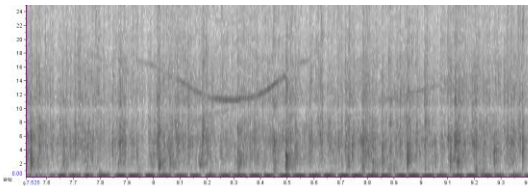
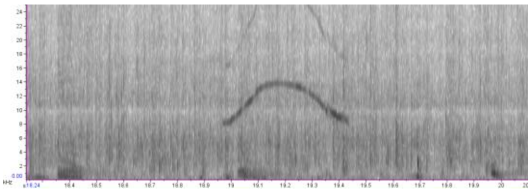
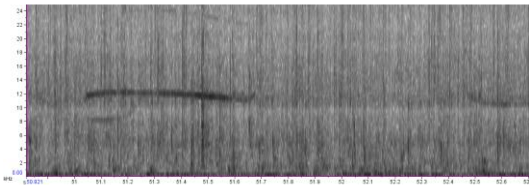
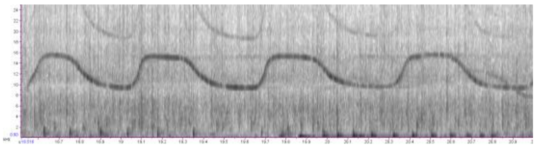
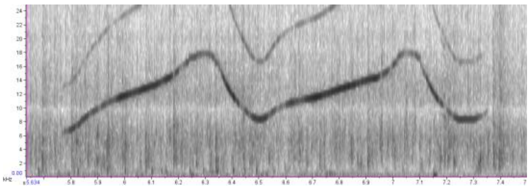


**Figure 4.2** Sample of a bottlenose dolphin whistle in Luscinia, highlighting the parameters that are measured for analysis.

### *4.2.4.3 Whistle type*

Luscinia was used to partially classify whistles into categories using the dynamic time-warping algorithm. The algorithm searches for an optimal alignment between two time series on the basis of the Euclidean distance between acoustic features (Lachlan et al. 2014): in the analysis, these features were spectrograph measures of whistles: time, fundamental frequency and fundamental frequency change. Each whistle was further matched by eye into eight defined types (Table 4.1).

**Table 4.1** Description and example of whistle types of bottlenose dolphins (*Tursiops truncatus*) at Great Barrier Island, New Zealand (based on Azevedo et al. 2007; Lopez 2010).

| Code | Name | Inflection Points | Example |
|---|---|---|---|
| Asc | Ascending (or Rise) | 0 |  |
| Desc | Descending (or Falling) | 0 |  |
| Sine | Sinusoidal | 2 |  |
| Desc-asc | Descending–Ascending (or Concave) | 1 |  |
| Asc-desc | Ascending–Descending (or Concave) | 1 |  |
| Constant | Constant (or flat) | 0 |  |
| Multi | Multi-looped | 4-19 |  |
| 3-loop | 3-Loops | 3 |  |

The percentage of each whistle type recorded was calculated to determine the most and least frequently recorded whistles overall. Chi-squared tests were performed to identify whether whistle type was correlated to behaviour and group size. The overall percentage of each whistle type was plotted by behavioural state and group size categories.

## 4.3 Results

### 4.3.1 Effort

Between July 2015 and March 2016, four dedicated boat-based surveys were conducted at GBI, resulting in a total 1511.1km of track around the western coast of GBI in ca. 139h. During this time, a total of 21 encounters with bottlenose dolphins occurred, totalling ca. 66h of observations.

A total of nine independent dolphin social groups were acoustically recorded. Group size varied from 6 to 65 individuals, with a mean of 33 (SD=18.4). All groups contained at least a single calf or juvenile and acoustic data were recorded through all austral seasons. As all groups recorded contained calves or juveniles, it could not be tested how their presence/absence affected whistle rates or types. Surveys resulted in 14h of acoustic recordings, in which 14,358 frequency modulated whistles were detected. A total of 7,606 whistles with good signal to noise ratio were analysed.

### 4.3.2 Whistle rates & parameters

The mean number of whistles per minute was 26.8 (±25.8) and the number of whistles per minute per dolphin was 0.50 (±0.53). The highest number of whistles was recorded during milling (n=2915), followed by resting (n=2881), travelling (n=1040), socialising (n=645) and foraging (n=125), with strong evidence of a difference in the number of whistles per dolphin per minute between behaviours (p=0.0063). Foraging displayed the highest number of whistles per minute per dolphin (1.17±0.98), which was significantly different from milling (p=0.02208), resting (p=0.00275) and travelling (p=0.02271), though not socialising (p=0.20838). Whistle rate did not vary significantly between any other behavioural states though socialising does appear to have a slightly higher rate than the other behaviours (Figure 4.3). No significant difference in number of whistles per minute per dolphin between different group sizes was revealed (p=0.4864). However, groups of smaller dolphins had a much wider range of whistle rates (Figure 4.4).

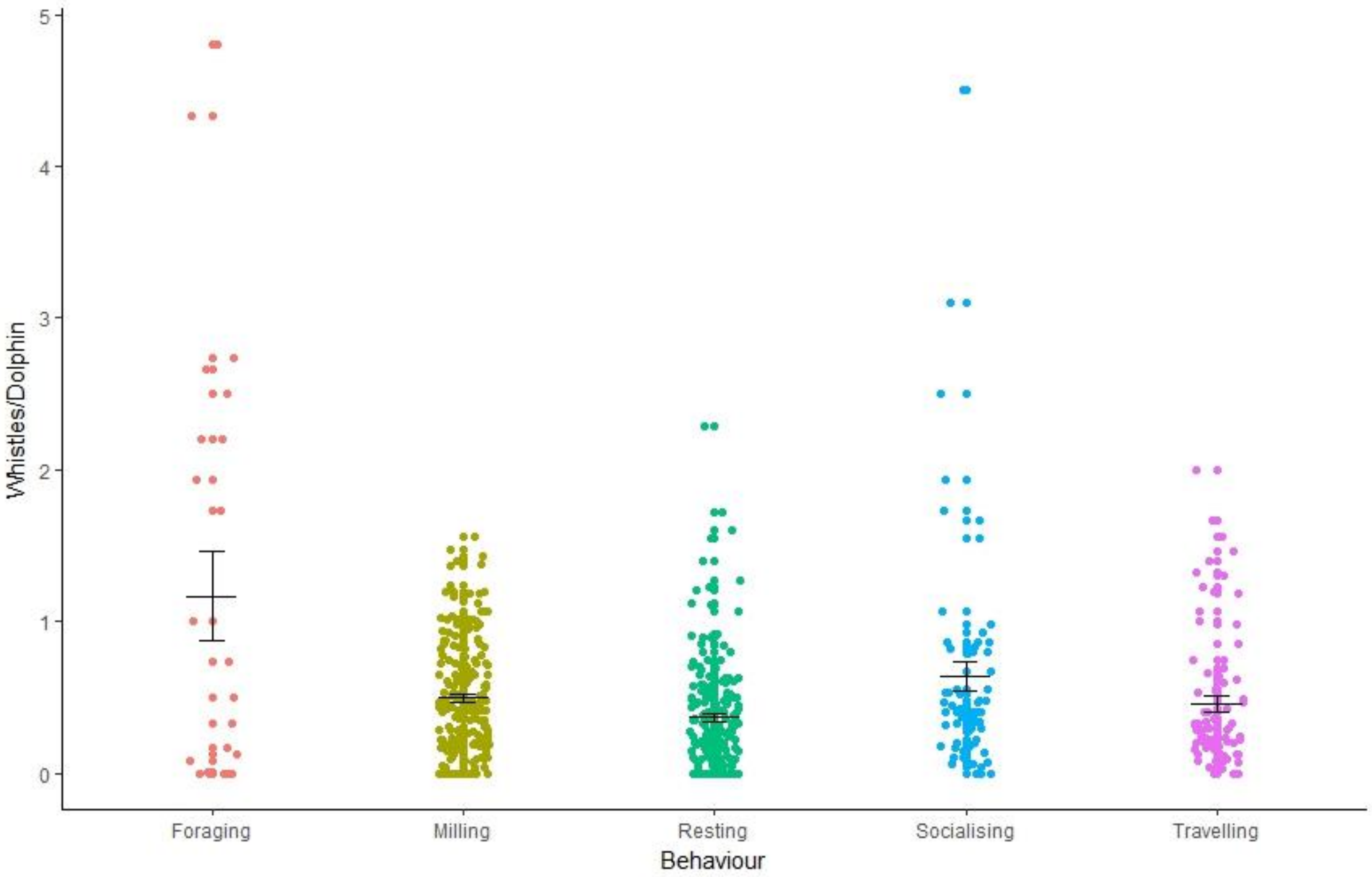


**Figure 4.3** Number of whistles per dolphin plotted for each minute of recording (displayed for each behavioural state) for bottlenose dolphins at Great Barrier Island, New Zealand. Whiskers represent mean and standard error.

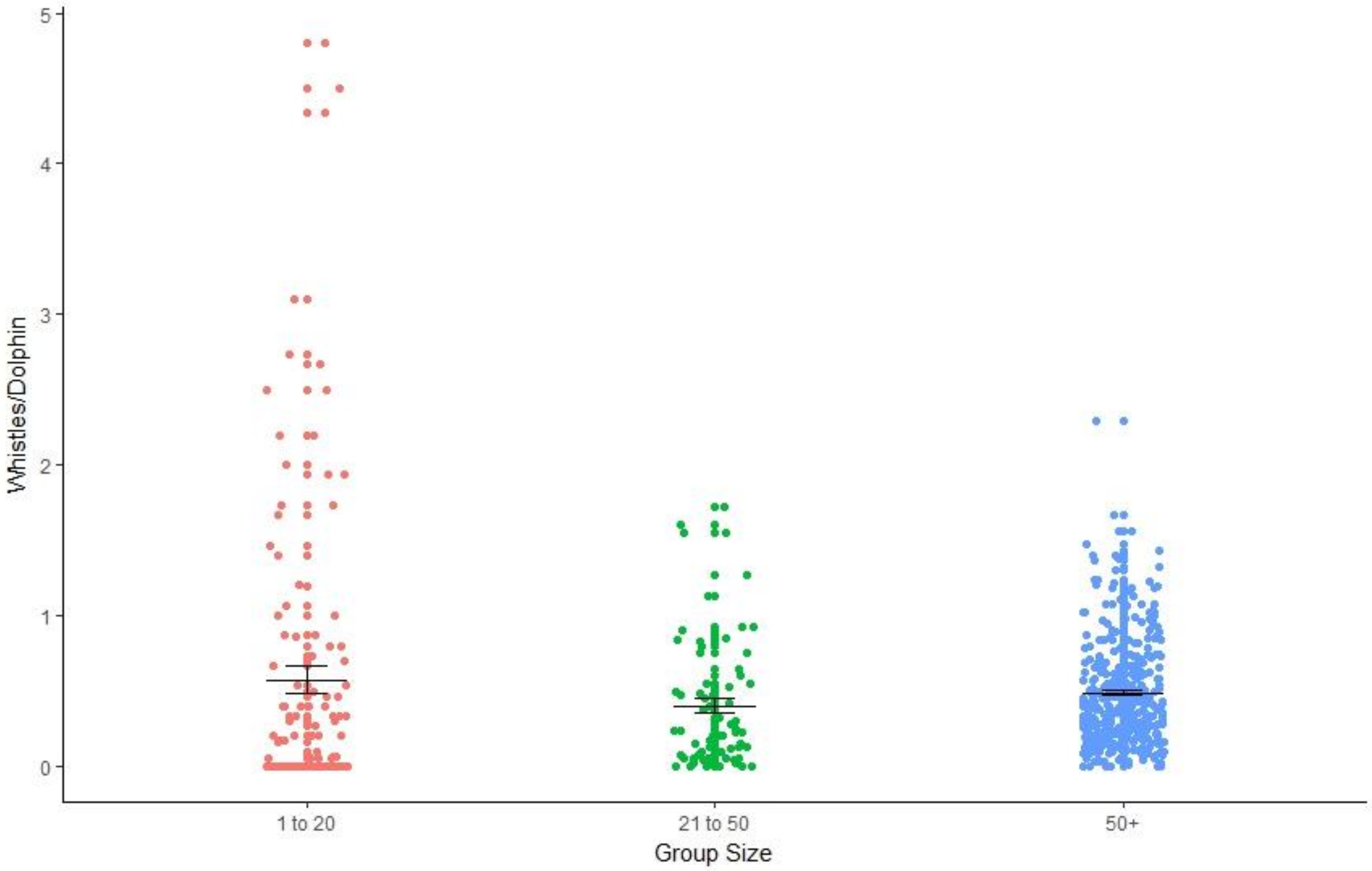


**Figure 4.4** Number of whistles per dolphin plotted for each minute of recording by group size for bottlenose dolphins at Great Barrier Islands, New Zealand. Whiskers represent mean and standard error.

Summarised data (mean, standard deviation, minimum and maximum, and coefficient of variation) of whistles recorded for bottlenose dolphins at GBI are shown in Table 4.2. The number of inflection points was the whistle characteristic with the highest variability, while mean frequency had the lowest.

**Table 4.2** Summarised descriptive statistics of whistles recorded for bottlenose dolphins at Great Barrier Island, New Zealand. Length units are displayed in seconds, while all frequency parameters are displayed in kHz.

| Parameter | Mean (SD) | Range | Coefficient of Variation % |
|---|---|---|---|
| *Length* | 0.84 (0.52) | 0.02-4.33 | 61.9 |
| *Mean Frequency* | 11.64 (2.34) | 3.29-22.05 | 21.3 |
| *Maximum Frequency* | 14.21 (3.32) | 3.62-23.74 | 23.4 |
| *Minimum Frequency* | 7.86 (2.36) | 1.48-21.28 | 30.0 |
| *Start Frequency* | 9.63 (3.02) | 1.94-23.42 | 31.4 |
| *End Frequency* | 11.66 (4.22) | 1.64-23.52 | 36.2 |
| *Frequency Range* | 6.35 (3.17) | 0.23-19.36 | 49.9 |
| *Inflection Points* | 1.41 (1.58) | 0.00-19.00 | 112.1 |

### 4.3.3 Whistle Type

After visually categorising whistle types, whistle contour Asc was the most observed whistle type (27.0%, n=2051) followed by Asc-desc (19.9%, n=1516), Sine (17.2%, n=1308), Multi (9.5%, n=719), Desc-asc (9.0%, 686), Desc (8.9%, 680), 3-loop (5.3%. n=401) and Constant (3.2%, n=245).

Whistle type was highly associated with behaviour ($X^2$=192.41, df=28, p=2.2e-16). Asc whistles were the most commonly recorded whistle type and made up a substantial proportion (between 17.7 to 22.2%) of whistles across all behaviours (Figure 4.5). Whistle types Desc-asc and Asc-desc were particularly associated with foraging, while whistle types Constant, Multi and 3-loop were particularly absent during this activity. Though, whistle type Asc-desc was recorded more commonly during socialising and travelling than resting and milling. Constant whistles were associated more with milling, while Desc whistles were particularly absent during bouts of travelling.

Whistle type was also highly associated with group size ($X^2$=106.82, df=14, p=2.31e-16). The frequency of whistle types Asc and Constant increase with group size, while whistle contour Desc-asc and Asc-desc decrease with group size (Figure 4.6). The Sine and 3-

loop whistle types were recorded most often in intermediate groups (21 to 50 animals) and Multi type occurred more often in large groups of over 50+ animals.

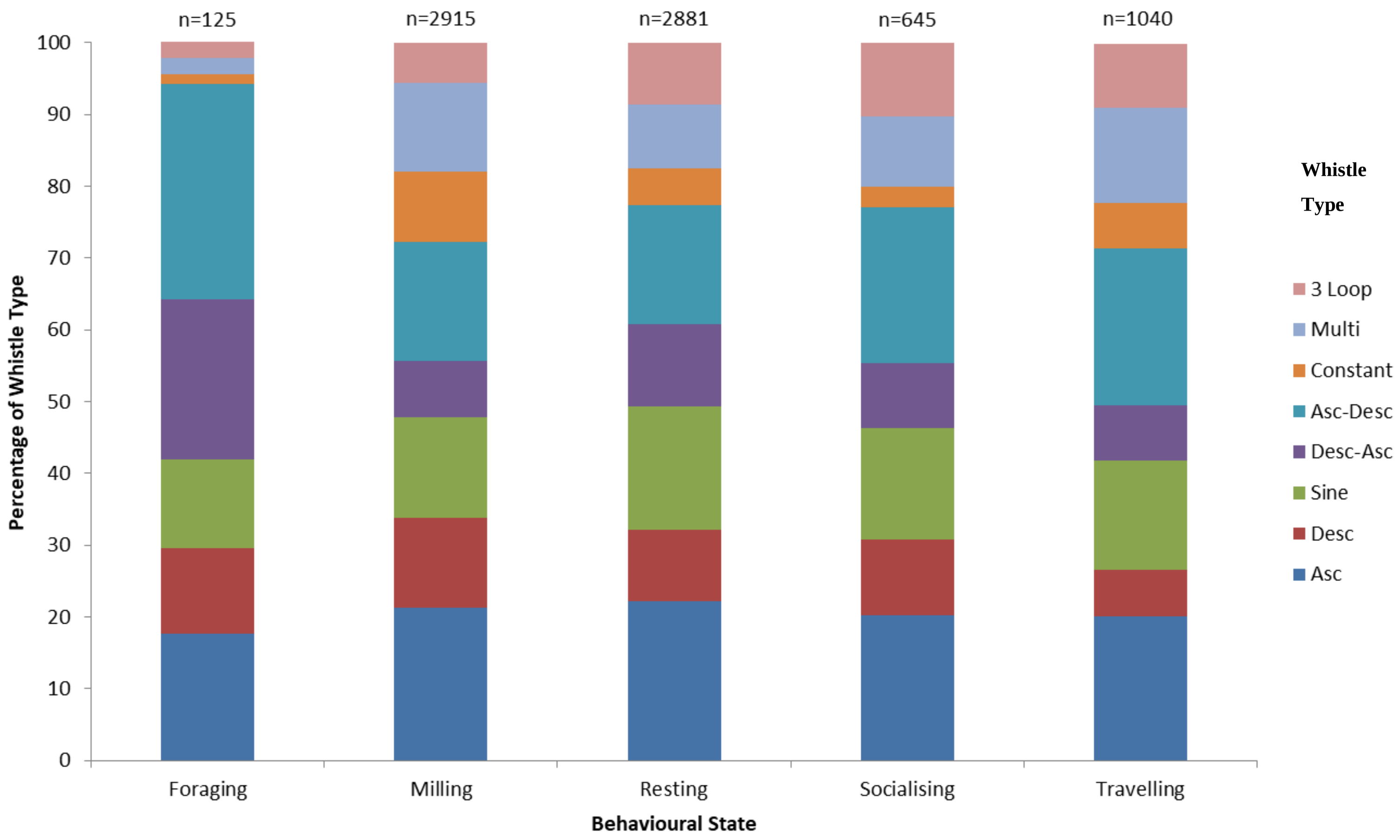


**Figure 4.5** The percentage of each whistle type within each behavioural state for bottlenose dolphins off Great Barrier Island, New Zealand.

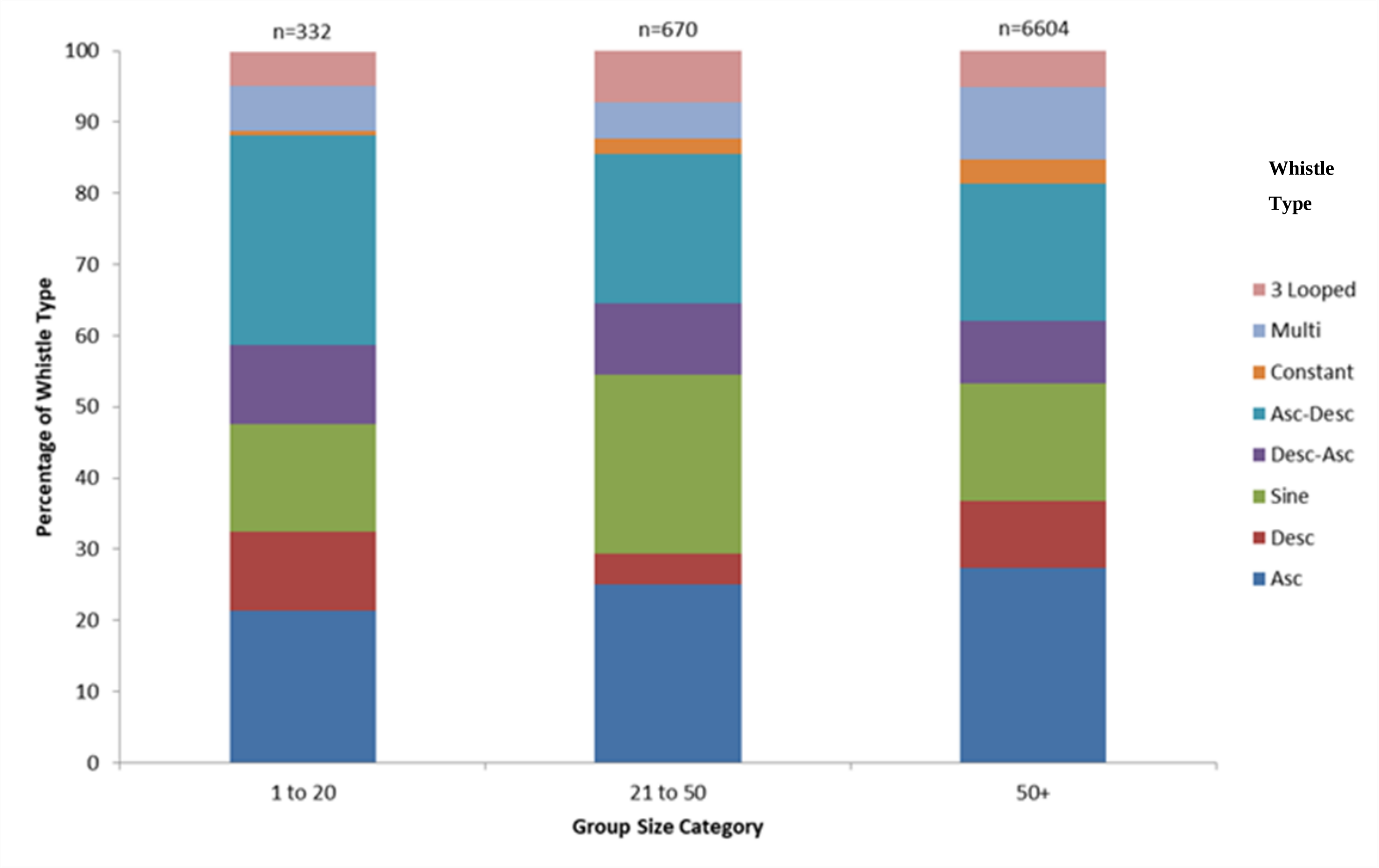


**Figure 4.6** The percentage of each whistle type within each group size category for bottlenose dolphins off Great Barrier Island, New Zealand.

## 4.4 Discussion

### 4.4.1 Whistle rates

Understanding the acoustic behaviour of a species provides insight into their population dynamics and habitat use. The number of whistles per minute per dolphin was very similar to that reported in the Bay of Islands (BOI), during periods of no boat traffic (Appendix 4.1). Additionally, the whistle rate for the single group of dolphins recorded with no calves (0.49 whistles per dolphin per minute) in the present study was similar to the whistle rates discussed above. This may suggest that there is a relatively consistent whistle rate for the population over its entire home range regardless of how the animals utilise an area. The mean number of whistles per minute per dolphin was not significantly different between group sizes in this study. Similarly, no difference in median number of whistles per minute per dolphin was detected with changes in group size in the BOI either (Snell 2000). Only foraging in the present study had significantly different whistle rates to other behavioural states, while in the BOI no significant difference in whistle rates was detected between behaviours. Thus, even though the behavioural budgets and group sizes differ between GBI and the BOI (refer to Chapter 3) whistle rates remain relatively constant. This may be explained by another variable that has not yet been considered to influence whistle rate which may have a stronger influence, such as social networks or cultural transmission.

The number of whistles per minute per dolphin reported here is lower than that reported in New South Wales, Australia, for Indo-Pacific bottlenose dolphins (*T. aduncus*), but is above that reported for bottlenose dolphins in other studies (Appendix 4.1). The number of whistles per minute per dolphin appears to be partially a function of behaviour, which can be dependent on location and topography (Constantine et al. 2004; Hanson & Defran 1993; Mattos et al. 2007). Differences in the proportions of behaviours recorded for each study could, therefore, be dependent on the specific location of the study within the home range of the population. This makes it difficult to gain an accurate idea of the true similarity or difference in population whistle rates. For example, the number of whistles per minute per dolphin given here is only for animals using a portion of the north-eastern North Island range, whereby animals appear to use the area primarily for resting, travelling and milling (Chapter 3; Section 3.3.2). This may have biased the results for the overall whistle rate in the present study as whistle rates have often been reported to be higher during foraging (Acevedo-Gutiérrez & Stienessen 2004; dos Santos et al. 2005) and socialising (Cook et al. 2004; dos Santos et al. 2005; Hawkins & Gartside 2010; Jones & Sayigh 2002; López & Shirai 2009; Quick & Janik 2008).

Cook et al. (2004) reports an increasing number of whistles per minute with increasing group size. However, as they measured whistle rate as the number of whistles per minute, comparisons are unreliable because they did not control for the number of animals present. The present study showed a much higher number of whistles per minute per dolphin than Cook et al. (2004), which is likely a function of the large group sizes at GBI. Jones & Sayigh (2002) reported that the number of whistles per minute, and the number of whistles per minute per dolphin were similar and also increased positively with group size. However, other studies using the number of whistles per minute per dolphin have found that whistle rate decreased with increasing group size (Hawkins & Gartside 2010; Quick & Janik 2008) or that there was no correlation (dos Santos et al. 2005; Jones & Sayigh 2002). A decreased number of whistles per minute per dolphin is hypothesised to occur to reduce signal masking as the overall number of the group's whistles increase (Quick & Janik 2008), while no correlation between group size and whistle rate has been hypothesised to result from a social restriction mechanism limiting whistle emissions (dos Santos et al. 2005). An upper limit of number of whistles per minute per dolphin would determine how many whistles can effectively transmit information at one time (Quick & Janik 2008).

Prior studies have noted that for Indo-Pacific bottlenose dolphins the number of whistles per minute per dolphin was lower for groups with calves, which is hypothesised to be an anti-predator response, anti-masking strategy or to reduce energy demands, which would be particularly relevant to mother-calf pairs (Hawkins & Gartside 2010; López & Shirai 2009; Smolker et al. 1993). Contrary to this, a study for *T. truncatus* reported that groups with calves have a higher number of whistles per minute per dolphin, which is thought to maintain contact and keep the calf in visual range (López & Shirai 2009). This may provide insight as to why this study found no significant increase in whistle rate with group size, and explain why the mean the number of whistles per minute per dolphin was higher for GBI than what has been reported for other populations (Appendix 4.1). Only one group did not contain calves or juveniles at GBI, and all groups acoustically recorded did. During all encounters, mother-calf pairs could have been maintaining contact while the group reached an upper limit of whistle transmission (dos Santos et al. 2005; López & Shirai 2009; Quick & Janik 2008). Mother-calf communication may also become increasingly difficult with the large group sizes at GBI, as calves or juveniles could move further away from their mother while remaining in the safety of the school. It has also been reported that groups containing only females (and thought to be in nursery pods) had higher whistle rates than groups containing only males in Fiordland, New Zealand

(Boisseau 2004). This was also hypothesised as a result of mother-calf pairs maintaining contact.

A number of studies have reported differences in whistle rates between behaviours for bottlenose dolphins (dos Santos et al. 2005; Jones & Sayigh 2002), while no significant difference has been reported Indo-Pacific bottlenose dolphins (Hawkins & Gartside 2010). In the BOI and Fiordland, no significant difference was found between whistle rates and behavioural state (Snell 2000; Boisseau 2004). Even though differences were not significant, the number of whistles per minute per dolphin was highest during socialising and lowest during resting in the BOI (Snell 2000), while in Milford Sound it was highest during social and travel behaviours and in Doubtful Sound, whistle rates were highest during foraging behaviour combined with milling or travel (Boisseau 2004).

This study found significant differences in whistle rates between behavioural states, with the highest rates consistent with those previously reported in the BOI and Fiordland. Whistle rates were highest during foraging followed by socialising, with no significant difference between them. The median whistle rate for foraging reported in the BOI was lower than that of other behaviours, and may reflect a different foraging strategy. Variations in foraging techniques may lead to different communication requirements (López 2011). This is realistic given the difference in mean group sizes reported between the BOI and GBI, combined with the likely differences in topography. The wide range of whistle rates during foraging at GBI may also reflect a variety of foraging strategies, especially given the variety of depths at which foraging was recorded (Chapter 3; Section 3.3). The high whistle rates reported here for socialising and foraging are consistent with other studies where higher whistle rates have often been associated with foraging (Acevedo-Gutiérrez & Stienessen 2004; dos Santos et al. 2005) and socialising (Cook et al. 2004; dos Santos et al. 2005; Hawkins & Gartside 2010; Jones & Sayigh 2002; López & Shirai 2009; Quick & Janik 2008).

It is hypothesised that high whistle rates are used to recruit more dolphins to the foraging event which in turn, reduces the number of sharks competing for prey (Acevedo-Gutiérrez & Stienessen 2004). While the Hauraki Gulf does contain shark species that may predate delphinids (Stockin, Pierce et al. 2008) and could potentially compete with them, this study did not detect increased group size during foraging activities. Rather, given the large average group sizes, coordinated hunting with higher numbers of individuals may require higher rates of communication (Janik 2000a). Additionally, increased whistle rates have been associated with a state of excitement or arousal regardless of group size (dos Santos et al. 2005). It is possible that during foraging events, the dolphins are in a higher state of excitement (dos Santos et al. 2005). However, this acoustic behaviour may be specific to certain populations' cultures or hunting strategies, given that low whistle rates have also been recorded for foraging (Hawkins & Gartside 2010; López & Shirai 2009). High whistle rates during socialising are thought to relate to maintaining contact and developing social relationships among individuals (Cook et al. 2004; Quick & Janik 2008).

It appears that, while not significantly different from any behavioural state except for foraging, the lowest mean rate of whistles occurred during resting. Low whistle rates have been previously reported for travel and milling (dos Santos et al. 2005; Hawkins & Gartside 2010; Quick & Janik 2008), though it should be noted that resting was combined with milling by Hawkins & Gartside (2010) and was not a recorded behavioural state in the other two studies described here, and could fit into the description of travel for Quick and Janik (2008). This suggests that it is possible that resting groups of dolphins could consistently have low whistle rates. This would be logical as the animals are not in an active state (i.e. a lower state of excitement) while increasing predator avoidance; as resting is likely their most vulnerable behavioural state due to reduced vigilance (Connor & Heithaus 1996; Heithaus 2001; Würsig et al. 1994).

It is difficult to determine why the number of whistles per minute per dolphin is higher in this study given that whistle rates appear to decrease with increasing group size, and that the dolphins were recorded resting and milling most often. The high whistle rate may be a function of the large group size combined with the high rate of groups containing calves. This high rate may represent mother-calf pairs maintaining contact in a large group of animals and could indicate that GBI may be important to nursery groups. Though, this would not explain the high whistle rates in the BOI.

Another explanation may be that whistle rates may be influenced by other forms of communication, such as visual, tactile or other forms of vocalisations. For example, choke, splash and sequenced calls were associated with contact and aerial behaviours, while whistles and buzzes were correlated with dive and aerial behaviours for bottlenose dolphins in Doubtful Sound (Boisseau 2004). In captivity, reduced vocalisations of bottlenose dolphins have been associated with pectoral fin contact (Evans-Wilent 2011). Vocalisations in spotted dolphins (*Stenella frontalis*) were influenced by visual and/or tactile behaviours, for example; loud, intense sound (e.g. squawks) were associated with aggressive contact, 'S' postures, frequent releases of bubbles, and direct approaches (Dudzinski 1998). Thus, whistle rates at GBI may be influenced by other forms of communication not measured in the present study.

### 4.4.2 Whistle Parameters

Intra-population has showed low variability in frequency parameters of whistles, but high variability has been reported in duration and number of inflection points (Azevedo et al. 2007; Gridley et al. 2015; López 2011; Morisaka et al. 2005; Wang et al. 1995). Both whistle duration and the number of inflection points had the highest coefficients of variation in this study (Table 4.2) which is in line with other studies (Azevedo et al. 2007; Morisaka et al. 2005). Duration, number of inflection points and maximum frequency have been reported to account for over 80% of whistle variation (López 2011). This high intraspecific variability has been suggested to result from individual modulation of these parameters to convey specific information from different contexts or individuals (such as emotional states, level of alertness, presence of food/danger) or variation to provide identities (Azevedo et al. 2007; Bazúa-Durán & Au 2004; López 2011; Morisaka et al. 2005; Rendell et al. 1999; Steiner 1981; Wang et al. 1995). Additionally, the context of referential signals may vary between populations (López 2011).

Whistle duration also varies greatly among bottlenose dolphin populations (Appendix 4.2; Azevedo et al. 2007). Mean whistle duration was similar to that recorded in Doubtful Sound, New Zealand, Portugal and USA, but falls within the middle of the range of what has been reported (Appendix 4.2). The median whistle duration recorded in this study was shorter than those recorded in the BOI, irrespective of boat presence (Appendix 4.2), but the mean was similar to that recorded in Fiordland (Boisseau 2005). However, intraspecific variability of whistle parameters may also be influenced by adaptation to background noise (Rendell et al. 1999). Within Fiordland, there were differences in acoustic parameters between Milford and Doubtful Sounds (Boisseau 2004). Dolphins in Milford sound were exposed to higher ambient noise than Doubtful Sound, as it is a smaller and shallower fiord, which is less sheltered from swell and wave action, with higher levels of boat traffic (Boisseau 2004). The whistle duration of the present study were similar to those of whistles recorded in Doubtful Sound and may reflect low ambient noise at GBI.

The mean whistle frequency recorded at GBI was also similar to both Milford and Doubtful Sound, but was closer to whistles recorded in Doubtful Sound (Boisseau 2004). The lower duration and mean frequency reported here and in Doubtful Sound, in comparison to Milford Sound, is likely due to the higher ambient noise in Milford Sound. It has been suggested that whistles produced within environments with higher ambient noise tend to be longer with higher mean frequencies, maximum frequencies, frequency ranges and more contour inflections (Boisseau 2004; Janik 2003). While duration and mean frequency reported in the present study are similar to those reported by Boisseau (2004) in Doubtful Sound, maximum frequency and range were lower at GBI. The sheltered bays with the perceived low levels of anthropogenic impact at GBI may result in lower ambient noise than Doubtful Sound. However, comparisons of ambient noise levels between Doubtful Sound and GBI are required to examine this hypothesis further. The BOI has high levels of boat traffic which likely result in higher ambient noise and may explain the larger median duration and maximum frequency recorded there (Snell 2000). Median maximum frequency was similar to that reported in the BOI, while boats were absent the mean was lower than that reported in Fiordland. The lower mean maximum frequency may also result from lower ambient noise levels at GBI. The mean maximum frequency falls within the middle range of what has been reported globally (Appendix 4.2).

As previously discussed, it has been reported that whistles produced in environments with higher ambient noise tend to be longer with higher mean frequencies, maximum frequencies, frequency ranges and more contour inflections (Boisseau 2004; Janik 2003). However, this may only hold true for comparisons within populations or between populations sharing similar repertoire characteristics, as this does not appear to be the case at GBI. The mean, minimum and maximum frequencies recorded at GBI and Fiordland were higher than most previously reported globally (Appendix 4.2). GBI is isolated and it remains reasonably un-urbanised with no commercial whale and dolphin watching tourism and few interactions with private watercraft were observed (unpubl. data). Thus, it would be expected that dolphins at GBI would produce more whistles at lower frequencies than other populations that are subject to higher levels of boat traffic and increased ambient noise.

Each population could be affected by different evolutionary and environmental influences (Bazúa-Durán & Au 2004; Conner 1982). It is hypothesised that the low intra-population variability of frequency parameters is linked to environmental adaptations and the biological limitations of sound production and similarities may occur in close populations (Wang et al. 1995). The higher frequency parameters (mean, minimum, maximum) for New Zealand populations may be a function of a unique environmental feature that the populations share that limit whistle production at lower frequencies or it could be a function of a shared cultural or biological heritage. Whistle characteristics could be shaped by differences in habitat, ecology, social group and contextual behaviour between different populations (López 2011).

Lower whistle frequencies in groups with calves and in larger groups (group size and calf presence was correlated) have been reported, and was hypothesised to be related to a larger group dispersal and mother-calf pairs remaining in vocal contact (Massey 2014). GBI consistently has large groups with calves yet whistle parameter frequencies were generally higher than what Massey (2014) reported in Cardigan Bay, Wales. Group size categories were much larger in this study than Massey (2014), and mean whistle frequency was similar, while maximum was lower, to that reported at BOI and Fiordland. This would be unexpected if group composition at GBI was influencing the whistle parameters, and it is likely to imply that other factors are contributing to these features.

There are a number of factors that can influence whistle parameters. The whistle frequency parameters of New Zealand populations seem to be higher than most others reported and may be a function of a unique feature effecting the three populations. The mean whistle duration and number of inflection points recorded at GBI may reflect the relative isolation of this habitat relative to other bottlenose dolphin populations.

### 4.4.3 Whistle type

It has been reported that specific types of vocalisations are produced within behavioural contexts for some mammal species. For example; pan hoots in chimpanzees (*Pan troglodytes*; Notman & Rendall 2005) contact calls of female baboons (*Papio cynocephalus ursinus*; Rendall et al. 2000), and alarm calls produced by suricates (*Suricata suricatta*; Manser 2001). Dolphin whistles are frequency-modulated signals which can be broadly categorised by their frequency contour, which are often associated with behavioural state (Cook et al. 2004; Hawkins & Gartside 2009a, 2009b, 2010; Janik et al. 1994). Associations between behaviours and call types or whistle types have been identified for killer whales (*Orcinus orca*; Foote et al. 2008) and North Atlantic pilot whales (*Globicephala melas*; Weilgart & Whitehead 1990).

Asc whistles were the most common whistle reported in this study, which is consistent with the literature, as this type of whistle is often reported in high rates (Appendix 4.3). Asc whistles were also recorded relatively consistently across all behavioural states. This further supports the idea that Asc whistles play an important part in bottlenose dolphin communication and function as a contact call (Janik et al. 1994; López 2011; McCowan & Reiss 2001). In addition to Asc whistles, Sine, Desc, 3-loop and Multi whistles were used broadly over behavioural states and may suggest that the function of these whistles is extensive and adjustments in their parameters may provide more context than can be identified in the present study. Constant whistles were the least commonly recorded whistle. Constant whistles were associated with milling during this study. Desc whistles were not recorded often, but were recorded in similar proportions across all behaviours; these whistles have previously been recorded in limited contexts or situations for *Tursiops* spp. (Hawkins & Gartside 2010; López 2011; Ward et al. 2016). Some whistle types may be used in different contexts for different populations or species. For example; Asc and Constant whistles have previously been associated with social behaviour in Indo-Pacific bottlenose dolphins, while concave whistles have been associated with milling, and Sine whistles have been associated with travelling (Hawkins & Gartside 2009a, 2009b, 2010).

Asc-desc whistles were recorded almost twice as often as Desc-asc whistles. Similar results have also been reported in Brazil, but occurred in reverse in Italy (Appendix 4.3). Both types of concave whistles (Asc-desc and Desc-asc) were associated with foraging, while Constant, Multi and 3-loop whistles were recorded in particularly low levels during foraging. This suggests that Asc-desc and Desc-asc whistles may serve different functions and should be assessed separately, which has not been the case in some studies for Indo-Pacific bottlenose dolphins (Hawkins & Gartside 2010; Ward et al. 2016).

Whistles with multiple inflection points were more difficult to compare against the literature, as the grouping of these whistles varies between studies. Asc whistles and Multi whistles were equally reported as the most common for one study on Indo-Pacific bottlenose dolphins in Australia (Hawkins & Gartside 2010), while another study suggested that Multi was the most recorded whistle (Ward et al. 2016). In Brazil, Multi whistles were also the most common for bottlenose dolphins (Azevedo et al. 2007). However, the previous three studies all classified Multi whistles as any whistle with greater than one inflection point. When combining these whistles (Sine, 3-loop and Multi; all whistle types with greater than one inflection point) in this study, they also make up the most prevalent whistles (31.9%). Alternatively, Díaz López (2011) separated Sine whistles, but combined Multi and 3-loop, though these were recorded less often than Asc whistles.

In the present study, whistle type was influenced by group size. Asc and Constant whistles were recorded more often as group size increased. Asc and Constant may increase as a function of group size as it would be more difficult for individuals within the group to remain in contact. This would further reinforce the hypothesis that Asc whistles function as a contact call (Janik et al. 1994; López 2011; McCowan & Reiss 2001). Concave whistles (Asc-desc & Desc-asc) decreased with group size. Sine and 3-loop whistles were recorded most often at an intermediate group size, while Multi was recorded most often in large groups. As mentioned prior, Sine, 3-loop and Multi were recorded relatively consistently across all behaviours, with the exception of foraging, and when combined were the most common whistle recorded. Sine whistles have previously been associated with group cohesion (Hawkins and Gartside 2009a) which may also reflect its use here. If Sine, 3-loop and Multi were classed as one whistle type, it may be a considered a repeating signal. As group sizes increase, the signal is repeated more often; from concave (Asc or Desc), to Sine, to 3-loop and finally to Multi type whistles. This may be a function of the sender trying to ensure their signal is heard by the intended recipient over the increased noise of a larger group by producing a repeating whistle. These results may indicate that these whistles are important for maintaining contact; potentially they may be of particular importance to mother-calf pairs, given the high proportion of immature animals at Great Barrier Island.

Further defining of whistle types by more details, such as steps and turns (Bazúa-Durán & Au 2002), may reveal more specific uses of whistles within behavioural contexts. The whistle types recorded may also be driven by individual behavioural events (e.g. breaching, spy hopping, chasing, etc.) rather than behavioural states. A particular behavioural event may occur across multiple behavioural states (Miller et al. 2011). A behavioural event may be associated with a certain whistle type, thus the whistle would also be recorded over multiple states, and vice versa; a behavioural event may be limited to certain behavioural state and thus, so too is the whistle type. As it is almost impossible to determine a wild individual dolphin’s acoustic productions within a group of animals, future studies may instead attempt to correlate the frequency of particular whistle types with the frequency of behavioural events. As mentioned previously, other forms of communication used by bottlenose dolphins may influence the rate of whistles; additionally, this could provide another explanation for the occurrence of certain whistle types. For example, whistles thought to function as contact calls, such as Asc whistles (Janik et al. 1994; López 2011; McCowan & Reiss 2001), may decrease in conjunction with an increased use of short range communication forms, such as tactile exchanges or posture signals.

### 4.4.4 Summary

Whistle rates recorded at GBI were consistent with other studies of bottlenose dolphins in New Zealand, though these rates are higher than those recorded in other populations, even given the high proportions of resting behaviour. These high whistle rates may correlate to the large group size and high number of immature animals. Some frequency parameters at GBI were higher than expected given the perceived low levels of anthropogenic noise, further research is required to determine the factors influencing whistle parameters here. Only three whistle types were correlated to behavioural states at GBI, though Asc whistles were the highest recorded which is consistent among studies of bottlenose dolphins. Including further details to differentiate whistle types may yield further insight into the use of whistles at GBI. Additionally, a full acoustic repertoire analysis should be completed in future to understand this population’s communications.

# Chapter 5

# General Discussion

Bottlenose dolphins breaching synchronously at Great Barrier Island, New Zealand.

## 5.1 Overview

Human population growth and increased per capita demands on resources represent the root cause of what is currently described as a mass biodiversity extinction (Caro & Sherman 2011). Preventing further biodiversity loss under increasing anthropogenic pressure is one of the greatest challenges facing ecology and conservation biology (Albouy et al. 2017). The situation of marine mammal conservation is particularly concerning, given that the conservation status of a large proportion of species remains unknown due to insufficient data (Davidson et al. 2012). Often cetaceans are wide ranging and found in diverse habitats, which makes them susceptible to a wide range of anthropogenic threats, including: incidental by-catch, habitat loss, entanglement in fishing gear, exposure to pathogens and pollutants, collisions with vessels, underwater noise, and tourism (Avila et al. 2015; Aznar-Alemany et al. 2017; Burgess et al. 2018; Cecchetti et al. 2017; Constantine et al. 2004; Cruz et al. 2018; Fenton et al. 2017; Fossi et al. 2017; Hoydal et al. 2017; Karczmarski et al. 2017; McWhinnie et al. 2017; Nichol et al. 2017; Peel et al. 2018; Putland et al. 2017; Sanganyado et al. 2018; Siciliano et al. 2017; Wisniewska et al. 2018).

Because cetaceans face a wide range of threats, the argument for their conservation is strong. Cetaceans are economically important as the whale-watching industry is worth over $1 billion per annum globally, and in New Zealand a total expenditure of over $80 million was contributed to the economy due to whale watching activities in 2008 (O'Connor et al. 2009). Cetaceans are also reported to be sentinel or indicator species for the decline in the state of marine ecosystems (Godard-Codding et al. 2011; Moore 2008). They are often essential to marine ecosystems and have a large influence on their community (Estes et al. 2011; Katona & Whitehead 1988; Roman & McCarthy 2010), helping to maintain the health and integrity of the ecosystem (Bowen 1997; Sergio et al. 2008). They also benefit from the attention of the public and media, as well as political interest, as cetaceans are often labelled as 'charismatic species' (Hoyt 2012). Charismatic species act as flagship species by promoting marine conservation and, as umbrella species by protecting other marine species indirectly through conservation efforts (e.g. marine protected areas) designed to protect the dolphins (Hooker & Gerber 2004; Hoyt 2012; Wang et al. 2016).

Currently, bottlenose dolphins (*Tursiops truncatus*) are globally considered to be *Least Concern* by the IUCN Red List (IUCN 2016) although, in New Zealand they are considered as *Nationally Endangered* (Baker et al. 2016). Finding appropriate means to effect management requires the identification of threats and critical habitat (Baird et al.

2012). So far, studies in habitat selection for the north-eastern North Island population have focused in the Bay of Islands (Constantine et al. 2004; Hartel et al. 2014; Peters 2018). Given their rating in the New Zealand Threat Classification System, it is a priority to determine important habitats for New Zealand bottlenose dolphins.

This final chapter outlines the key research findings and their contribution and significance. The limitations are examined and finally, directions for future research are assessed, with resulting recommendations presented.

## 5.2 Summary of research findings

The main research findings of this thesis are summarised for each chapter. It is important to note that the results of this study are based on data collected during El Niño conditions. Subsequently, occurrence trends described in Chapter 2 and behavioural, and therefore acoustic, data described in Chapter 3 and 4 respectively, may be expected to vary under La Niña and neutral conditions. Though this study is limited to El Niño conditions, the findings of Chapter 2 suggest future variation in occurrence caused by these conditions could be at least partially tracked using citizen science.

Citizen science is becoming an increasingly popular method of data collection for scientific inquiry, including disciplines such as ecology and environmental science (Ballard et al. 2017; Bhattacharjee 2005; Bonney et al. 2009; Conrad & Hilchey 2011; Cooper et al. 2014; McKinley et al. 2017; Shannon et al. 2016; Silvertown 2009). Citizen science has been used in a range of conservation studies, including: monitoring anthropogenic litter (Nelms et al. 2017) and invasive species movements (Grason et al. 2018; Pocock et al. 2017), predicting population trends (Dennis et al. 2017), assessing species distributions (Fournier et al. 2017), investigating biodiversity (Stuart-Smith et al. 2017) and for adaptive management purposes (Mair et al. 2017). Yet, it is not a common method in cetacean research. It has been applied to population studies for harbour porpoises (*Phocoena phocoena*; Camphuysen 2011), humpback whales (*Megaptera novaeangliae*; Tonachella et al. 2012) and bottlenose dolphins (Embling et al. 2015b; Veneruso & Evans 2012), and the occurrence and distribution of multiple cetaceans off the south-eastern coast of Brazil (Lodi & Tardin 2018).

This thesis provides evidence that citizen science could assist in collecting data over large spatial scales for coastal cetaceans, especially where dedicated systematic science is lacking. However, training is required to ensure accurate data collection, as citizen scientists often failed to identify species appropriately. The social media platform

Facebook provided a great means for promoting recruitment, conservation and ethical viewing practices, though it proved difficult for rigid data collection. Facebook should be used to compliment citizen science efforts rather than as a direct means to collect data per se. Facebook was utilised in data collection for Lodi and Tardin (2018), however their citizen science data were based on photographs/video footage and fewer details were required from citizen scientists, thus less stringent data collection practices were required.

Citizen scientists reported three species of delphinids; bottlenose dolphins, common dolphins (*Delphinus* spp.) and killer whales (*Orcinus orca*). Citizen scientists were able to identify killer whales based on their distinctive characteristics but struggled to differentiate between common or bottlenose dolphins, instead just reporting ‘dolphins’. Misidentifications were rare as species was not often identified in citizen scientist reports, but occasionally bottlenose dolphins were misclassified as common dolphins and killer whales, while common dolphins were misidentified as bottlenose dolphins. Researcher confirmation was the method used most commonly to validate citizen science reports. Observer rating was rarely used as confirmation of species identity, which highlights the need for training in citizen science. Citizen scientists often underestimated group size and rarely reported behavioural states.

Citizen science was able to detect more sightings of bottlenose dolphins than the research vessel alone. Citizen scientists often greatly expand temporal and spatial efforts of studies to scales that professionals could not reach on their own (e.g. Kelling et al. 2015; Ries & Oberhauser 2015; Van der Wal et al. 2015), which has also been demonstrated previously in cetacean research (Embling et al. 2015; Lodi & Tardin 2018; Wharton 2015). This increase in spatial and temporal data collection that professional scientists could not achieve in isolation is one of the most compelling arguments for the use of citizen science. Citizen science reports often allowed the dolphins’ movement to be tracked along the coastline. Citizen science was also useful in alerting the research vessel to the presence of bottlenose dolphins in real time for further data collection. As residents live on or close to the coastline, they observe or visit beaches and coastal areas often daily and thus, the probability of sighting dolphins is greater than that of professional surveys alone (Lodi & Tardin 2018).

Rigorous comparisons of the data reported by citizen science and that of researchers in the present study were not possible due to the low sample sizes from the research vessel. Only three sightings of bottlenose dolphins that were detected by the research vessel and platform of opportunity remained undetected by citizen scientists. There appears to be little bias in effort based on season, as no bottlenose dolphins were reported in summer and a similar number of independent reports occurred throughout autumn, winter and spring. Similarly, there appears to be little bias in effort for time of day, as there were more sightings of bottlenose dolphins in the morning in autumn and winter. It was expected that reports would peak in the afternoon, as effort would be concentrated to the warmest time of day. Citizen science reports did appear biased towards the Whangaparaoa section of the study area. Though, it is difficult to determine whether this is a bias in search effort or reflective of the dolphins' movement patterns, as the research vessel did not detect further sightings in the North Shore area. Some studies use statistical tools to counter errors and biases from citizen science data (Bird et al. 2014; Kelling et al. 2015), though in some cases there was little difference in data quality between professionals and citizen scientists (Danielsen et al. 2014; Edgar & Stuart-smith 2009; Kosmala 2016; Lewandowski & Specht 2015). High data quality may be possible for this type of study if citizen scientists are given appropriate training resources.

This chapter also assessed bottlenose dolphin occurrence in a limited area of the inner Hauraki Gulf using citizen science and boat based surveys. As the study area was a small proportion of the entire Hauraki Gulf, the average citizen science sighting rate was low (0.28 confirmed reports per day). Bottlenose dolphins primarily use the area during winter and were notably absent during summer, which is consistent of habitat use reported for the inner Hauraki Gulf (Berghan et al. 2008; Dwyer et al. 2016; Martinez et al. 2010). The bottlenose dolphins were often reported close to the coastline by citizen science which may infer why previous studies have failed to detect them so readily. Bottlenose dolphins were often recorded travelling, while foraging and resting were rarely observed. This high proportion of travelling is consistent with other studies in New Zealand (Constantine 2002; Lusseau 2004; Merriman 2007; Schneider 1999; Peters & Stockin 2016).

Citizen science may be able to aid data collection for coastal cetaceans in the Hauraki Gulf if the method can be improved. The citizen science data collected in the present study may indicate that bottlenose dolphins occur within the inner Hauraki Gulf more frequently than previously thought. Though, the study area surveyed appears to primarily serve a corridor for the dolphins to reach other important habitats.

Protecting a species requires an understanding of the variables driving their distribution and abundance (Boulangeat et al. 2012; Manly et al. 2002; Moe et al. 2007). Habitat selection studies demonstrate how environmental factors influence how animals navigate and select habitats (Allen et al. 2014; Jones 2001; Sánchez-Clavijo et al. 2016). Group parameters and environmental variables were assessed for bottlenose dolphins at Great

Barrier Island to gain an understanding of how these animals select habitat. The north-eastern North Island population of bottlenose dolphins have been poorly studied outside of the Bay of Islands. Determining which areas are important is crucial for their conservation. Great Barrier Island has been reported as an important location for this population given the large group sizes and high prevalence of calves (Dwyer et al. 2014). Bottlenose dolphins at Great Barrier Island were recorded in large group sizes in this studywith all but one group containing immature animals.

Bottlenose dolphins were recorded in temperatures ranging from 13.5 - 24.1°C and depths of 1.8 - 55.3m. They were also recorded in a range of depths and temperatures each season, though bottlenose dolphins were observed in higher mean sea surface temperature and greater mean depths for autumn and summer than for winter and spring. This is consistent with a previous study at Great Barrier Island, whereby encounter probability was higher in deeper waters for summer and shallower waters during winter and spring (Dwyer et al. 2014). Temperatures recorded by Dwyer (2014) were also higher in summer and autumn. The largest group size category (50+ animals) at Great Barrier Island was only recorded during autumn, which is inconsistent with Dwyer et al. (2014). However, the largest groups recorded in the present study were recorded with the highest mean sea surface temperatures, which is consistent with Dwyer et al. (2014). The largest groups were also recorded in the greatest mean depths in comparison to smaller groups in the present study.

Bottlenose dolphins at Great Barrier Island were primarily observed to be engaged in a resting behavioural state, which is inconsistent with other studies of bottlenose dolphins in New Zealand (Lusseau 2004; Merriman 2007; Peters & Stockin 2016; Schneider 1999) and globally (Baker, O’Brien, McHugh, Ingram & Berrow 2017; Baş et al. 2017; Bearzi et al. 1999; Beddia 2007; Filby et al. 2017; Inoue et al. 2017; Mattos et al. 2007; Vermeulen et al. 2015). Resting was often observed close to shore and was positively influenced by SST and negatively by depth. The large proportion of resting is hypothesised to correlate to the high number of immature animals reported at Great Barrier Island, which is thought to offset the cost of lactation (Kastelein et al. 2002) and is the main behavioural state in which female dolphins nurse their calves (Stensland & Berggren 2007).

Milling and travelling made up similarly large proportions of the behavioural budget. This is inconsistent with other studies of bottlenose dolphins, as travelling often makes up the largest proportion of the behavioural budget (Baker, O’Brien, McHugh, Ingram & Berrow 2017; Bas et al. 2017; Bearzi et al. 2009; Beddia 2007; Filby et al. 2017; Inoue et al. 2017) while milling makes up the smallest (Filby et al. 2017; Hanson & Defran 1993; Lusseau 2004; Merriman 2007; Sini et al. 2005; Vermeulen et al. 2015). Sea surface temperature was the most important factor to influence milling, which had a negative correlation. The role that milling plays is still not understood (Neumann 2001b), but it is thought to fulfil multiple behavioural requirements (Constantine 2001; Neumann 2001b). Travelling was influenced by sea surface temperature and depth, and had a positive correlation with these variables. As travel is thought to function as means of locating prey (Beddia 2007; Garcia et al. 2017; Karniski et al. 2015; Mattos et al. 2007b), it is thought that the warmer waters may influence prey distributions and that the bottlenose dolphins at Great Barrier Island forage in deeper waters. Travel - slow was the most recorded travelling speed and is thought to correlate to the high proportion of resting behaviour (Bearzi et al. 1999).

Foraging and socialising were rarely observed behavioural states and thus were not predicted by the model. Though, the model did indicate that foraging had a positive correlation with depth and increased at lower latitudes and longitudes, while increasing longitude, sea surface temperature and depth were important for predicting socialising. Foraging can make up large (Garcia et al. 2017; Mattos et al. 2007; Sini et al. 2005; Veneruso & Evans 2012) or small (Bearzi et al. 2009; Merriman 2007; Schneider 1999) proportions of bottlenose dolphin behavioural budgets. The low proportion of foraging recorded at Great Barrier Island may indicate that dolphins primarily engage in solitary foraging and/or it could suggest low levels of prey.

Socialising does not commonly make up a significant proportion of behavioural budgets (Baker, O'Brien, McHugh, Ingram & Berrow 2017; Beddia 2007; Filby et al. 2017; Garcia et al. 2017; Kiszka et al. 2011; Lusseau 2004; Veneruso & Evans 2012; Vermeulen et al. 2015). The correlation socialising has with longitude and depth are hypothesised to correlate with the physical space required or seabed substrate necessary to facilitate the behavioural events (e.g. breaching or playing with seaweed) that are associated with this behaviour. The positive correlation with sea surface temperature may be associated with a mating season for bottlenose dolphins at Great Barrier Island (Miller et al. 2010).

These results provide further evidence that Great Barrier Island is an important habitat for the north-eastern North Island bottlenose dolphins. These waters may be important for nursery groups, indicated by the high proportion of resting behaviour and prevalence of immature animals. The habitat at Great Barrier Island could support this, as it has many sheltered bays and potentially an abundance of prey.

Vocal communication is crucial to mediating the interactions of social animals (McGregor & Peake 2000; Tyack 2003). Categorising these vocalisations provides an understanding of the functionality, social relevance and geographical variation of these signals (Boisseau 2005; López & Shirai 2009). The whistle repertoire of bottlenose dolphins at Great Barrier Island was assessed and categorised to gain insight into their vocal behaviour. The median number of whistles per minute per dolphin (0.38) is consistent with that reported in the Bay of Islands (Snell 2000); however the mean number of whistles per minute per dolphin (0.5 ±0.53) was higher than that reported for bottlenose dolphins elsewhere (Azevedo et al. 2007; dos Santos et al. 2005; Jones & Sayigh 2002). There was no significant difference of the mean whistle rate between the different group size categories; though, the highest whistle rates were recorded in the smallest group sizes. Trends appear to vary between studies, as negative correlation between group size and whistle rates have been reported previously (Hawkins & Gartside 2010; Quick & Janik 2008). The consistently high whistle rate is hypothesised to occur due to the large group sizes and the high numbers of immature animals at Great Barrier Island, as mother-calf pairs remain in contact; alternatively, it may be a function of this population's acoustic repertoire, which remains constant throughout the bottlenose dolphins' home range and various group dynamics.

The highest whistle rate was recorded during foraging for bottlenose dolphins at Great Barrier Island. Socialising also appeared to have a higher whistle rate than milling, resting and travelling, though it was not significantly different. The high whistle rates reported here for foraging and socialising are consistent with other studies of *Tursiops* spp. (Acevedo-Gutiérrez & Stienessen 2004; Cook et al. 2004; dos Santos et al. 2005; Hawkins & Gartside 2010; Jones & Sayigh 2002; López & Shirai 2009; Quick & Janik 2008). High whistle rates during foraging may have been recorded as high rates of communication could be required to coordinate large groups. Alternatively, increased whistle rates may be correlated to increased levels of excitement during foraging and socialising.

The whistle parameter with the largest variation was the number of inflection points, followed by length and frequency range. The number of inflection points and whistle length has previously been associated with high variability and are thought to convey specific information from different contexts or individuals (Azevedo et al. 2007; Gridley et al. 2015; López 2011; Morisaka et al. 2005; Wang et al. 1995). The mean length of whistles for bottlenose dolphins at GBI was 0.84s with a mean frequency of 11.64kHz and a mean number of inflections points of 1.41. Given the high variability of duration and the number of inflection points, these means fall within the range typically reported for bottlenose dolphins. Conversely, the mean whistle frequency is similar to that reported in other New Zealand populations, but higher than that previously reported in Brazil and the Mediterranean Sea (Appendix 4.3). Notably, minimum and maximum frequencies for Great Barrier Island (present study) and Fiordland (Boisseau 2004) are higher than what is typically reported globally for bottlenose dolphins (Appendix 4.3). It is difficult to determine why these parameters are higher at Great Barrier Island, given the perceived low levels of anthropogenic noise. The high frequencies may relate to a unique feature of New Zealand’s waters or alternatively, may occur due to a shared heritage.

Ascending whistles were the most commonly recorded whistle type while Constant whistles were rarely recorded. They are usually reported in high proportions in the whistle repertoire of *Tursiops* spp. and it is thought to function as a contact call (Hawkins & Gartside 2010; López 2011; Ward et al. 2016). Only three whistle types were associated with behavioural states. Ascending-descending and Descending-ascending were associated with the behavioural state foraging and Constant whistles were associated with milling. Group size also influenced whistle type, as Ascending and Constant whistles increased with group size; Ascending-descending and Descending-ascending showed the opposite trend. Sine and 3-looped whistle types were recorded more often at intermediate group sizes while the Multiple looped whistle type was recorded more often in the largest group size category. The pattern described above for Ascending-descending, Descending-ascending, Sine, 3-looped and Multiple looped whistles is thought to represent a repeated contact signal. As the group size increases, the contact signal is repeated more often to ensure it reaches the intended receiver.

The whistle parameters recorded at Great Barrier Island warrant further investigation. The high whistle rates and frequency parameters were unexpected given the perceived low levels of anthropogenic noise, and may relate to the high prevalence of calves or be indicative of population wide acoustic traits. Ascending whistles appear to play a key role in bottlenose dolphin communication at Great Barrier Island. It is also possible that all whistles featuring one inflection point or greater are actually the same whistle type, being repeated without a break in the signal (i.e. the more inflection points it has, the more often the signal is repeated) and could be important for maintaining contact.

## 5.3 Limitations

The engagement of the general public in data collection (i.e. citizen science) has the potential to deliver unparalleled quantities of data over large spatial and temporal scales, as well as encouraging the public to engage in the scientific process (Bela et al. 2016; Geldmann et al. 2016; Tewksbury et al. 2014). However, citizen science is often limited by four categories of sampling bias originating from recording activity: 1) uneven recording intensity over time, 2) uneven spatial coverage, 3) uneven sampling effort per visit, 4) variability in detection skills among volunteers (Geldmann et al. 2016; Isaac et al. 2014; Xue et al. 2016). As citizen scientists in the present study were passive rather than active volunteers, it was not possible to examine biases in uneven sampling effort and detection skills. Uneven recording intensity may have contributed to some bias reported over time, as the number of members involved increased during the study period and it is not possible to determine whether old members maintained the same level of effort during the entire study period. Similarly, Lodi and Tardin (2018) could not measure sampling effort from opportunistic citizen science reports of cetaceans.

This study primarily examined uneven spatial and temporal coverage. While citizen science was able to provide a larger set of data than the research vessel alone, the spatial range of this data collection was very limited in relation to the Hauraki Gulf coast line. This limitation was largely a function of the scale of community in which the Facebook was established for. Creating Facebook groups at this scale for the whole Hauraki Gulf would make data consolidation extremely difficult, yet setting up larger groups to cover these areas may reduce the sense of community and stewardship, and increase the risk of increased boat traffic around the animals. Instead, it is recommended that a dedicated data collection platform is established and promoted in existing general community Facebook groups. Yet, data collected should be shared to ensure a sense of communal importance and encourage sighting reports. The opportunistic nature of the reports also limited data collection as volunteers remained untrained. Providing volunteers with materials could improve data collection to ensure species are identified correctly and ensure the accurate reporting of group sizes and behavioural data.

Behavioural studies have previously been limited to day light hours, uneven effort across seasons, low behavioural sample sizes, and limited sampling days (Baker, O'Brien, McHugh, Ingram & Berrow 2017; Filby et al. 2013, 2017; Kiszka et al. 2011; Mattos et al. 2007; Veneruso & Evans 2012). Due to the limited study period and unfavourable weather conditions, fewer trips and subsequently less data were collected than expected for the present study at Great Barrier Island. Three of the behavioural states examined were explained well by the models, but limited sample sizes for foraging and socialising meant that the models never predicted these behavioural states. Data analysis for behaviour was hindered by low samples sizes. This limited study period also resulted in a bias of search effort, and therefore observations, to be concentrated on the south-western coastline of Great Barrier Island, as time constraints compelled search efforts to be focused on previous sightings of bottlenose dolphins. Thus, the behavioural budget here may be reflective of the area surveyed rather than the entire western Great Barrier Island coastline. Additionally, the present study was limited to diurnal hours and thus rare behaviours reported here may be under-represented.

Limitations that have previously been reported for acoustic studies include; low acoustic sample sizes, limited equipment capabilities and restricted survey areas (Acevedo-Gutiérrez & Stienessen 2004; Ansmann et al. 2007; Azevedo et al. 2007; Hawkins & Gartside 2010; May-Collado & Wartzok 2008). While this study did provide insight into the whistle repertoire for bottlenose dolphins at Great Barrier Island, sample sizes were limited in the same manner previously outlined for behavioural samples. This study was also limited to whistle repertoire due to the recording limitations of the equipment and the broad scale of the overall thesis structure. Many studies have focused on whistle repertoire (Boisseau 2005; Díaz López 2011; Ralston & Herman 1995), though it is only part of the acoustic repertoire of bottlenose dolphins which also includes sounds such as buzz trains and squeaks (Boisseau 2005).

## 5.4 Future research

This study highlights the need to further investigate habitat use for bottlenose dolphins in the inner Hauraki Gulf. Key research questions should focus on habitat use within the Hauraki Gulf, including occurrence, movement patterns, and habitat selection. Given the large area of the Hauraki Gulf, future studies attempting to better understand the use of the Hauraki Gulf for bottlenose dolphins should consider expanding citizen science data collection, particularly to cover larger expanses of coastline in the inner Hauraki Gulf and the coastline of the inner Hauraki Gulf islands. Training would be required to ensure citizen scientists are reporting accurate data (Newman et al. 2003) and a dedicated data entry platform would offer a certain level of rigidity to data collection. Citizen science training would not just ensure that the correct species is being reported, but also allow citizen scientists to accurately report more parameters, such as group size/composition and behavioural state. It would also be beneficial to encourage citizen scientists to upload photographs and video footage. Though, this may be limited, as it may be difficult for citizen scientists to capture good quality images from shore without the use of a high quality camera. Using a dedicated data collection platform, such as an application for a mobile phone, would also allow the inclusion of GPS coordinates for each report. It is also recommended that citizen sightings are validated by a dedicated research vessel (Lodi & Tardin 2018).

It is recommended that behavioural and acoustic data collection is continued at Great Barrier Island to increase the sample size, which is required to better understand the habitat selection of the local bottlenose dolphins. In particular, further samples are required for the behaviour of smaller groups and the acoustic behaviour during rare behavioural states. Furthermore, attempts should be made to collect behavioural and acoustic data covering a more uniform area of the west coast of Great Barrier Island to better understand the importance of these waters. Longer habitat selection studies are also warranted in Great Barrier Island waters for bottlenose dolphins to assess the effects of annual variations and La Niña/El Niño weather patterns on their behavioural budget. Investigating bottlenose dolphin prey selection and their abundance at Great Barrier Island could help to explain differences in behavioural budgets inter-annually and may justify the individual foraging observed close to shore.

Future studies should analyse the full range of the bottlenose dolphins' acoustic sounds at Great Barrier Island to provide insight into the functionality, social relevance and geographical variation of their repertoire. Understanding the whistle repertoire of bottlenose dolphins in the context of their full acoustic repertoire may further explain the results of the present study. Additionally, another variable that could influence whistle frequency parameters is the seabed substrate (Massey 2014; Quintana-Rizzo et al. 2006). This variable was not measured during the present study, though future studies should collect information on the sea bed within the habitat the dolphins are utilising while taking acoustic recordings. Ambient noise levels should also be measured to expand understanding of the whistle rate and frequency parameters measured at Great Barrier Island (Ward et al. 2016).

It is recommended that dedicated and continued photo-identification efforts are extended to determine population demographics (Huang et al. 2012), social structures (Foley et al. 2010), and monitor reproductive parameters (Baker et al. 2018). It would also be prudent to gain information regarding bottlenose dolphin occurrence on the east coast of Great Barrier Island and Rakitu Island to determine if these waters are also important to the bottlenose dolphins.

## 5.5 Concluding statement

This study was intended as an initial step to assess the usefulness of citizen science in the Hauraki Gulf and to investigate the occurrence of bottlenose dolphins in the inner Hauraki Gulf coastline. The results presented here indicate that Facebook is not an efficient way to collect reliable cetacean data, but it is useful for promoting conservation and stewardship. Despite the difficulties and limitations outlined, citizen science did supplement dedicated surveys and helped to determine that bottlenose dolphins occur within the study area most often in winter and rarely, if at all, in summer. Training citizen scientists is essential to ensure the accuracy of the data collected. Recognising how bottlenose dolphins utilise the inner Hauraki Gulf will provide a better understanding of the movements and occurrence of the north-eastern North Island population. Understanding how the north-eastern North Island population of bottlenose dolphins utilise their entire range will enable for more comprehensive protection of this population.

This thesis also constitutes the first assessment of the behavioural budget and whistle repertoire of bottlenose dolphins at Great Barrier Island. While further assessment is required to understand the habitat use of bottlenose dolphins are Great Barrier Island, the results reported here support the idea that these waters are important for bottlenose dolphins. Policy makers and managers should note the significance of maintaining the integrity of these waters, given the large group sizes, high number of calves and the unique behavioural budget reported here. It is recommended that policies beyond the MMPR are proactively implemented to protect these waters for the north-eastern North Island population of bottlenose dolphins. Additionally, the collection and analysis of long-term datasets is required to account for inter-annual variation in occurrence and behaviour. A deeper understanding of the habitat selection of bottlenose dolphins at Great Barrier Island will enable the effective management and conservation for this *Nationally Endangered* species.

# Literature cited

Acevedo-Gutiérrez, A., & Stienessen, S. C. (2004). Bottlenose Dolphins (*Tursiops truncatus*) increase number of whistles when feeding. *Aquatic Mammals*, *30*(3), 357–362.

Albouy, C., Delattre, V. L., Mérigot, B., Meynard, C. N., & Leprieur, F. (2017). Multifaceted biodiversity hotspots of marine mammals for conservation priorities. *Diversity and Distributions*, *23*(6), 615–626.

Alcock, J. (2001). *Animal behavior: an evolutionary approach* (7th ed.), Sinauer Associates, Sunderland, USA.

Allen, M. C., Read, A. J., Gaudet, J., & Sayigh, L. S. (2001). Fine-scale habitat selection of foraging bottlenose dolphins *Tursiops truncatus* near Clearwater, Florida. *Marine Ecology Progress Series*, *222*, 253–264.

Allen, S. J., Tyne, J. A., Kobryn, H. T., Bejder, L., Pollock, K. H., & Loneragan, N. R. (2014). Patterns of Dolphin Bycatch in a North-Western Australian Trawl Fishery. *PLoS ONE*, *9*(4), e93178. https://doi.org/10.1371/journal.pone.0093178

Altmann, J. (1974). Observational study of behavior: sampling methods. *Behaviour*, *49*(3), 227–267.

Ansmann, I. C., Goold, J. C., Evans, P. G. H., Simmonds, M., & Keith, S. G. (2007). Variation in the whistle characteristics of short-beaked common dolphins, *Delphinus delphis*, at two locations around the British Isles. *Journal of the Marine Biological Association of the UK*, *87*, 19–26.

Apps, C. D., McLellan, B. N., Woods, J. G., & Proctor, M. F. (2004). Estimating Grizzly Bear Distribution and Abundance Relative to Habitat and Human Influence. *Journal of Wildlife Management*, *68*(1), 138–152.

Au, D., & Perryman, W. (1982). Movement and speed of dolphin schools responding to an approaching ship. *Fishery Bulletin*, *80*(2), 371–379.

Au, W. W. L., Lemonds, D. W., Vlachos, S., Nachtigall, P. E., & Roitblat, H. L. (2002). Atlantic bottlenose dolphin (*Tursiops truncatus*) hearing threshold for brief broadband signals. *Journal of Comparative Psychology*, *116*(2), 151–157.

Augusto, J. F., Rachinas-Lopes, P., & dos Santos, M. E. (2012). Social structure of the declining resident community of common bottlenose dolphins in the Sado Estuary, Portugal. *Journal of the Marine Biological Association of the UK*, *92*(8), 1773–1782.

Avila, I. C., Correa, L. M., & Parsons, E. C. M. (2015). Whale-watching activity in Bahía Málaga, on the Pacific Coast of Colombia, and its effect on humpback whale (*Megaptera Novaeangliae*) behavior. *Tourism in Marine Environments*, *11*(1), 19–32.

Azevedo, A. F., Oliveira, A. M., Dalla Rosa, L., & Lailson-Brito, J. J. (2007). Characteristics of whistles from resident bottlenose dolphins (*Tursiops truncatus*) in southern Brazil. *Journal of the Acoustical Society of America*, *121*(5), 2978–2983.

Aznar-Alemany, Ò., Giménez, J., de Stephanis, R., Eljarrat, E., & Barceló, D. (2017). Insecticide pyrethroids in liver of striped dolphin from the Mediterranean Sea. *Environmental Pollution*, *225*, 346–353.

Bailey, H., & Thompson, P. M. (2006). Quantitative analysis of bottlenose dolphin movement patterns and their relationship with foraging. *Journal of Animal Ecology*, *75*(2), 456–465.

Baird, R. W., & Dill, L. M. (1996). Ecological and social determinants of group size in transient killer whales. *Behavioral Ecology*, *7*(4), 408–416.

Baird, R. W., Hanson, M. B., Schorr, G. S., Webster, D. L., McSweeney, D. J., Gorgone, A. M., … Andrews, R. D. (2012). Range and primary habitats of Hawaiian insular false killer whales: informing determination of critical habitat. *Endangered Species Research*, *18*(1), 47–61.

Baker, C. S., Chilvers, B. L., Childerhouse, S. J., Constantine, R., Currey, R. J. C., Mattlin, R., … Rohlf, F. J. (2016). Conservation Status of New Zealand Marine Mammals, 2013. *New Zealand Threat Classification Series*, *14*, 1–18.

Baker, C. S., Chivers, S., Constantine, R., DuFresne, S., Mattlin, R., van Helden, A. L., & Hitchmough, R. (2010). Conservation status of New Zealand marine mammals (suborders Cetacea and Pinnipedia), 2009. *New Zealand Journal of Marine and Freshwater Research*, *44*(2), 101–115.

Baker, I., O’Brien, J., McHugh, K. A., & Berrow, S. D. (2017). An Ethogram for Bottlenose Dolphins (Tursiops truncatus) in the Shannon Estuary, Ireland. *Aquatic Mammals*, *43*(6), 594–613.

Baker, I., O'Brien, J., McHugh, K. A., Ingram, S. N., & Berrow, S. D. (2017). Bottlenose dolphin (*Tursiops truncatus*) social structure in the Shannon Estuary, Ireland, is distinguished by age- and area-related associations. *Marine Mammal Science*.

Baker, I., O'Brien, J., McHugh, K., & Berrow, S. (2018). Female reproductive parameters and population demographics of bottlenose dolphins (*Tursiops truncatus*) in the Shannon Estuary, Ireland. *Marine Biology*, *165*(15), 1–19.

Ballance, L. T. (1992). Habitat Use Patterns and Ranges of the Bottlenose Dolphin in the Gulf of California , Mexico. *Marine Mammal Science*, *8*(3), 262–274.

Ballard, H. L., Robinson, L. D., Young, A. N., Pauly, G. B., Higgins, L. M., Johnson, R. F., & Tweddle, J. C. (2017). Contributions to conservation outcomes by natural history museum-led citizen science: Examining evidence and next steps. *Biological Conservation*, *208*, 87–97.

Balmer, J. E., Ylitalo, G. M., Rowles, T. K., Mullin, K. D., Wells, R. S., Townsend, F. I., … Schwacke, L. H. (2018). Persistent organic pollutants (POPs) in blood and blubber of common bottlenose dolphins (*Tursiops truncatus*) at three northern Gulf of Mexico sites following the Deepwater Horizon oil spill. *Science of the Total Environment*, *621*, 130–137.

Barco, S. G., Swingle, W. M., McLellan, W. A., Harris, R. N., & Pabst, D. A. (1999). Local abundance and distribution of bottlenose dolphins (Tursiops truncatus) in the nearshore waters of Virginia Beach, Virginia. *Marine Mammal Science*, *15*(2), 394–408.

Barros, F. C., Herrel, A., & Kohlsdorf, T. (2011). Head shape evolution in Gymnophthalmidae: Does habitat use constrain the evolution of cranial design in fossorial lizards? *Journal of Evolutionary Biology*, *24*(11), 2423–2433.

Baş, A. A., Amaha Öztürk, A., & Öztürk, B. (2014). Selection of critical habitats for bottlenose dolphins (*Tursiops truncatus*) based on behavioral data, in relation to marine traffic in the Istanbul Strait, Turkey. *Marine Mammal Science*, *31*(3), 979-997.

Baş, A. A., Christiansen, F., Öztürk, A. A., Öztürk, B., & McIntosh, C. (2017). The effects of marine traffic on the behaviour of Black Sea harbour porpoises (*Phocoena phocoena relicta*) within the Istanbul Strait, Turkey. *PLoS ONE*, *12*(3), e0172970. https://doi.org/10.1371/journal.pone.0183597

Baş, A. A., Christiansen, F., Öztürk, B., Amaha, Ö. A., Erdogˇan, M. A., & Watson, L. J. (2017). Marine vessels alter the behaviour of bottlenose dolphins *Tursiops truncatus* within the Istanbul Strait , Turkey. *Endangered Species Research*, *34,* 1-14.

Bates, A. J., Jon, P., Everett, G., Grundy, D., Lowe, N., Baker, D., … Young, H. (2013). Assessing the value of the Garden Moth Scheme citizen science dataset: how does light trap type affect catch? *Entomologia Experimentalis et Applicata*, *146*(3), 386–397.

Bazúa-Durán, C., & Au, W. W. L. (2002). The whistles of Hawaiian spinner dolphins. *The Journal of the Acoustical Society of America*, *112*(6), 3064–3072.

Bazúa-Durán, C., & Au, W. W. L. (2004). Geographic variations in the whistles of spinner dolphins (*Stenella longirostris*) of the Main Hawai'ian Islands. *Journal of the Acoustical Society of America*, *116*(6), 3757–3769.

Bearzi, G., Azzellino, A., Politi, E., Costa, M., & Bastianini, M. (2008). Influence of seasonal forcing on habitat use by bottlenose dolphins *Tursiops truncatus* in the northern Adriatic Sea. *Ocean Science Journal*, *43*(4), 175–182.

Bearzi, G., Politi, E., & Sciara, G. N. (1999). Diurnal behavior of free-ranging bottlenose dolphins in the Kvarneril (Northern Adriatic Sea). *Marine Mammal Science*, *15*(4), 1065-1097.

Bearzi, M. (2005). Aspects of the ecology and behaviour of bottlenose dolphins (*Tursiops truncatus*) in Santa Monica Bay, California. *Journal of Cetacean Research & Management*, *7*(1), 75–83.

Bearzi, M., Saylan, C. A., & Hwang, A. (2009). Ecology and comparison of coastal and offshore bottlenose dolphins (*Tursiops truncatus*) in California. *Marine and Freshwater Research*, *60*, 584–593.

Beddia, L. (2007). *Diurnal behaviour of bottlenose dolphins (Tursiops truncatus) in the Cardigan Bay, West Wales* (Doctoral dissertation). University of Wales, Bangor, United Kingdom.

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

Bejder, L., Samuels, A., Whitehead, H., Gales, N. J., Mann, J., Connor, R. C., …

Krützen, M. (2006). Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology*, *20*(6), 1791–1798.

Bela, G., Peltola, T., Young, J. C., Balázs, B., Arpin, I., Pataki, G., … Bonn, A. (2016). Learning and the transformative potential of citizen science. *Conservation Biology*, *30*(5), 990–999.

Berghan, J., Algie, K. D., Stockin, K. A., Wiseman, N., Constantine, R., Tezanos-Pinto, G., & Mourão, F. (2008). A preliminary photo-identification study of bottlenose dolphin (*Tursiops truncatus*) in Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, *42*(4), 465–472.

Best, L. B., Freemark, K. E., Dinsmore, J. J., & Camp, M. (1995). A Review and Synthesis of Habitat Use by Breeding Birds in Agricultural Landscapes of Iowa. *The American Midland Naturalist*, *134*(1), 1–29.

Bhattacharjee, Y. (2005). Citizen Scientists Supplement Work of Cornell Researchers. *Science*, *308*(5725), 1402–1403.

Bird, T. J., Bates, A. E., Lefcheck, J. S., Hill, N. A., Thomson, R. J., Edgar, G. J., … Frusher, S. (2014). Statistical solutions for error and bias in global citizen science datasets. *Biological Conservation*, *173*, 144–154.

Bird, T. J., Bates, A. E., Lefcheck, J. S., Hill, N. A., Thomson, R. J., Edgar, G. J., … Frusher, S. (2014). Statistical solutions for error and bias in global citizen science datasets. *Biological Conservation*, *173*, 144–154.

Black, K. P., Bell, R. G., Oldman, J. W., Carter, G. S., & Hume, T. M. (2000). Features of 3-dimensional barotropic and baroclinic circulation in the Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, *34*(1), 1–28.

Blackwell, S. B., Nations, C. S., Thode, A. M., Kauffman, M. E., Conrad, A. S., Norman, R. G., & Kim, K. H. (2017). Effects of tones associated with drilling activities on bowhead whale calling rates. *PLoS ONE, 12*(11), e0188459. https://doi.org/10.1371/journal.pone.0188459

Block, W.M., Brennan, L.A., 1993. *The habitat concept in ornithology: theory and applications*. In: Power, D. M. (Ed.), Current Ornithology, Vol. 11. Plenum Press, New York, pp. 35–91.

Boisseau, O. (2004). *The acoustic behaviour of resident bottlenose dolphins in Fiordland,* *New Zealand* (Doctoral dissertation). University of Otago, New Zealand.

Boisseau, O. (2005). Quantifying the acoustic repertoire of a population: The vocalizations of free-ranging bottlenose dolphins in Fiordland, New Zealand. *Journal of the Acoustical Society of America*, *117*(4), 2318–2329.

Bonney, R., Cooper, C. B., Dickinson, J. L., Kelling, S., Phillips, T. B., Rosenberg, K. V., & Shirk, J. L. (2009). Citizen science: a developing tool for expanding science knowledge and scientific literacy. *BioScience*, *59*(11), 977–984.

Bonney, R., Shirk, J. L., Phillips, T. B., Wiggins, A., Ballard, H. L., Miller-Rushing, A. J., & Parrish, J. K. (2014). Citizen science: next steps for citizen science. *Science*, *343*(6178), 1436–1437.

Bossley, M., & Woolfall, M. A. (2014). Recovery from severe cutaneous injury in two free ranging bottlenose dolphins (*Tursiops* spp.). *Journal of Marine Animals and their Ecology*, *7*(1), 12-16.

Boulangeat, I., Gravel, D., & Thuiller, W. (2012). Accounting for dispersal and biotic interactions to disentangle the drivers of species distributions and their abundances. *Ecology Letters*, *15*(6), 584–593.

Bowen, W. D. (1997). Role of marine mammals in aquatic ecosystems. *Marine Ecology Progress Series*, *158*, 267–274.

Bräger, S., Harraway, J. A., & Manly, B. F. J. (2003). Habitat selection in a coastal dolphin species (*Cephalorhynchus hectori*). *Marine Biology*, *143*(2), 233–244.

Brill, R. L., Moore, P. W. B., & Dankiewicz, L. A. (2001). Assessment of dolphin (*Tursiops truncatus*) auditory sensitivity and hearing loss using jawphones. *The Journal of the Acoustical Society of America*, *109*(4), 1717–1722.

Bristow, T., Glanville, N., & Hopkins, J. (2001). Shore-based monitoring of bottlenose dolphins (*Tursiops truncatus*) by trained volunteers in Cardigan Bay, Wales. *Aquatic Mammals*, *27*(2), 115–120.

Brough, T., Guerra, M., & Dawson, S. M. (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), 150–158.

Bruce, E., Albright, L., Sheehan, S., & Blewitt, M. (2014). Distribution patterns of migrating humpback whales (*Megaptera novaeangliae*) in Jervis Bay, Australia: A spatial analysis using geographical citizen science data. *Applied Geography*, *54*, 83–95.

Brumm, H. (ed.) (2013). *Animal Communication and Noise*. Springer, Heidelberg.

Brumm, H., & Slabbekoorn, H. (2005). Acoustic communication in noise. *Advances in the Study of Behavior*, *35*, 151-209.

Buck, J. R., & Tyack, P. L. (1993). A quantitative measure of similarity for *Tursiops truncatus* signature whistles. *Journal of the Accoustical Society of America*, *94*(5), 2497–2506.

Buckstaff, K. C. (2004). Effects of watercraft noise on the acoustic behaviour of bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Marine Mammal Science*, *20*(4), 709–725.

Burgess, M. G., Mcdermott, G. R., Owashi, B., Reeves, L. E. P., Clavelle, T., Ovando, D., … Costello, C. (2018). Protecting marine mammals, turtles, and birds by rebuilding global fisheries. *Science*, *359*(6381), 1255–1258.

Burns, J. M., Hindell, M. A., Bradshaw, C. J. A., & Costa, D. P. (2008). Fine-scale habitat selection of crabeater seals as determined by diving behavior. *Deep-Sea Research Part II: Topical Studies in Oceanography*, *55*, 500–514.

Butterworth, A., Brakes, P., Vail, C. S., & Reiss, D. (2013). A veterinary and behavioral analysis of dolphin killing methods currently used in the “drive hunt” in Taiji, Japan. *Journal of Applied Animal Welfare Science*, *16*(2), 184–204.

Caldwell, D.K. and Caldwell, M.C. (1972). Behaviour of marine mammals. In S. H. Ridgway (eds). *Mammals of the Sea, Biology and Medicine*. Charles C Thomas, Springfield, Illinois. 419-465.

Caldwell, M. C., Caldwell, D. K., & Tyack, P. L. (1990). Review of the signature-whistle hypothesis for the Atlantic bottlenose dolphin. In S. Leatherwood and R. R. Reeves (Eds.), *The bottlenose dolphin* (pp. 199-234). Academic Press, San Diego, USA.

Campbell, G., Bilgre, B., & Defran, R. (2002). Bottlenose dolphins (*Tursiops truncatus*) in Turneffe Atoll, Belize: occurrence, site fidelity, group size, and abundance. *Aquatic Mammals*, *28*(2), 170–180.

Camphuysen, K. C. (2011). Recent trends and spatial patterns in nearshore sightings of harbour porpoises (*Phocoena phocoena*) in the Netherlands (Southern Bight, North Sea). *Lutra, 54*, 39–47.

Caro, T., & Sherman, P. W. (2011). Endangered species and a threatened discipline: Behavioural ecology. *Trends in Ecology and Evolution*, *26*(3), 111–118.

Carvell, C. (2001). Habitat use and conservation of bumblebees (*Bombus* spp.) under different grassland management regimes. *Biological Conservation, 103*, 33–49.

Cecchetti, A., Stockin, K. A., Gordon, J., & Azevedo, J. M. N. (2017). Short-term effects of tourism on the behaviour of common dolphins (*Delphinus delphis*) in the Azores. *Journal of the Marine Biological Association of the United Kingdom*, 1-10.

Chabanne, D., Finn, H., Salgado Kent, C. P., & Bejder, L. (2012). Identification of a resident community of bottlenose dolphins (*Tursiops aduncus*) in the Swan Canning Riverpark, Western Australia, using behavioural information. *Pacific Conservation Biology*, *18*(4), 247–262.

Charlton-robb, K., Gershwin, L., Thompson, R., Austin, J., & Owen, K. (2011). A new dolphin species, the Burrunan dolphin *Tursiops australis* sp. nov., endemic to Southern Australian coastal waters. *PloS One*, *6*(9), e24047. https://doi.org/10.1371/journal.pone.0024047

Chin, A., Tobin, A. J., Heupel, M. R., & Simpfendorfer, C. A. (2013). Population structure and residency patterns of the blacktip reef shark *Carcharhinus melanopterus* in turbid coastal environments. *Journal of Fish Biology*, *82*(4), 1192-1210.

Christiansen, F., Lusseau, D., Stensland, E., & Berggren, P. (2010). Effects of tourist boats on the behaviour of Indo-Pacific bottlenose dolphins off the south coast of Zanzibar. *Endangered Species Research*, *11*(1), 91–99.

Cipriano, F. W. (1992). *Behavior and occurrence patterns, feeding ecology, and life history of dusky dolphins (Lagenorhynchus obscurus) off Kaikoura, New Zealand* (Doctoral dissertation). The University of Arizona, USA.

Clausen, K. T., Wahlberg, M., Beedholm, K., Deruiter, S., & Madsen, P. T. (2010). Click communication in harbour porpoises *Phocoena Phocoena*. *The International Journal of Animal Sound and Its Recording*, *20*, 1–28.

Cockcroft, V. G., & Ross, G. J. B. (1989). Age, growth, and reproduction of bottlenose dolphins Tursiops truncatus from the East coast of Southern Africa. *Fishery Bulletin, 88*(2), 289–302.

Cohn, J. P. (2008). Citizen Science: Can Volunteers Do Real Research? *BioScience, 58*(3), 192–197.

Committee on Taxonomy. (2016). *List of marine mammal species and subspecies.* Society for Marine Mammalogy, www.marinemammalscience.org, consulted on 9th January 2017

Conner, D. A. (1982). Dialects versus geographic variation in mammalian vocalizations. *Animal Behaviour, 30*(1), 297–298.

Connor, R. C., & Heithaus, M. R. (1996). Approach by great white sharks elicts flight. *Marine Mammal Science, 12,* 602–606.

Connor, R. C., & Krützen, M. (2015). Male dolphin alliances in Shark Bay: Changing perspectives in a 30-year study. *Animal Behaviour, 103,* 223–235.

Connor, R. C., Wells, R. S., Mann, J., & Read, A. J. (2000). Social Relationships in a Fission-Fusion Society. In J. Mann (Ed.), *Cetacean Societies: Field Studies of Dolphins and Whales* (pp. 91–126). University of Chicago Press, Chicago.

Conrad, C. C., & Hilchey, K. G. (2011). A review of citizen science and community-based environmental monitoring: Issues and opportunities. *Environmental Monitoring and Assessment*, *176*, 273–291.

Constantine, R. (2001). Increased avoidance of swimmers by wild bottlenose dolphins (*Tursiops Truncatus*) due to long-term exposure to swim-with-dolphin tourism. *Marine Mammal Science*, *17*(4), 689–702.

Constantine, R. (2002). *The Behavioural Ecology of the Bottlenose Dolphins ( Tursiops truncatus ) of Northeastern New Zealand : A Population Exposed to Tourism* (Doctoral dissertation). The University of Auckland, New Zealand.

Constantine, R. & Baker, C. S. (1997). Monitoring the commercial swim-with-dolphin operations in the Bay of Islands. *Science and Research Series* 104. Wellington, Department of Conservation

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

Cook, M. L. H., Sayigh, L. S., Blum, J. E., & Wells, R. S. (2004). Signature-whistle production in undisturbed free-ranging bottlenose dolphins (*Tursiops truncatus*). *Proceedings of the Royal Society of London B: Biological Sciences*, *271*(1543), 1043–1050.

Cooper, C. B. (2014). Is there a weekend bias in clutch-initiation dates from citizen science? Implications for studies of avian breeding phenology. *International Journal of Biometeorology*, *58*(7), 1415–1419.

Cooper, C. B., Dickinson, J. L., Phillips, T. B., & Bonney, R. (2007). Citizen Science as a tool for conservation in residential ecosystems. *Ecology and Society*, *12*(2), 11.

Cooper, C. B., Shirk, J. L., & Zuckerberg, B. (2014). The invisible prevalence of citizen science in global research: Migratory birds and climate change. *PLoS ONE*, *9*(9), e106508. https://doi.org/10.1371/journal.pone.0106508

Crall, A. W., Newman, G. J., Stohlgren, T. J., Holfelder, K. A., Graham, J., & Waller, D. M. (2011). Assessing citizen science data quality: an invasive species case study. *Conservation Letters*, *4*(6), 433–442.

Cruz, M. J., Machete, M., Menezes, G., Rogan, E., & Silva, M. A. (2018). Estimating common dolphin bycatch in the pole-and-line tuna fishery in the Azores. *PeerJ*, *6*, e4285. https://doi.org/10.7717/peerj.4285

Currey, R. J. C. (2008). *Conservation biology of bottlenose dolphins in Fiordland , New Zealand* (Doctoral dissertation). University of Otago, Dunedin, New Zealand.

Currey, R. J. C., Dawson, S. M., Slooten, E., Schneider, K., Lusseau, D., Boisseau, O., … Williams, J. A. (2009). Survival rates for a declining population of bottlenose dolphins in Doubtful Sound, New Zealand: An information theoretic approach to assessing the role of human impacts. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *19*, 658–670.

Currey, R. J. C., Rowe, L. E., Dawson, S. M., & Slooten, E. (2008). Abundance and demography of bottlenose dolphins in Dusky Sound, New Zealand, inferred from dorsal fin photographs. *New Zealand Journal of Marine and Freshwater Research*, *42*(4), 439–449.

CyberTracker Software [GPS and data recording software]. (2013). Retrieved from: http://www.cybertracker.org/software/free-download

Dahood, A. D., & Benoit-Bird, K. J. (2010). Dusky dolphins foraging at night. In B. Würsig and M. Würsig (Eds.), *The Dusky Dolphin* (pp. 99-114). Acedemic Press, London, United Kingdom.

Danielsen, F., Jensen, P. M., Burgess, N. D., Altamirano, R., Alviola, P. A., Andrianandrasana, H., … Young, R. (2014). A multicountry assessment of tropical resource monitoring by local communities. *Bioscience*, *64*(3), 236–251.

Davidson, A. D., Boyer, A. G., Kim, H., Pompa-Mansilla, S., Hamilton, M. J., Costa, D. P., … Brown, J. H. (2012). Drivers and hotspots of extinction risk in marine mammals. *Proceedings of the National Academy of Sciences*, *109*(9), 3395–3400.

Davies, T. K., Stevens, G., Meekan, M. G., Struve, J., & Rowcliffe, J. M. (2013). Can citizen science monitor whale-shark aggregations? Investigating bias in mark-recapture modelling using identification photographs sourced from the public. *Wildlife Research*, *39*(8), 696–704.

Dawkins, R. & Krebs, J. R. (1978). Animal signals: manipulation or information? In J. R. Krebs, & N. B. Davies (Eds.), *Behavioural Ecology: an Evolutionary Approach* (pp. 289-309) Blackwell Scientific Press, Oxford, United Kingdom.

Dawson, S. M. (1991). Clicks and Communication: The Behavioural and Social Contexts of Hector’s Dolphin Vocalizations. *Ethology*, *88*, 265–276.

Defran, R. H., & Weller, D. W. (1999). Occurrence, distribution, site fidelity, and school size of bottlenose dolphins (*Tursiops truncatus*) off San Diego, California. *Marine Mammal Science*, *15*(2), 366–380.

Defran, R. H., Weller, D. W., Kellar, N. M., & Chivers, S. (2017). Research on coastal bottlenose dolphins (*Tursiops truncatus*), including a photo-identification catalog, following the 2015 Refugio Beach oil spill in Santa Barbara County, California. U.S. Department of Commerce, USA.

Delaney, D. G., Sperling, C. D., Adams, C. S., & Leung, B. (2008). Marine invasive species: Validation of citizen science and implications for national monitoring networks. *Biological Invasions*, *10*(1), 117–128.

Dennis, E. B., Morgan, B. J. T., Brereton, T. M., Roy, D. B., & Fox, R. (2017). Using citizen science butterfly counts to predict species population trends. *Conservation Biology*, *31*(6), 1350–1361.

dos Santos, M. E., Louro, S., Couchinho, M. N., & Brito, C. (2005). Whistles of bottlenose dolphins (*Tursiops truncatus*) in the Sado Estuary, Portugal: Characteristics, production rates, and long-term contour stability. *Aquatic Mammals, 31*(4), 453–462.

Dungan, S. Z., Wang, J. Y., Araújo, C. C., Yang, S. C., & White, B. N. (2016). Social structure in a critically endangered Indo-Pacific humpback dolphin (*Sousa chinensis*) population. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *26*(3), 517–529.

Dwyer, S. L. (2014). *Spatial Ecology and Conservation of Cetaceans using the Hauraki Gulf, New Zealand* (Master's thesis). Massey University, Auckland, New Zealand.

Dwyer, S. L., Clement, D., Pawley, M. D. M., & Stockin, K. A. (2016). Distribution and relative density of cetaceans in the Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, *50*(3), 457–480.

Dwyer, S. L., Kozmian-Ledward, L., & Stockin, K. A. (2014). Short-term survival of severe propeller strike injuries and observations on wound progression in a bottlenose dolphin. *New Zealand Journal of Marine and Freshwater Research*, *48*(2), 294–302.

Dwyer, S. L., Tezanos-Pinto, G., Visser, I. N., Pawley, M. D. M., Meissner, A. M., Berghan, J., & Stockin, K. A. (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.

Dwyer, S. L., & Visser, I. N. (2011). Cookie cutter shark (*Isistius* sp.) Bites on cetaceans, with particular reference to killer whales (*Orcinus orca*). *Aquatic Mammals*, *37*(2), 111–138.

Edelaar, P., Alonso, D., Lagerveld, S., Senar, J. C., & Björklund, M. (2012). Population differentiation and restricted gene flow in Spanish crossbills: Not isolation-by-distance but isolation-by-ecology. *Journal of Evolutionary Biology*, *25*(3), 417–430.

Edgar, G. J., & Stuart-smith, R. D. (2009). Ecological effects of marine protected areas on rocky reef communities — a continental-scale analysis. *Marine Ecolog, 388,* 51–62.

Elliott, R. G. (2010). *Passive acoustic monitoring of habitat use by bottlenose dolphins in Doubtful Sound* (Doctoral dissertation). University of Otago, Dunedin, New

Zealand.

Elliott, R. G., Dawson, S. M., & Henderson, S. D. (2011). Acoustic monitoring of habitat use by bottlenose dolphins in Doubtful Sound, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, *45*(4), 637–649.

Embling, C. B., Walters, A. E. M., & Dolman, S. J. (2015). How much effort is enough? The power of citizen science to monitor trends in coastal cetacean species. *Global Ecology and Conservation*, *3*, 867–877.

Engel, S. R., & Voshell, J. R. (2002). Volunteer biological monitoring: Can it accurately assess the ecological condition of streams? *American Entomologist*, *48*(3), 164–177.

Esch, H. C., Sayigh, L. S., Blum, J. E., & Wells, R. S. (2009). Whistles as potential indicators of stress in bottlenose dolphins (*Tursiops truncatus*). *Journal of Mammalogy*, *90*(3), 638–650.

Esch, H. C., Sayigh, L. S., & Wells, R. S. (2009). Quantifying parameters of bottlenose dolphin signature whistles. *Marine Mammal Science*, *25*(4), 976–986.

Estep, H. (2012). *Population Structure of Tursiops truncatus in North Inlet, South Carolina and use of Inlet as a nursery ground* (Doctoral dissertation). Coastal Carolina Unveristy, South Carolina, USA.

Estes, J. A., Terborgh, J., Brashares, J. S., Power, M. E., Berger, J., Bond, W. J., … Wardle, D. A. (2011). Trophic downgrading of planet earth. *Science*, *333*, 301–306.

Evans, C., Abrams, E., Reitsma, R., Roux, K., Salmonsen, L., & Marra, P. (2005). The Neighborhood Nestwatch Program : Participant outcomes of a citizen-science ecological research project. *Conservation Biology*, *19*(3), 589–594.

Evans, P. G. H. (1980). Mammal Review. *Mammal Review*, *10*(1), 1–52.

Evans, P. G. H., & Hammond, P. S. (2004). Monitoring cetaceans in European waters. *Mammal Review*, *34*(1), 131–156.

Facebook. (2017). *Company info*. Retrieved from: https://newsroom.fb.com/company-info/

Farhadinia, M. S., Hunter, L. T. B., Jourabchian, A., Hosseini-Zavarei, F., Akbari, H., Ziaie, H., … Jowkar, H. (2017). The critically endangered Asiatic cheetah *Acinonyx jubatus venaticus* in Iran: a review of recent distribution, and conservation status.

*Biodiversity and Conservation*, *26*(5), 1027–1046.

Félix, F., Centeno, R., Romero, J., Zavala, M., & Vásconez, Ó. (2017). Prevalence of scars of anthropogenic origin in coastal bottlenose dolphin in Ecuador. *Journal of the Marine Biological Association of the United Kingdom*, 1–10. https://doi.org/10.1017/S0025315417000686

Fellers, G., & Kleeman, P. (2007). Red-legged frog (*Rana draytonii*) movement and habitat use: Implications for conservation. *Journal of Herpetology*, *41*(2), 276–286.

Felton, A. M., Felton, A., Cromsigt, J. P. G. M., Edenius, L., Malmsten, J., & Wam, H. K. (2017). Interactions between ungulates, forests, and supplementary feeding: the role of nutritional balancing in determining outcomes. *Mammal Research*, *62*(1), 1–7.

Fenton, H., Daoust, P., Forzán, M., Vanderstichel, R., Ford, J., Spaven, L., … Raverty, S. (2017). Causes of mortality of harbor porpoises Phocoena phocoena along the Atlantic and Pacific coasts of Canada. *Diseases of Aquatic Organisms*, *122*(3), 171–183.

Filby, N. E., Bossley, M., & Stockin, K. A. (2013). Behaviour of free-ranging short-beaked common dolphins (*Delphinus delphis*) in Gulf St Vincent , South Australia. *Australian Journal of Zoology*, *61*(4), 291–300.

Filby, N. E., Christiansen, F., Scarpaci, C., & Stockin, K. A. (2017). Effects of swim-with-dolphin tourism on the behaviour of a threatened species, the Burrunan dolphin *Tursiops australis*. *Endangered Species Research*, *32*, 479–490.

Fink, D., Hochachka, W. M., Zuckerberg, B., Winkler, D. W., Shaby, B., Munson, M. A., … December, N. (2010). Spatiotemporal exploratory models for broad-scale survey data. *Ecological Applications*, *20*(8), 2131–2147.

Foley, A., McGrath, D., Berrow, S., & Gerritsen, H. (2010). Social structure within the bottlenose dolphin (Tursiops truncatus) population in the Shannon Estuary, Ireland. *Aquatic Mammals*, *36*(4), 372–381.

Foote, A. D., Osborne, R. W., & Rus Hoelzel, A. (2008). Temporal and contextual patterns of killer whale (*Orcinus orca*) call type production. *Ethology*, *114*(6), 599–606.

Fore, L. S., Paulsen, K. I. T., & Laughlin, K. O. (2001). Assessing the performance of volunteers in monitoring. *Freshwater Biology*, *46*(1), 109–123.

Fossi, M. C., Romeo, T., Baini, M., Panti, C., Marsili, L., Campani, T., … Lapucci, C. (2017). Plastic debris occurrence, convergence areas and fin whales feeding ground in the Mediterranean Marine Protected Area Pelagos Sanctuary: A modeling approach. *Frontiers in Marine Science*, *4*(167), 1-15.

Foster-smith, J., & Evans, S. M. (2003). The value of marine ecological data collected by volunteers. *Biological Conservation*, *113*(2), 199–213.

Fournier, A. M. V., Sullivan, A. R., Bump, J. K., Perkins, M., Shieldcastle, M. C., & King, S. L. (2017). Combining citizen science species distribution models and stable isotopes reveals migratory connectivity in the secretive Virginia rail. *Journal of Applied Ecology*, *54*(2), 618–627.

Fristrup, K. M., Hatch, L. T., & Clark, C. W. (2003). Variation in humpback whale (*Megaptera novaeangliae*) song length in relation to low-frequency sound broadcasts. *The Journal of the Acoustical Society of America*, *113*(6), 3411–3424.

Gannon, D. P., & Waples, D. M. (2004). Diets of coastal bottlenose dolphins from the U.S. Mid-Atlantic coast differ by habitat. *Marine Mammal Science*, *20*(3), 527–545.

Garaffo, G. V., Dans, S. L., Pedraza, S. N., Crespo, E. A., & Degrati, M. (2007). Habitat use by dusky dolphin in patagonia: how predictable is their location? *Marine Biology*, *152*(1), 165–177.

Garcia, J., Self-Sullivan, C., & Funicelli, N. A. (2017). Changes in bottlenose dolphin (*Tursiops truncatus*) distribution and behavior in the Drowned Cayes, Belize, and correlation to human impacts. *Aquatic Mammals*, *43*(6), 661–672.

García Erize, F., & Gómez Villafañe, I. E. (2016). Habitats selected by the endangered Greater Rhea (Rhea americana) - Implications for conservation. *Emu*, *116*(4), 379–386.

Gardiner, M. M., Allee, L. L., Brown, P. M. J., Losey, J. E., Roy, H. E., & Smyth, R. R. (2012). Lessons from lady beetles: Accuracy of monitoring data from US and UK citizen-science programs. *Frontiers in Ecology and the Environment*, *10*(9), 471–476.

Geberzahn, N., Goymann, W., Muck, C., & ten Cate, C. (2009). Females alter their song when challenged in a sex-role reversed bird species. *Behavioral Ecology and*

*Sociobiology, 64*(2), 193–204.

Geldmann, J., Heilmann-Clausen, J., Holm, T. E., Levinsky, I., Markussen, B., Olsen, K., … Tøttrup, A. P. (2016). What determines spatial bias in citizen science? Exploring four recording schemes with different proficiency requirements. *Diversity and Distributions*, *22*(11), 1139–1149.

Ghaskadbi, P., Habib, B., & Qureshi, Q. (2016). A whistle in the woods: an ethogram and activity budget for the dhole in central India. *Journal of Mammalogy, 97*(6), 1745–1752.

Gibson, Q. A., & Mann, J. (2008). The size, composition and function of wild bottlenose dolphin (*Tursiops* sp.) mother-calf groups in Shark Bay, Australia. *Animal Behaviour*, *76*(2), 389–405.

Giovos, I., Ganias, K., Garagouni, M., & Gonzalvo, J. (2016). Social Media in the service of conservation: A case study of dolphins in the Hellenic Seas. *Aquatic Mammals*, *42*(1), 12–19.

Gliozzo, G., Pettorelli, N., & Muki Haklay, M. (2016). Using crowdsourced imagery to detect cultural ecosystem services: A case study in South Wales, UK. *Ecology and Society*, *21*(3), 6.

Godard-Codding, C. A. J., Clark, R., Fossi, M. C., Marsili, L., Maltese, S., West, A. G., … Stegeman, J. J. (2011). Pacific ocean-wide profile of CYP1A1 expression, stable carbon and nitrogen isotope ratios, and organic contaminant burden in sperm whale skin biopsies. *Environmental Health Perspectives*, *119*(3), 337–343.

Gollan, J., Lobry, L., Reid, N., & Wilkie, L. (2012). Can volunteers collect data that are comparable to professional scientists ? A study of variables used in monitoring the outcomes of ecosystem rehabilitation. *Environmental Management*, *50*(5), 969–978.

Goodall, J. (1986). The chimpanzees of Gombe: Patterns of behavior. Cambridge, Massachusetts, and London, England: The Belknap Press of Harvard University Press.

Gospić, N. R., & Picciulin, M. (2016). Changes in whistle structure of resident bottlenose dolphins in relation to underwater noise and boat traffic. *Marine Pollution Bulletin*, *105*(1), 193–198.

Grason, E. W., Mcdonald, P. S., Adams, J., Litle, K., Apple, J. K., & Pleus, A. (2018).

Citizen science program detects range expansion of the globally invasive European green crab in Washington State (USA). *Management of Biological Invasions*, *9*(1), 39–47.

Greene, C. R. & Moore, S. E. (1995). Man-made noise. In W. J. Richardson, C. R. Greene, J. R. C. I. Malme & D. H. Thompson (Eds.) *Marine Mammals and Noise* (pp. 101-158), Acedmeic Press, New York, USA.

Gregory, P. R., & Rowden, A. A. (2001). Behaviour patterns of bottlenose dolphins (*Tursiops truncatus*) relative to tidal state, time-to-day, and boat traffic in Cardigan Bay, West Wales. *Aquatic Mammals*, *27*(2), 105–113.

Greig, E. I., Price, J. J., & Pruett-Jones, S. (2013). Song evolution in Maluridae: Influences of natural and sexual selection on acoustic structure. *Emu*, *113*(3), 270–281.

Gridley, T., Nastasi, A., Kriesell, H. J., & Elwen, S. H. (2015). The acoustic repertoire of wild common bottlenose dolphins (*Tursiops truncatus*) in Walvis Bay, Namibia. *Bioacoustics*, *24*(2), 153–174.

Grigg, E., & Markowitz, H. (1997). Habitat use by bottlenose dolphins (Tursiops truncatus) at Turneffe Atoll , Belize. *Aquatic Mammals*, *23*(3), 163–170.

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

Haase, P. A., & Schneider, K. (2001). Birth demographics of bottlenose dolphins, *Tursiops truncatus*, in Doubtful Sound, Fiordland, New Zealand - Preliminary findings. *New Zealand Journal of Marine and Freshwater Research*, *35*, 675–680.

Halfwerk, W., Bot, S., & Slabbekoorn, H. (2012). Male great tit song perch selection in response to noise-dependent female feedback. *Functional Ecology*, *26*(6), 1339–1347.

Halliday, T. R. (1983). Information and communication. In T. R. Halliday, & P. J. B. Slater (Eds.), *Animal behaviour: Number 2, Communication* (pp. 43-81), Blackwell Scientific Press, Oxford, United Kingdom.

Hann, C. (2015). *Citizen Science Research: A Focus on Historical Whaling Data and a Current Marine Mammal Citizen Science Project, Whale mAPP* (Doctoral dissertation). Oregon State

Hansen, L. J. (1990). California Coastal Bottlenose Dolphins. In S. Leatherwood & R. R. Reeves (Eds.), *The Bottlenose Dolphin* (pp. 403-420). Academic Press, San Diego, USA.

Hanson, M. T., & Defran, R. H. (1993). The behavior and feeding ecology of the Pacific coast bottlenose dolphin, *Tursiops truncatus*. *Aquatic Mammals*, *19*(3), 127–142.

Hartel, E. F. (2010). *Habitat Use by Bottlenose Dolphins (Tursiops truncatus) in the Bay of Islands, New Zealand* (Doctoral dissertation). The University of Auckland, New Zealand.

Hartel, E. F., Constantine, R., & Torres, L. G. (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), 562–572.

Harvey, K. (2006). Monitoring change: Citizen science and international environmental treaty-making. *Papers on International Environmental Negotiation: Ensuring a Sustainable Future*, *15*, 77–90.

Hastie, G. D., Wilson, B., Tufft, L. H., & Thompson, P. M. (2003). Bottlenose dolphins increase breathing synchrony in response to boat traffic. *Marine Mammal Science*, *19*(1), 74–84.

Hastie, G. D., Wilson, B., Wilson, L. J., Parsons, K. M., & Thompson, P. M. (2004). Functional mechanisms underlying cetacean distribution patterns: Hotspots for bottlenose dolphins are linked to foraging. *Marine Biology*, *144*(2), 397–403.

Hatch, L. T., & Wright, A. J. (2007). A brief review of anthropogenic sound in the oceans a brief review of anthropogenic sound in the oceans. *International Journal of Comparative Psychology*, *20*(2), 121–133.

Hawkins, E. R., & Gartside, D. F. (2009a). Interactive behaviours of bottlenose dolphins (*Tursiops aduncus*) during encounters with vessels. *Aquatic Mammals*, *35*(2), 259–268.

Hawkins, E. R., & Gartside, D. F. (2009b). Patterns of whistles emitted by wild Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) during a provisioning program. *Aquatic Mammals, 35*(2), 171–186.

Hawkins, E. R., & Gartside, D. F. (2010). Whistle emissions of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) differ with group composition and surface behaviors. *Journal of the Acoustical Society of America*, *127*(4), 2652–2663.

Heiler, J., Elwen, S. H., Kriesell, H. J., & Gridley, T. (2016). Changes in bottlenose dolphin whistle parameters related to vessel presence, surface behaviour and group composition. *Animal Behaviour*, *117*, 167–177.

Heithaus, M. R. (2001). Predator-prey and competitive interactions between sharks (order Selachii) and dolphins (suborder Odontoceti): a review. *Journal of Zoology London*, *253*, 53–68.

Heithaus, M. R., & Dill, L. M. (2002). Food availability and tiger shark predation risk influence bottlenose dolphin habitat use. *Ecology*, *83*(2), 480–491.

Heithaus, M. R., & Dill, L. M. (2006). Does tiger shark predation risk influence foraging habitat use by bottlenose dolphins at multiple spatial scales. *Oikos*, *114*(2), 257–264.

Helweg, D. A., Dankiewicz, L. A., Zafran, J. M., & Brill, R. L. (2003). Discrimination of complex synthetic echos by an echolocating bottlenose dolphin. *The Journal of the Acoustical Society of America*, *113*(2), 1138–1144.

Henderson, E. E., Hildebrand, J. A., Smith, M. H., & Falcone, E. A. (2011). The behavioral context of common dolphin (*Delphinus* sp.) vocalizations. *Marine Mammal Science*, *28*(3), 439–460.

Henderson, S. D., Dawson, S. M., Currey, R. J. C., Lusseau, D., & Schneider, K. (2014). Reproduction, birth seasonality, and calf survival of bottlenose dolphins in Doubtful Sound, New Zealand. *Marine Mammal Science*, *30*(3), 1067–1080.

Herzing, D. L. (2000). Acoustics and social behavior of wild dolphins: Implications for a sound society. In W. W. L. Au, A. N. Popper, & R. R. Fay (Eds.) *Hearing by Whales and Dolphins* (pp. 225–272). Springer, New York, USA.

Higby, L. K., Stafford, R., & Bertulli, C. G. (2012). An evaluation of ad hoc presence-only data in explaining patterns of distribution: Cetacean sightings from whale-watching vessels. *International Journal of Zoology*, 1-5.

Holt, M. M., Noren, D. P., Dunkin, R. C., & Williams, T. M. (2015). Vocal performance affects metabolic rate in dolphins: implications for animals communicating in noisy environments. *Journal of Experimental Biology*, *218*(11), 1647–1654.

Holt, M. M., Noren, D. P., Emmons, C. K., & Veirs, S. (2009). Speaking up : Killer whales (*Orcinus orca*) increase their call amplitude in response to vessel noise. *The Journal of the Acoustical Society of America*, *125*(1), E27–E32. https://doi.org/10.1121/1.3040028

Holveck, M. J., Vieira De Castro, A. C., Lachlan, R. F., Ten Cate, C., & Riebel, K. (2008). Accuracy of song syntax learning and singing consistency signal early condition in zebra finches. *Behavioral Ecology*, *19*(6), 1267–1281.

Hooker, S. K., & Gerber, L. R. (2004). Marine Reserves as a tool for ecosystem-based management: The potential importance of megafauna. *BioScience*, *54*(1), 27–39.

Hoydal, K. S., Styrishave, B., Ciesielski, T. M., Letcher, R. J., Dam, M., & Jenssen, B. M. (2017). Steroid hormones and persistent organic pollutants in plasma from North-eastern Atlantic pilot whales. *Environmental Research*, *159*, 613–621.

Hoyt, E. (2012). *Marine protected areas for whales, dolphins and porpoises: a world handbook for cetacean habitat conservation and planning* (2nd ed.). Earthscan, New York, USA.

Huang, S. L., Karczmarski, L., Chen, J., Zhou, R., Lin, W., Zhang, H., … Wu, Y. (2012). Demography and population trends of the largest population of Indo-Pacific humpback dolphins. *Biological Conservation*, *147*(1), 234–242.

Hupman, K. (2016). *Photo-identification and its application to gregarious delphinids: Common dolphins (Delphinus sp.) in the Hauraki Gulf, New Zealand* (Doctoral dissertation). Massey University, Auckland, New Zealand.

Hupman, K., Visser, I. N., Martinez, E., & Stockin, K. A. (2014). Using platforms of opportunity to determine the occurrence and group characteristics of orca (*Orcinus orca*) in the Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, *49*(1), 132–149.

Hutto, R. L. (1985). Habitat selection by nonbreeding, migratory land birds. In M. L. Cosy (Ed.), *Habitat Selection in Birds* (pp. 455–476).

Hwang, A., Defran, R. H., Bearzi, M., & Maldini, D. (2014). Coastal Range and Movements of Common Bottlenose Dolphins (*Tursiops truncatus*) off California and Baja California, Mexico. *Bulletin, Southern California Academy of Sciences*, *113*(1), 1–13.

Inoue, K., Terashima, Y., Shirakihara, M., & Shirakihara, K. (2017). Habitat use by Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Amakusa, Japan. *Aquatic Mammals*, *43*(2), 127–138.

Isaac, N. J. B., van Strien, A. J., August, T. A., de Zeeuw, M. P., & Roy, D. B. (2014). Statistics for citizen science: Extracting signals of change from noisy ecological data. *Methods in Ecology and Evolution*, *5*(10), 1052–1060.

IUCN. (2016). *IUCN Red List of Threatened Species*. Retrieved from: http://www.iucnredlist.org/

Janik, V. M. (2000a). Food−related bray calls in wild bottlenose dolphins (*Tursiops truncatus*). *Proceedings of the Royal Scociety of London B: Biological Sciences, 267*(1446), 923–927.

Janik, V. M. (2000b). Source levels and the estimated active space of bottlenose dolphin (*Tursiops truncatus*) whistles in the Moray Firth, Scotland. *Journal of Comparative Physiology*, *186*(7–8), 673–680.

Janik, V. M. (2003). *Geographic differences in inter-type variability of bottlenose dolphin whistles*. Proceedings of the 17th Conference of the European Cetacean Society, Gran Canaria, Spain.

Janik V. M. (2009) Acoustic communication in delphinids. *Advances in the Study of Behavior, 40*, 123–157.

Janik, V. M., Sayigh, L. S., & Wells, R. S. (2006). Signature whistle shape conveys identity information to bottlenose dolphins. *Proceedings of the National Academy of Sciences of the USA*, *103*(21), 8293–8297.

Janik, V. M., & Thompson, P. M. (1996). Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Marine Mammal Science*, *12*(4), 597–602.

Janik, V. M., Todt, D., & Dehnhardt, G. (1994). Signature whistle variations in a bottlenosed dolphin, Tursiops truncatus. *Behavioral Ecology and Sociobiology*, *35*(4), 243–248.

Jefferson, T. A., Webber, M. A., & Pitman, R. L. (2008). *Marine Mammals of the World: A Comprehensive Guide to Their Identification*. London: Academic Press.

Jepson, P. D., Deaville, R., Barber, J. L., Aguilar, À., Borrell, A., Murphy, S., … Law, R. J. (2016). PCB pollution continues to impact populations of orcas and other dolphins in European waters. *Scientific Reports*, *6*(18573), 1-17.

Joanna Barker, & Simon Berrow. (2016). Temporal and spatial variation in group size of bottlenose dolphins (*Tursiops truncatus*) in the Shannon Estuary, Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy*, *116*(1), 63–70.

Johnson, D. H. (1980). The comparison of usage and availability measurements for evaluating resource preference. *Ecology*, *61*(1), 65–71.

Johnson, C. M., & Norris, K. S. (1986). Delphinid social organisation and social behaviour. In R. J. Schusterman, J. A. Thomas, & F. G. Wood (Eds.), *Dolphin cognition and behaviour: A comparative approach* (pp. 335-346). Lawrence Erlbaum Associates, Hillsdale, New Jersey, USA.

Jones, G. J., & Sayigh, L. S. (2002). Geographic variation in rates of vocal production of free-ranging bottlenose dolphins. *Marine Mammal Science*, *18*(2), 374–393.

Jones, J. (2001). Habitat selection studies in avian ecology: A critical review. *The Auk*, *118*(2), 557–562.

Jordan, R. C., Brooks, W. R., Howe, D. V., & Ehrenfeld, J. G. (2012). Evaluating the performance of volunteers in mapping invasive plants in public conservation lands. *Environmental Management*, *49*(2), 425–434.

Karczmarski, L., Cockcroft, V. G., & Mclachlan, A. (2000). Habitat use and preferences of Indo-Pacific humpback dolphins in Algoa Bay, South Africa. *Marine Mammal Science*, *16*(1), 65–79.

Karczmarski, L., Huang, S. L., Wong, W. H., Chang, W. L., Chan, S. C., & Keith, M. (2017). Distribution of a coastal delphinid under the impact of long-term habitat loss: Indo-Pacific humpback dolphins off Taiwan’s west coast. *Estuaries and Coasts, 40(2),* 594-603.

Karczmarski, L., Würsig, B., Gailey, G., Larson, K. W., & Vanderlip, C. (2005). Spinner dolphins in a remote Hawaiian atoll: Social grouping and population structure. *Behavioral Ecology*, *16*(4), 675–685.

Karniski, C., Patterson, E. M., Krzyszczyk, E., Foroughirad, V., Stanton, M. A., & Mann, J. (2015). A comparison of survey and focal follow methods for estimating individual activity budgets of cetaceans. *Marine Mammal Science*, *31*(3), 839–852.

Kastelein R. A., van der Elst C. A., Tennant, H. K., & Wiepkema, P. R. (2000) Food consumption and growth of a female dusky dolphin (Lagenorhynchus obscurus). *Zoo Biology, 19*(2), 131–142.

Kastelein R. A., Vaughan, N., Walton, S., & Wiepkema, P. R. (2002) Food intake and body measurements of Atlantic bottlenose dolphins (*Tursiops truncatus*) in captivity. *Marine Environmental Research, 53*(2), 199–218.

Katona, S., & Whitehead, H. (1988). Are Cetacea ecologically important? *Oceanography and Marine Biology Annual Review*, *26*, 553–568.

Keeler, B. L., Wood, S. A., Polasky, S., Kling, C., Filstrup, C. T., & Downing, J. A. (2015). Recreational demand for clean water: Evidence from geotagged photographs by visitors to lakes. *Frontiers in Ecology and the Environment*, *13*(2), 76–81.

Kelling, S., Fink, D., La Sorte, F. A., Johnston, A., Bruns, N. E., & Hochachka, W. M. (2015). Taking a “Big Data” approach to data quality in a citizen science project. *Ambio*, *44*(4), 601–611.

Klinowska, M. (1991). *Dolphins, porpoises and whales of the world: the IUCN red data book.* IUCN, Cambridge, United Kingdom.

Kiszka, J. J., Méndez-Fernandez, P., Heithaus, M. R., & Ridoux, V. (2014). The foraging ecology of coastal bottlenose dolphins based on stable isotope mixing models and behavioural sampling. *Marine Biology*, *161*(4), 953–961.

Kiszka, J. J., Simon-Bouhet, B., Martinez, L., Pusineri, C., Richard, P., & Ridoux, V. (2011). Ecological niche segregation within a community of sympatric dolphins around a tropical island. *Marine Ecology Progress Series*, *433*, 273–288.

Kosmala, M. (2016). Assessing data quality in citizen science. *Frontiers in Ecology and the Environment*, *14*(10), 551–560.

Kremen, C., Ullmann, K. S., & Thorp, R. W. (2011). Evaluating the quality of citizen-scientist data on pollinator communities. *Conservation Biology*, *25*(3), 607–617.

Kuczaj, S. A., & Eskelinen, H. C. (2014). Why do dolphins play? *Animal Behavior and Cognition*, *1*(2), 113–127.

Kyba, C. C. M., Wagner, J. M., Kuechly, H. U., Walker, C. E., Elvidge, C. D., Falchi, F., & Ruhtz, T. (2013). Citizen science provides valuable data for monitoring global night sky luminance. *Scientific reports*, *3*(1835), 1-6.

Lachlan, R. F. (2007). Luscinia [A bioacoustics analysis computer program]. Retrieved from http://rflachlan.github.io/Luscinia/

Lachlan, R. F., Anderson, R. C., Peters, S., Searcy, W. A, & Nowicki, S. (2014). Typical versions of learned swamp sparrow song types are more effective signals than are less typical versions. *Proceedings of the Royal Society B: Biological Sciences*, *281*(1785), 1–7.

Lachlan, R. F., van Heijningen, C. A. A., ter Haar, S. M., & ten Cate, C. (2016). Zebra finch song phonology and syntactical structure across populations and continents-a computational comparison. *Frontiers in Psychology*, *7*(980), 1-19).

Lammers, M. O. (2004). Occurrence and behavior of Hawaiian spinner dolphins (*Stenella longirostris*) along Oahu's Leeward and South Shores. *Aquatic Mammals*, *30*(2), 237–250.

LeDuc, R. G., Perrin, W., & Dizon, A. (1999). Phylogenetic relationships among the Delphinid cetaceans based on full cytochrome B sequences. *Marine Mammal Science*, *15*(3), 619–648.

Lefebvre, L. W., Reid, J. P., Kenworthy, W. J., & Powell, J. A. (1999). Characterizing manatee grazing of seagrasses in Florida and Puerto Rico: Implications for conservation and management. *Pacific Conservation Biology*, *5*, 289–298.

Legendre, P., & Fortin, M. J. (1989). Spatial pattern and ecological analysis. *Vegetatio*, *80*(2), 107–138.

Lesage, V., Barrette, C., Kingsley, M. C. S., & Sjare, B. (1999). The Effect of Vessel Noise on the Vocal Behavior of Belugas in the St. Lawrence River Estuary, Canada. *Marine Mammal Science*, *15*(1), 65–84.

Leatherwood, S., & Reeves, R. R. (1990). *The bottlenose dolphin*. Academic Press, San Diego. 653pp.

Levesque, S., Reusch, K., Baker, I., O'Brien, J., & Berrow, S. D. (2016). Photo-identification of bottlenose dolphins (*Tursiops truncatus*) in Tralee Bay and Brandon Bay, Co. Kerry: A case for SAC boundary extension. *Biology and*

*Environment: Proceedings of the Royal Irish Academy*, *116*(2), 109-118.

Lewandowski, E., & Specht, H. (2015). Influence of volunteer and project characteristics on data quality of biological surveys. *Conservation Biology*, *29*(3), 713–723.

Li, C., Zhou, L., Xu, L., Zhao, N., & Beauchamp, G. (2015). Vigilance and activity time-budget adjustments of wintering hooded cranes, Grus Monacha, in human-dominated foraging habitats. *PLoS ONE*, *10*(3), e0118928. https://doi.org/10.1371/journal.pone.0118928

Lind, A. J., & Welsh, H. H. J. (1994). Ontogenetic changes in foraging behaviour and habitat use by the Oregon garter snake, *Thamnophis atratus hydrophilus*. *Animal Behaviour*, *48*, 1261–1273.

Lindenmayer, D. B., & Laurance, W. F. (2016). The ecology, distribution, conservation and management of large old trees. *Biological Reviews*, *92*(3), 1434–1458.

Lodi, L., & Tardin, R. (2018). Citizen science contributes to the understanding of the occurrence and distribution of cetaceans in southeastern Brazil – A case study. *Ocean & Coastal Management*, *158*, 45–55.

López, B. D. (2011). Whistle characteristics in free-ranging bottlenose dolphins (Tursiops truncatus) in the Mediterranean Sea: Influence of behaviour. *Mammalian Biology*, *76*(2), 180–189.

López, B. D., & Shirai, J. A. B. (2009). Mediterranean common bottlenose dolphin's repertoire and communication use. In: A. G. Pearce & L. M. Correa (Eds.), *Dolphins: Anatomy, Behavior and Threats* (pp. 129-148). Nova Science Publishers, Inc. New York, USA.

Louis, M., Buanic, M., Lefeuvre, C., Nilliot, P. Le, Ridoux, V., & Spitz, J. (2017). Strong bonds and small home range in a resident bottlenose dolphin community in a marine protected area (Brittany, France, Northeast Atlantic). *Marine Mammal Science*, *33*(4), 1194–1203.

Lowther-Thieleking, J. L., Archer, F. I., Lang, A. R., & Weller, D. W. (2015). Genetic differentiation among coastal and offshore common bottlenose dolphins, *Tursiops truncatus*, in the eastern North Pacific Ocean. *Marine Mammal Science*, *31*(1), 1–20.

Luís, A. R., Couchinho, M. N., & Dos Santos, M. E. (2014). Changes in the acoustic behavior of resident bottlenose dolphins near operating vessels. *Marine Mammal Science*, *30*(4), 1417–1426.

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

Lusseau, D. (2003b). The emergent properties of a dolphin social network. *Proceedings of the Royal Society of London B: Biological Sciences*, *270*(2), S186-S188.

Lusseau, D. (2004). The hidden cost of tourism: Detecting long-term effects of tourism using behavioral information. *Ecology and Society*, *9*(1), 1–15.

Lusseau, D. (2005). Residency pattern of bottlenose dolphins Tursiops spp. in Milford Sound, New Zealand, is related to boat traffic. *Marine Ecology Progress Series*, *295*, 265–272. https://doi.org/10.3354/meps295265

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

Lusseau, D., Schneider, K., Boisseau, O., Haase, P. A., Slooten, E., & Dawson, S. M. (2003). The bottlenose dolphin community of doubtful sound features a large proportion of long-lasting associations: Can geographic isolation explain this unique trait? *Behavioral Ecology and Sociobiology*, *54*(4), 396–405.

Lusseau, S. M., & Wing, S. R. (2006). Importance of local production versus pelagic subsidies in the diet of an isolated population of bottlenose dolphins *Tursiops* sp. *Marine Ecology Progress Series*, *321*, 283–293.

Maguire, G. S., Miller, K. K., Weston, M. A., & Young, K. (2011). Being beside the seaside : Beach use and preferences among coastal residents of south-eastern Australia. *Ocean and Coastal Management*, *54*, 781–788.

Mair, L., Harrison, P. J., Jönsson, M., Löbel, S., Nordén, J., Siitonen, J., … Snäll, T. (2017). Evaluating citizen science data for forecasting species responses to national forest management. *Ecology and Evolution*, *7*(1), 368–378.

Manighetti, B., & Carter, L. (1999). Across-shelf sediment dispersal, Hauraki Gulf, New Zealand. *Marine Geology*, *160*(3), 271–300.

Manly, B.F.J., McDonald, L.L., Thomas, D. L., McDonald, T. L., and Erickson, W. P.

(2002). *Resource selection by animals: statistical design and analysis for field studies* (2nd ed.). Kluwer Academic Publishers, Dordrecht, the Netherlands.

Mann, J. (1999). Behavioral sampling methods for cetaceans: A review and critique. *Marine Mammal Science*, *15*(1), 102–122.

Mann, J. (2000). *Cetacean societies: field studies of dolphins and whales*. University of Chicago Press, Chicago, USA.

Mann, J., Connor, R. C., Barre, L. M., & Heithaus, M. R. (2000). Female reproductive success in bottlenose dolphins (*Tursiops* sp.): life history, habitat, provisioning, and group-size effects. *Behavioral Ecology*, *11*(2), 210–219.

Mann J. and Sargeant B. (2003) Like mother, like calf: The ontogeny of foraging traditions in wild Indian Ocean bottlenose dolphins (Tursiops sp.). In: D. M. Fragaszy and S. Perry (Eds.), *The biology of traditions: Models and evidence* (pp. 236–266). Cambridge University Press, Cambridge, United Kingdom.

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

Manser, M. B. (2001). The acoustic structure of suricates’ alarm calls varies with predator type and the level of response urgency. *Proceedings of the Royal Society B: Biological Sciences*, *268*(1483), 2315–2324.

Markowitz, W. J. (2012). *Comparative socioecology of the dusky dolphin (Lagenorynchus obscurus) in New Zealand* (Doctoral dissertation). Massey University, Manawatu, New Zealand.

Marley, S. A., Salgado Kent, C. P., Erbe, C., & Parnum, I. M. (2017). Effects of vessel traffic and underwater noise on the movement, behaviour and vocalisations of bottlenose dolphins in an urbanised estuary. *Scientific Reports*, *7*(13437), 1-14.

Martinez, E., Jordan, F., Rankmore, K., & Stockin, K. A. (2010). *An analysis of cetacean sightings data from 2000 to 2009 within the Hauraki Gulf, New Zealand*. Internal Report, Department of Conservation.

Martínez Pastur, G., Peri, P. L., Lencinas, M. V., García-Llorente, M., & Martín-López, B. (2016). Spatial patterns of cultural ecosystem services provision in Southern Patagonia. *Landscape Ecology*, *31*(2), 383–399.

Massey, D. M. (2014). *Whistle variations within the bottlenose dolphin population of*

*Cardigan Bay , Wales* (Master’s thesis). Bangor University, Bangor, Wales.

Mate, B. R., Rossbach, K. A., Nieukirk, S. L., Wells, R. S., Irvine, A. B., Scott, M. D., & Read, A. J. (1995). Satellite-monitored movements and dive behavior of bottlenose dolphin (*Tursiops truncatus)* in Tampa Bay, florida. *Marine Mammal Science*, *11*(4), 452–463.

Mattos, P. H., Dalla Rosa, L., & Fruet, P. F. (2007a). Activity budgets and distribution of bottlenose dolphins (*Tursiops truncatus*) in the Patos Laggon estuary, Southern Brazil. *Latin American Journal of Aquatic Mammals*, *6*(2), 161–169.

May-Collado, L. J. (2010). Changes in whistle structure of two dolphin species during interspecific associations. *Ethology*, *116*(11), 1065–1074.

May-Collado, L. J., & Wartzok, D. (2008). A comparison of bottlenose dolphin whistles in the Atlantic Ocean: Factors promoting whistle variation. *Journal of Mammalogy*, *89*(5), 1229–1240.

Mccaffrey, R. (2005). Using citizen science in urban bird studies. *Urban Habitats*, *3*(1), 70–86.

McCowan, B., & Reiss, D. (2001). The fallacy of “signature whistles” in bottlenose dolphins: A comparative perspective of “signature information” in animal vocalizations. *Animal Behaviour*, *62*(6), 1151–1162.

McGregor, P. K., & Peake, T. M. (2000). Communication networks: social environments for receiving and signalling behaviour. *Acta Ethologica*, *2*, 71–81.

McHugh, K. A., Allen, J. B., Barleycorn, A. A., & Wells, R. S. (2011). Severe Karenia brevis red tides influence juvenile bottlenose dolphin (*Tursiops truncatus*) behavior in Sarasota Bay, Florida. *Marine Mammal Science*, *27*(3), 622–643.

McKinley, D. C., Miller-Rushing, A. J., Ballard, H. L., Bonney, R., Brown, H., Cook-Patton, S. C., … Soukup, M. A. (2017). Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation*, *208*, 15–28.

McWhinnie, L., Smallshaw, L., Serra-Sogas, N., O’Hara, P. D., & Canessa, R. (2017). The grand challenges in researching marine noise pollution from vessels: A horizon scan for 2017. *Frontiers in Marine Science*, *4*(31), 1-17.

Mekonnen, A., Fashing, P. J., Bekele, A., Hernandez-Aguilar, R. A., Rueness, E. K., Nguyen, N., & Stenseth, N. C. (2017). Impacts of habitat loss and fragmentation on the activity budget, ranging ecology and habitat use of Bale monkeys (*Chlorocebus djamdjamensis*) in the southern Ethiopian Highlands. *American Journal of Primatology*, *79*(7), e22644.

Merriman, M. G. (2007). *Abundance and behavioural ecology of bottlenose dolphins (Tursiops truncatus) in the Marlborough Sounds, New Zealand* (Master's thesis). Massey University, New Zealand.

Merriman, M. G., Markowitz, T. M., Harlin-Cognato, A. D., & Stockin, K. A. (2009). Bottlenose dolphin (*Tursiops truncatus*) abundance, site fidelity, and group dynamics in the Marlborough sounds, New Zealand. *Aquatic Mammals*, *35*(4), 511–522.

Miketa, M., Krzyszczyk, E., & Mann, J. (2017). Behavioral responses to fishing line entanglement of a juvenile bottlenose dolphin in Shark Bay, Australia. *Matters*, *12*(3), e201711000011. https://doi.org/10.19185/matters.201711000011

Miller, L. J., Solangi, M., & Kuczaj, S. A. (2010). Seasonal and diurnal patterns of behavior exhibited by Atlantic bottlenose dolphins (*Tursiops truncatus*) in the Mississippi Sound. *Ethology*, *116*(12), 1127–1137.

Miller, P. J. (2006). Diversity in sound pressure levels and active space of killer whale vocalizations. *Journal of Comparative Physiology A*, *192*(5), 449–459.

Miller, P. J., Biassoni, N., Samuels,  a, & Tyack, P. L. (2000). Whale songs lengthen in response to sonar. *Nature*, *405*(6789), 903-904.

Moe, T. F., Kindberg, J., Jansson, I., & Swenson, J. E. (2007). Importance of diel behaviour when studying habitat selection: examples from female Scandinavian brown bears (*Ursus arctos*). *Canadian Journal of Zoology*, *85*(4), 518–525.

Moller, L. M., & Harcourt, R. G. (1998). Social dynamics and activity patterns of bottlenose dolphins, *Tursiops truncatus*, in Jervis Bay, Southeastern Australia. *Proceedings of the Linnean Society of New South Wales*, *120*, 181–189.

Moore, S. E. (2008). Marine mammals as ecosystem sentinels. *Journal of Mammalogy*, *89*(3), 534–540.

Morisaka, T., Shinohara, M., Nakahara, F., & Akamatsu, T. (2005). Geographic variations in the whistles among three Indo-Pacific bottlenose dolphin *Tursiops* *aduncus* populations in Japan. *Fisheries Science*, *71*(3), 568–576.

Morris, D. W. (1987). Ecological scale and habitat use. *Ecology*, *68*(2), 362–369.

Morteo, E., Rocha-Olivares, A., & Abarca-Arenas, L. G. (2017). Abundance, residency, and potential hazards for coastal bottlenose dolphins (*Tursiops truncatus*) off a productive lagoon in the gulf of Mexico. *Aquatic Mammals*, *43*(3), 308–319.

Mysterud, A., Larsen, P. K., Ims, R. A., & Østbye, E. (1999). Habitat selection by roe deer and sheep: does habitat ranking reflect resource availability? *Canadian Journal of Zoology*, *77*(5), 776–783.

NCH Software [WavePad Sound Editor]. (2014). Retrieved from http://www.nch.com.au/wavepad/

Nelms, S. E., Coombes, C., Foster, L. C., Galloway, T. S., Godley, B. J., Lindeque, P. K., & Witt, M. J. (2017). Marine anthropogenic litter on British beaches: A 10-year nationwide assessment using citizen science data. *Science of the Total Environment*, *579*, 1399–1409.

Nelson, D. V., Klinck, H., Carbaugh-Rutland, A., Mathis, C. L., Morzillo, A. T., & Garcia, T. S. (2016). Calling at the highway: The spatiotemporal constraint of road noise on Pacific chorus frog communication. *Ecology and Evolution*, *7*(1), 429–440.

Neumann, D. R. (2001a). Seasonal movements of short-beaked common dolphins (*Delphinus delphis*) in the north-western Bay of Plenty, New Zealand: Influence of sea surface temperature and El Niño/La Niña. *New Zealand Journal of Marine and Freshwater Research*, *35*(2), 371–374.

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

New, L. F., Harwood, J., Thomas, L., Donovan, C., Clark, J. S., Hastie, G., … Lusseau, D. (2013). Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. *Functional Ecology*, *27*(2), 314–322.

Newman, C., Buesching, C. D., & Macdonald, D. W. (2003). Validating mammal monitoring methods and assessing the performance of volunteers in wildlife conservation — “Sed quis custodiet ipsos custodies ?”. *Biological Conservation*, *113*(2), 189–197.

Ng, S. L., & Leung, S. (2003). Behavioral response of Indo-Pacific humpback dolphin (*Sousa chinensis*) to vessel traffic. *Marine Environmental Research*, *56*(5), 555–567.

Nichol, L. M., Wright, B. M., O'Hara, P., & Ford, J. K. B. (2017). Risk of lethal vessel strikes to humpback and fin whales off the west coast of Vancouver Island, Canada. *Endangered Species Research*, *32*, 373–390.

NIWA National Climate Centre. (2015). *New Zealand climate summary: 2015. Annual climate summary*. Retrieved from: https://www.niwa.co.nz/climate/summaries/annual/annual-climate-summary-2015

NIWA National Climate Centre. (2016). *New Zealand climate summary: 2016. Annual climate summary*. Retrieved from: https://www.niwa.co.nz/climate/summaries/annual-climate-summary-2016

Norberg, U. M., & Rayner, J. M. V. (1987). Ecological morphology and flight in bats (mammalia; chiroptera): wing adaptations, flight performance, foraging stratergy and echolocation. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *316*(1179), 335–427.

Norgrove, K., & Jordan, C. (2006). *Economic influences on the future of Great Barrier Island*. Report to City Planning, Auckland City Council, New Zealand.

Norris, K.S., Würsig, B., Wells, R.S., Würsig, M., Brownlee, S.M., Johnson, C. & Solow, J. (1994). *The Hawaiian spinner dolphin*. University of California Press, Berkeley and Los Angeles, California.

Notman, H., & Rendall, D. (2005). Contextual variation in chimpanzee pant hoots and its implications for referential communication. *Animal Behaviour*, *70*(1), 177–190.

Nowacek, S. M., Wells, R. S., & Solow, A. R. (2001). Short-term effects of boat traffic on bottlenose dolphins, *Turisops truncatus*, in Sarasota Bay, Florida. *Marine Mammal Science*, *17*(4), 673–688.

O'Connor, S., Campbell, R., Knowles, T., & Cortez, H. (2009). *Whale watching worldwide: Tourism numbers, expenditures and economic benefits*. A special report from the International Fund for Animal Welfare, Yarmouth MA, USA.

Oremus, M., Leqata, J., & Baker, C. S. (2015). Resumption of traditional drive hunting of dolphins in the Solomon Islands in 2013. *Royal Society Open Science*, *2*(5), 1-9.

Owen, E. C. ., Wells, R. S., & Hofmann, S. (2002). Ranging and association patterns of paired and unpaired adult male Atlantic bottlenose dolphins, *Tursiops truncatus,* in Sarasota, Florida, provide no evidence for alternative male strategies. *Canadian Journal of Zoology, 80*(12), 2072–2089.

Panova, E. M., Belikov, R. A., Agafonov, A. V., & Bel'kovich, V. M. (2012). The relationship between the behavioral activity and the underwater vocalization of the beluga whale (*Delphinapterus leucas*). *Oceanology*, *52*(1), 79–87.

Papale, E., Buffa, G., Filiciotto, F., Maccarrone, V., Mazzola, S., Ceraulo, M., … Buscaino, G. (2015). Biphonic calls as signature whistles in a free-ranging bottlenose dolphin. *Bioacoustics*, *24*(3), 223–231.

Parks, S. E., Johnson, M., Nowacek, D. P., & Tyack, P. L. (2011). Individual right whales call louder in increased environmental noise. *Biology Letter*, *7*(1), 33–35.

Parra, G. J. (2006). Resource partitioning in sympatric delphinids: Space use and habitat preferences of Australian snubfin and Indo-Pacific humpback dolphins. *Journal of Animal Ecology*, *75*(4), 862–874.

Parsons E. C. M., Bauer, A., McCafferty, D., Simmonds, M. P. & Wright, A. J. (2012). *An introduction to marine mammal biology and conservation*. Jones & Bartlett Publishing, Massachusetts, USA.

Parsons, E. C. M., & Scarpaci, C. (2016). Recent advances in whale-watching research: 2014 - 2015. *Tourism in Marine Environments*, *11*(4), 251–262.

Pattengill-Semmens, C. V., & Semmens, B. X. (1990). Conservation and management applications of the reef volunteer fish monitoring program. *Environmental Monitoring and Assessment*, *81*, 43–50.

Pelea 2015. *Facebook NZ demographics and usage statistics (infographic)*. Retrieved from: http://www.firstdigital.co.nz/blog/2015/09/16/facebook-nz-demographics-usage-statistics-2015/

Peel, D., Smith, J. N., & Childerhouse, S. (2018). Vessel strike of whales in Australia: The challenges of analysis of historical incident data. *Frontiers in Marine Science*, *5*(69), 1-14.

Perrin, W. F. (2002). Common dolphins *Delphinus delphis*, *D. capensis*, and *D. tropicalis*. In W. F. Perrin, B. Würsig & J. C. M. Thewissen (Eds.), *Encyclopedia of* *marine mammals* (pp. 245-248). San Diego, USA: Academic Press.

Peters, C. (2018). *Context-specific signal plasticity of two bottlenose dolphin ecotypes (Tursiops truncatus) in Far North Waters, New Zealand* (Doctoral dissertation). Massey University, Auckland, New Zealand.

Peters, C. H., & Stockin, K. A. (2016). *Responses of bottlenose dolphin (Tursiops truncatus) to vessel activity in Northland , New Zealand*. Progress report to Department of Conservation, Northland, New Zealand.

Phillips, M. K. (1987). Behavior and habitat use of grizzly bears in Northeastern Alaska. *Bears: Their Biology and Management*, *7*, 159–167.

Pierpoint, C., Allan, L., Arnold, H., Evans, P. G. H., Perry, S., Wilberforce, L., & Baxter, J. (2009). Monitoring important coastal sites for bottlenose dolphin in Cardigan Bay, UK. *Journal of the Marine Biological Association of the United Kingdom*, *89*(5), 1033-1043.

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

Pivari, D., & Rosso, S. (2005). Whistles of small groups of *Sotalia fluviatilis* during foraging behavior in southeastern Brazil. *The Journal of the Acoustical Society of America*, *118*(4), 2725–2731.

Pocock, M. J. O., Roy, H. E., Fox, R., Ellis, W. N., & Botham, M. (2017). Citizen science and invasive alien species: Predicting the detection of the oak processionary moth *Thaumetopoea processionea* by moth recorders. *Biological Conservation*, *208*, 146–154.

Powell, J. R., & Wells, R. S. (2011). Recreational fishing depredation and associated behaviors involving common bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *Marine Mammal Science*, *27*(1), 111–129.

Powell, L. L., Cordeiro, N. J., & Stratford, J. A. (2015). Ecology and conservation of avian insectivores of the rainforest understory: A pantropical perspective. *Biological Conservation*, *188*, 1–10.

Prather, J. F., Peters, S., Nowicki, S., & Mooney, R. (2010). Persistent representation of juvenile experience in the adult songbird brain. *Journal of Neuroscience*, *30*(31), 10586–10598.

Putland, R. L., Merchant, N. D., Farcas, A., & Radford, C. A. (2017). Vessel noise cuts down communication space for vocalizing fish and marine mammals. *Global Change Biology*, *24*(4), 1708–1721.

Quadling, D. P. (2006). *Assessment of seedling recruitment under Manuka (Leptospermum scoparium) and Kanuka (Kunzea ericoides) plantings at Shakespear and Wenderholm Regional Parks* (Master's thesis). Auckland University of Technology, Auckland, New Zealand.

Quick, N. J., & Janik, V. M. (2008). Whistle rates of wild bottlenose dolphins (*Tursiops truncatus*): Influences of group size and behavior. *Journal of Comparative Psychology*, *122*(3), 305–311.

Quintana-Rizzo, E., Mann, D. A., & Wells, R. S. (2006). Estimated communication range of social sounds used by bottlenose dolphins (*Tursiops truncatus*). *Journal of the Acoustical Society of America*, *120*(3), 1671–1683.

R Core Team (2016). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Ralston, J. V., & Herman, L. M. (1995). Perception and generalization of frequency contours by a bottlenose dolphin (*Tursiops truncatus*). *Journal of Comparative Psychology*, *109*(3), 268–277.

Reeves, R. R., & Leatherwood, S. (1994). *Dolphins, Porpoises, and Whales. 1994-1998 Action Plan for the Conservation of Cetaceans*. IUCN, Gland, Switzerland. 92pp.

Reeves, R. R., Smith, B. D., Crespo, E. A., & Sciara, G. N. (2003). *Dolphins, whales, and porpoises: 2003–2010 conservation action plan for the world's cetaceans*. IUCN, Gland, Switzerland.

Rendall, D., Cheney, D. L., & Seyfarth, R. M. (2000). Proximate factors mediating "contact" calls in adult female baboons (*Papio cynocephalus ursinus*) and their infants. *Journal of Comparative Psychology*, *114*(1), 36–46. .

Rendell, L. E., & Gordon, J. C. D. (1999). Vocal response of long-finned pilot whales (*Globicephala Melas*) to military sonar in the Ligurian Sea. *Marine Mammal Science*, *15*(1), 198–204.

Rendell, L. E., Matthews, J. N., Gill, A., Gordon, J. C. D., & Macdonald, D. W. (1999). Quantitative analysis of tonal calls from five odontocele species, examining interspecific and intraspecific variation. *Journal of Zoology*, *249*, 403–410.

Rice, D. W. (1998). Marine mammals of the world, systematics and distribution. *Society for Marine Mammalogy Special Publication*, *4*, 1-231.

Ridgeway, G. (2017). *GBM: Generalized boosted regression models*. R package version 2.1.3. https://CRAN.R-project.org/package=gbm

Ries, L., & Oberhauser, K. (2015). A citizen army for science: Quantifying the contributions of citizen scientists to our understanding of monarch butterfly biology. *BioScience*, *65*(4), 419–430.

Robinson, K. P., Sim, T. M. C., Culloch, R. M., Bean, T. S., Cordoba Aguilar, I., Eisfeld, S. M., … Pierce, G. J. (2017). Female reproductive success and calf survival in a North Sea coastal bottlenose dolphin (*Tursiops truncatus*) population. *Plos One*, *12*(9), e0185000. https://doi.org/10.1371/journal.pone.0185000

Roman, J., & McCarthy, J. J. (2010). The whale pump: Marine mammals enhance primary productivity in a coastal basin. *PLoS ONE*, *5*(10), e13255. https://doi.org/10.1371/journal.pone.0013255

Rosenzweig, M. L. (1974). On the evolution of habitat selection. In *Proceedings of the First International Congress of Ecology*. Centre for Agricultural Publishing and Documentation, The Hague. 401–404.

Rossi, A., Scordamaglia, E., Bellingeri, M., Gnone, G., Nuti, S., Salvioli, F., … Santangelo, G. (2017). Demography of the bottlenose dolphin *Tursiops truncatus* (Mammalia: Delphinidae) in the Eastern Ligurian Sea (NW Mediterranean): Quantification of female reproductive parameters. *European Zoological Journal*, *84*(1), 294–302.

Rubow, J., Cherry, M. I., & Sharpe, L. L. (2017a). Calling for help: dwarf mongoose recruitment calls inform receivers about context and elicit disparate responses. *Animal Behaviour, 127*, 7–14.

Rubow, J., Cherry, M. I., & Sharpe, L. L. (2017b). Dwarf mongooses use sex and identity cues in isolation calls to discriminate between callers. *Animal Behaviour, 127*, 23–31.

Sánchez-Clavijo, L. M., Hearns, J., & Quintana-Ascencio, P. F. (2016). Modeling the effect of habitat selection mechanisms on population responses to landscape structure. *Ecological Modelling*, *328*, 99–107.

Sanganyado, E., Rajput, I. R., & Liu, W. (2018). Bioaccumulation of organic pollutants in Indo-Pacific humpback dolphin: A review on current knowledge and future prospects. *Environmental Pollution*, *237*, 111–125.

Sargeant, B. L., & Mann, J. (2009). Developmental evidence for foraging traditions in wild bottlenose dolphins. *Animal Behaviour*, *78*(3), 715–721.

Sargeant, B. L., Mann, J., Berggren, P., & Krützen, M. (2005). Specialization and development of beach hunting, a rare foraging behavior, by wild bottlenose dolphins (*Tursiops* sp.). *Canadian Journal of Zoology*, *83*(11), 1400–1410.

Sayigh, L. S., Tyack, P. L., Wells, R. S., & Scott, M. D. (1990). Signature Whistles of free-ranging bottlenose dolphins *Tursiops truncatus*: Stability and mother-offspring comparisons. *Behavioral Ecology and Sociobiology*, 26(4), 247-260.

Scarpaci, C., Bigger, S. W., Corkeron, P. J., & Nugegoda, D. (2000). Bottlenose dolphins (*Tursiops truncatus*) increase whistling in the presence of “ swim-with-dolphin ” tour operations. *Journal of Cetacean Research*, *2*(3), 183–185.

Schaffar, A., Madon, B., Garrigue, C., & Constantine, R. (2013). Behavioural effects of whale-watching activities on an endangered population of humpback whales wintering in New Caledonia. *Endangered Species Research*, *19*(3), 245–254.

Scheifele, P. M., Andrew, S., Cooper, R. A., Darre, M., Musiek, F. E., & Max, L. (2005). Indication of a Lombard vocal response in the St. Lawrence River beluga. *The Journal of the Acoustical Society of America*, *117*(3), 1486–1492.

Schmidt, A. K. D., & Balakrishnan, R. (2014). Ecology of acoustic signalling and the problem of masking interference in insects. *Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology*, *201*(1), 133–142.

Schneider, K. (1999). *Behaviour and ecology of bottlenose dolphins in Doubtful Sound, Fiordland, New Zealand* (Doctoral dissertation). University of Otago, Dunedin, New Zealand.

Scholik, A. R., & Yan, H. Y. (2002). Effects of boat engine noise on the auditory sensitivity of the fathead minnow, *Pimephales promelas*. *Environmental Biology of*

*Fishes, 63*(2), 203-209.

Schooley, R. L. (1994). Annual Variation in Habitat Selection: Patterns Concealed by Pooled Data. *The Journal of Wildlife Management*, *58*(2), 367–374.

Schwabl, H., Dowling, J., Baldassarre, D. T., Gahr, M., Lindsay, W. R., & Webster, M. S. (2015). Variation in song system anatomy and androgen levels does not correspond to song characteristics in a tropical songbird. *Animal Behaviour*, *104*, 39–50.

Scott, M. D., & Chivers, S. J. (1990). Distribution and Herd Structure of Bottlenose Dolphins in the Eastern Tropical Pacific Ocean. In S. Leatherwood & R. R. Reeves (Eds.), *The Bottlenose Dolphin* (pp. 387-402). Academic Press, San Diego, USA.

Scott, M. D., Wells, R. S., & Irvine, A. B. (1990). A long-term study of bottlenose dolphins on the west coast of Florida. In *The Bottlenose Dolphin* (pp. 235–244). Acedemic Press, Inc, San Diego, USA.

Seibold, S., Brandl, R., Buse, J., Hothorn, T., Schmidl, J., Thorn, S., & Müller, J. (2015). Association of extinction risk of saproxylic beetles with ecological degradation of forests in Europe. *Conservation Biology*, *29*(2), 382–390.

Sequeira, A. M. M., Roetman, P. E. J., Daniels, C. B., Baker, A. K., & Bradshaw, C. J. A. (2014). Distribution models for koalas in South Australia using citizen science-collected data. *Ecology and Evolution*, *4*(11), 2103–2114.

Sergio, F., Caro, T., Brown, D., Clucas, B., Hunter, J., Ketchum, J., … Hiraldo, F. (2008). Top predators as conservation tools: Ecological rationale, assumptions, and efficacy. *Annual Review of Ecology, Evolution, and Systematics*, *39*, 1–19.

Seyfarth, R. M., & Cheney, D. L. (2003). Signalers and receivers in animal communication. *Annual review of psychology, 54*, 145-173.

Shamir, L., Yerby, C., Simpson, R., von Benda-Beckmann, A. M., Tyack, P. L., Samarra, F., … Wallin, J. (2014). Classification of large acoustic datasets using machine learning and crowdsourcing: Application to whale calls. *The Journal of the Acoustical Society of America*, *135*(2), 953–962.

Shane, S. H. (1990a). Behavior and Ecology of the Bottlenose Dolphin at Sanibel Island, Florida. In S. Leatherwood & R. R. Reeves (Eds.), *The Bottlenose Dolphin* (pp. 245-265), Academic Press, San Diego, USA.

Shane, S. H. (1990b). Comparisons of bottlenose dolphin behavior in Texas and Florida, with a critique of methods for studying dolphin behavior. In S. Leatherwood and R. R. Reeves (Eds.), *The Bottlenose Dolphin* (pp. 541-558), Academic Press, San Diego, USA.

Shane, S. H., Wells, R. S., & Würsig, B. (1986). Ecology, behavior and social organization of the bottlenose dolphin: A review. *Marine Mammal Science*, *2*(1), 34–63. https://doi.org/10.1111/j.1748-7692.1986.tb00026.x

Shannon, G., McKenna, M. F., Angeloni, L. M., Crooks, K. R., Fristrup, K. M., Brown, E., … Wittemyer, G. (2016). A synthesis of two decades of research documenting the effects of noise on wildlife. *Biological Reviews*, *91*(4), 982–1005.

Shannon, C.E. & Weaver, W. (1949) *The mathematical theory of communication*. Illinois University Press, Urbana.

Shirihai, H. (2006). *Whales, dolphins, and seals; a field guide to the marine mammals of the world.* Bloomsbury, London.

Siciliano, S., Corrêa, L. G., & Di Beneditto, A. P. M. (2017). Real-time record of entanglement of a guiana dolphin (Sotalia guianensis) in recreational fishing gear. *Aquatic Mammals*, *43*(3), 320–323.

Silvertown, J. (2009). A new dawn for citizen science. *Trends in Ecology & Evolution*, *24*(9), 467–471.

Sinclair, C. (2016). *Comparison of Group Size , Abundance Estimates and Movement Patterns of Common Bottlenose Dolphins (Tursiops Truncatus) in Mississippi Sound , Mississippi* (Master's thesis). Central Michigan University, Michigan.

Sini, M. I., Canning, S. J., Stockin, K. A., & Pierce, G. J. (2005). Bottlenose dolphins around Aberdeen harbour, north-east Scotland: A short study of habitat utilization and the potential effects of boat traffic. *Journal of the Marine Biological Association of the United Kingdom*, *85*, 1547–1554.

Slater, P. J. B. (1983). The study of communication. In T. R. Halliday, & P. J. B. Slater (Eds.), *Animal behaviour* (pp. 9-42). Blackwell Scientific Press, Oxford, United Kingdom.

Smith, H., Frere, C., Kobryn, H., & Bejder, L. (2016). Dolphin sociality, distribution and calving as important behavioural patterns informing management. *Animal*

*Conservation, 19*(5), 462–471.

Smolker, R. A., Mann, J., & Smuts, B. (1993). Use of signature whistles during seperations and reunions by wild bottlenose dolphin mothers and infants. *Behavioral Ecology and Sociobiology, 33*(6), 393–402.

Smolker, R. A., Richards, A. F., Connor, R. C., & John, W. (1992). Sex differences in patterns of association among Indian Ocean bottlenose dolphins. *Behaviour*, *123*(1), 38–69.

Smolker, R. A., Richards, A. F., Connor, R. C., Mann, J., & Berggren, P. (1997). Sponge carrying by dolphins (Delphinidae, *Tursiops* sp.): A foraging specialization involving tool use? *Ethology*, *103*, 454–465.

Snell, P. (2000). *Acoustic behaviour of bottlenose dolphins, Tursiops truncatus, in response to dolphin tourism in the Bay of Islands, New Zealand* (Master's thesis). University of Auckland, New Zealand.

Sonter, L. J., Watson, K. B., Wood, S. A., & Ricketts, T. H. (2016). Spatial and temporal dynamics and value of nature-based recreation, estimated via social media. *PLoS ONE, 11*(9), e0162372. https://doi.org/10.1371/journal.pone.0162372

Sprogis, K. R., Christiansen, F., Wandres, M., & Bejder, L. (2018). El Niño Southern Oscillation influences the abundance and movements of a marine top predator in coastal waters. *Global Change Biology, 24,* 1085–1096.

Sprogis, K. R., Pollock, K. H., Raudino, H. C., Allen, S. J., Kopps, A. M., Manlik, O., … Bejder, L. (2016). Sex-specific patterns in abundance, temporary emigration and survival of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in coastal and estuarine waters. *Frontiers in Marine Science, 3*(12), 1–15.

Spurr, E. B. (2012). New Zealand Garden Bird Survey – analysis of the first four years. *New Zealand Journal of Ecology, 36*(3), 1-13.

Stafford, R., Hart, A. G., Collins, L., Kirkhope, C. L., Williams, R. L., Rees, S. G., … Goodenough, A. E. (2010). Eu-social science: The role of internet social networks in the collection of bee

Statistics New Zealand (2013). *2013 census map – quickstats about a place*. Retrieved from:
http://archive.stats.govt.nz/StatsMaps/Home/People%20and%20households/2013-

census-quickstats-about-a-place-map.aspxbiodiversity data. *PLoS ONE*, *5*(12), 1–7.

Steiner, W. W. (1981). Species-specific differences in pure tonal whistle vocalizations of five western north Atlantic dolphin species. *Behavioral Ecology and Sociobiology*, *9*, 241–246.

Stelle, L. L., & King, M. (2015). Ocean Earth. In *Ocean solutions Earth solutions* (pp. 151–170). Esri Press, California.

Stensland, E., & Berggren, P. (2007). Behavioural changes in female Indo-Pacific bottlenose dolphins in response to boat-based tourism. *Marine Ecology Progress Series*, *332*, 225–234.

Stevenson, D. J., Jensen, J. B., Schlimm, E. A., & Moore, M. J. (2015). The distribution, habitat use, activity, and status of the spotted turtle (*Clemmys guttata*) in Georgia. *Conservation Biology*, *14*(2), 132–142.

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

Stockin, K. A., Lusseau, D., Binedell, V., Wiseman, N., & Orams, M. B. (2008). 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. A., Pierce, G. J., Binedell, V., Wiseman, N., & Orams, M. B. (2008). 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. A., Weir, C. R., & Pierce, G. J. (2006). Examining the importance of Aberdeenshire (UK) coastal waters for North Sea bottlenose dolphins (*Tursiops truncatus*). *Journal of the Marine Biological Association of the United Kingdom*, *86*, 201–207.

Stuart-Smith, R. D., Edgar, G. J., Barrett, N. S., Bates, A. E., Ker, S. C., Bax, N. J., … Russell, T. (2017). Assessing national biodiversity trends for rocky and coral reefs through the integration of citizen science and scientific monitoring programs. *BioScience*, *67*(2), 134–146.

Subba, S. A., Shrestha, A. K., Thapa, K., Malla, S., Thapa, G. J., Shrestha, S., … Ottvall, R. (2017). Distribution of grey wolves *Canis lupus lupus* in the Nepalese Himalaya:

Implications for conservation management. *Oryx*, *51*(3), 403–406.

Sullivan, B. L., Aycrigg, J. L., Barry, J. H., Bonney, R., Bruns, N., Cooper, C. B., … Wong, W. K. (2014). The eBird enterprise : An integrated approach to development and application of citizen science. *Biological Conservation*, *169*, 31–40.

Templeton, C. N., Zollinger, S. A., & Brumm, H. (2016). Traffic noise drowns out great tit alarm calls. *Current Biology*, *26*(22), R1173–R1174.

Tenerelli, P., Demšar, U., & Luque, S. (2016). Crowdsourcing indicators for cultural ecosystem services: A geographically weighted approach for mountain landscapes. *Ecological Indicators*, *64*, 237–248.

Tewksbury, J. J., Anderson, J. G. T., Bakker, J. D., Billo, T. J., Dunwiddie, P. W., Groom, M. J., … Wheeler, T. A. (2014). Natural history's place in science and society. *BioScience*, *64*(4), 300–310.

Tezanos-Pinto, G. (2009). *Population structure, abundance and reproductive parameters of bottlenose dolphins (Tursiops truncatus) in the Bay of Islands (Northland, New Zealand)*(Doctoral dissertation). The Universtiy of Auckland, New Zealand.

Tezanos-Pinto, G. (2011). *Photo-identification and re-sighting rates of bottlenose dolphins (Tursiops truncatus) in the Hauraki Gulf and abundance along the north-eastern coast of the North Island*. Department of Conservation Internal Report, Bay of Islands, New Zealand. 26 pp.

Tezanos-Pinto, G., Baker, C. S., Russell, K., Martien, K., Baird, R. W., Hutt, A., … Garrigue, C. (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., Constantine, R., Brooks, L., Jackson, J. A., Mourão, F., Wells, S., & Scott Baker, C. (2013). Decline in local abundance of bottlenose dolphins (*Tursiops truncatus*) in the Bay of Islands, New Zealand. *Marine Mammal Science*, *29*(4), 1–21.

Tezanos-Pinto, G., Constantine, R., Mourão, 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.

Thayer, V. G., Read, A. J., Friedlaender, A. S., Colby, D. R., Hohn, A. A., McLellan, W.

A., … Rittmaster, K. A. (2003). Reproductive seasonality of western Atlantic bottlenose dolphins off North Carolina, USA. *Marine Mammal Science*, *19*(4), 617–629.

Thorne, L. H., Johnston, D. W., Urban, D. L., Tyne, J., Bejder, L., Baird, R. W., … Chapla Hill, M. (2012). Predictive modeling of spinner dolphin (*Stenella longirostris*) resting habitat in the main Hawaiian Islands. *PLoS ONE*, *7*(8), e43167. https://doi.org/10.1371/journal.pone.0043167

Tieskens, K. F., Schulp, C. J. E., Levers, C., Lieskovský, J., Kuemmerle, T., Plieninger, T., & Verburg, P. H. (2017). Characterizing European cultural landscapes: Accounting for structure, management intensity and value of agricultural and forest landscapes. *Land Use Policy*, *62*, 29–39.

Tolley, A. K. A., Read, A. J., Wells, R. S., Urian, K. W., Scott, M. D., Irvine, A. B., & Hohn, A. A. (1995). American Society of Mammalogists Sexual Dimorphism in Wild Bottlenose Dolphins (*Tursiops truncatus*) from Sarasota. *Journal of Mammalogy*, *76*(4), 1190–1198.

Tonachella, N., Nastasi, A., Kaufman, G. D., Maldini, D., & Rankin, R. W. (2012). Predicting trends in humpback whale (*Megaptera novaeangliae*) abundance using citizen science. *Pacific Conservation Biology*, *18*, 297–309.

Torres, L. G., & Read, A. J. (2009). Where to catch a fish? The influence of foraging tactics on the ecology of bottlenose dolphins (*Tursiops truncatus*) in Florida Bay, Florida. *Marine Mammal Science*, *25*(4), 797–815.

Toth, J. L., Hohn, A. A., Able, K. W., & Gorgone, A. M. (2011). Patterns of seasonal occurrence, distribution, and site fidelity of coastal bottlenose dolphins (*Tursiops truncatus*) in southern New Jersey, U.S.A. *Marine Mammal Science*, *27*(1), 94–110.

Tregidgo, D. J., West, S. E., & Ashmore, M. R. (2013). Can citizen science produce good science? Testing the OPAL Air Survey methodology, using lichens as indicators of nitrogenous pollution. *Environmental Pollution*, *182*, 448–451.

Tyack, P. L. (2003). Dolphins communicate about individual-specific social relationships. In F. B. M. De Waal & P. L. Tyack (Eds.), *Animal Social Complexity: Intelligence, Culture, and Individualized Societies* (pp. 342–361). Harvard University Press, London.

Tyack, P. L., & Janik, V. M. (2013). Effects of noise on acoustic signal production in marine mammals. In *Animal communication and noise* (pp. 251-271). Springer, Berlin, Heidelberg.

Tyack P. and Sayigh L. (1997) Vocal learning in cetaceans. In: C. Snowdon and M. Hausburger (Eds.), *Social influences on vocal development* (pp. 208–233). Cambridge University Press, Cambridge, United Kingdom.

Tyne, J. A., Johnston, D. W., Christiansen, F., & Bejder, L. (2017). Temporally and spatially partitioned behaviours of spinner dolphins: implications for resilience to human disturbance. *Royal Society Open Science, 4,* 160626. https://doi.org/10.1098/rsos.160626

Van der Wal, R., Anderson, H., Robinson, A., Sharma, N., Mellish, C., Roberts, S., … Siddharthan, A. (2015). Mapping species distributions: A comparison of skilled naturalist and lay citizen science recording. *Ambio, 44*(4), 584–600.

Van Opzeeland, I. C., Corkeron, P. J., Leyssen, T., Similä, T., & Van Parijs, S. M. (2005). Acoustic behaviour of Norwegian killer whales, *Orcinus orca*, during carousel and seiner foraging on spring-spawning herring. *Aquatic Mammals*, *31*, 110–119.

Van Parijs, S. M., & Corkeron, P, J. (2001). Boat traffic affects the acoustic behaviour of Pacific humpback dolphins, Sousa chinensis. *Journal of the Marine Biological Association of the UK, 81*(3), 533–538.

Vauclair, J. (1996). *Animal cognition: An introduction to modern comparative psychology*. Harvard University Press, Cambridge, United Kingdom.

Veneruso, G., & Evans, P. G. H. (2012). *Bottlenose dolphin and harbour porpoise monitoring in Cardigan Bay and Pen Llyn a'r Sarnau Special Areas of Conservation.* CCW Monitoring Report 95. 65-165. Sea Watch Foundation, United Kingdom.

Vermeulen, E., Balbiano, A., Belenguer, F., Colombil, D., Failla, M., Intrieri, E., & Bräger, S. (2016). Site-fidelity and movement patterns of bottlenose dolphins (*Tursiops truncatus*) in central Argentina: essential information for effective conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems, 27,* 282–292.

Vermeulen, E., Holsbeek, L., & Das, K. (2015). Diurnal and seasonal variation in the behaviour of bottlenose dolphins (*Tursiops truncatus*) in Bahía San Antonio, Patagonia, Argentina. *Aquatic Mammals*, *41*(3), 272–283.

Versluis, M., Schmitz, B., von der Heydt, A., & Lohse, D. (2000). How snapping shrimp snap: Through cavitating bubbles. *Science*, *289*, 2114-2117.

Verzijden, M. N., Van Heusden, J., Bouton, N., Witte, F., Ten Cate, C., & Slabbekoorn, H. (2010). Sounds of male Lake Victoria cichlids vary within and between species and affect female mate preferences. *Behavioral Ecology*, *21*(3), 548–555.

Viddi, F. A., Harcourt, R. G., Hucke-Gaete, R., & Field, I. C. (2011). Fine-scale movement patterns of the sympatric Chilean and Peale's dolphins in the northern Patagonian fjords, Chile. *Marine Ecology Progress Series*, *436*, 245–256.

Viddi, F. A., & Lescrauwaet, A.-K. (2005). Insights on habitat selection and behavioural patterns of Peale's dolphins (*Lagenorhynchus australis*) in the Strait of Magellan, Southern Chile. *Aquatic Mammals*, *31*(2), 176–183.

Vikingsson, G. A., Pike, D. G., Valdimarsson, H., Schleimer, A., Gunnlaugsson, T., Silva, T., … Hammond, P. S. (2015). Distribution, abundance, and feeding ecology of baleen whales in Icelandic waters: have recent environmental changes had an effect? *Frontiers in Ecology and Evolution*, *3*(6), 1–18.

Visser, I. N. (1999). Benthic foarging on stingrays by killer whals (*Orcinus orca*) in New Zealand waters. *Marine Mammal Science*, *15*(1), 220–227.

Visser, I. N., Zaeschmar, J. R., Halliday, J., Abraham, A., Ball, P., Bradley, R., … Pace, D. S. (2010). First record of predation on false killer whales (*Pseudorca crassidens*) by killer whales (*Orcinus orca*). *Aquatic Mammals*, *36*(2), 195–204.

Wang, D., Würsig, B., & Evans, W. (1995). Whistles of bottlenose dolphins: comparisons among populations. *Aquatic Mammals*, *21*(1), 65–77.

Wang, J. Y., Riehl, K. N., Klein, M. N., Javdan, S., Hoffman, J. M., Dungan, S. Z., … Araújo-Wang, C. (2016). Biology and conservation of the Taiwanese humpback dolphin, *Sousa chinensis taiwanensis*. *Advances in Marine Biology*, *73*, 91–117.

Ward, R., Parnum, I., Erbe, C., & Salgado Kent, C. P. (2016). Whistle characteristics of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in the Fremantle Inner Harbour, Western Australia. *Acoustics Australia*, *44*, 159–169.

Weilgart, L. S., & Whitehead, H. (1990). Vocalizations of the North Atlantic pilot whale (*Globicephala melas*) as related to behavioral contexts. *Behavioral Ecology and*

*Sociobiology*, *26*(6), 399–402.

Weilgart, L. S., & Whitehead, H. (1993). Coda communication by sperm (*Physeter macrocephalus*) off the Galápagos Islands. *Canadian Journal of Zoology*, *71*, 744–752.

Wells, R. S. (1991). The role of long-term study in understanding the social structure of a bottlenose dolphin community. In K. Pryor and K. S. Norris (Eds.), *Dolphin societies: discoveries and puzzles* (pp. 199-225). University of California Press, Oxford, California, USA.

Wells, R. S. (2003). Dolphin social complexity: lessons from long-term study and life history. In: F. B. M. de Waal & P. L. Tyack (Eds.), *Animal Social Complexity: Intelligence, Culture and Individualized Societies* (pp. 31-56). Harvard University Press, Massachusetts, USA.

Wells, R. S. (2014). Social structure and life history of bottlenose dolphins near Sarasota Bay, Florida: Insights from four decades and five generations. In J. Yamagiwa and L. Karczmarski (Eds.), P*rimates and cetaceans: Field research and conservation of complex mammalian societies* (pp. 149–172). Springer, Tokyo, Japan.

Wells R. S., & Scott M. D. (2009). Common bottlenose dolphins (Tursiops truncatus). In: Perrin W. F., Würsig B., Thewissen J. G. M. (Eds.), *Encyclopedia of marine mammals* (pp. 593–599). San Diego, CA: Elsevier, Inc.

Wells, R. S., & Scott, M. D. (2017). Bottlenose dolphin, Tursiops truncatus, common bottlenose dolphin. In B. Würsig, J. G. M. Thewissen, & K. M. Kovacs (Eds.), *Encyclopedia of Marine Mammals* (pp. 118–125). Academic Press, London.

Wells, R. S., Scott, M. D., & Irvine, A. B. (1987). The social structure of free-ranging bottlenose dolphins. In *Current Mammalogy* (pp. 247–305). Plenum Press, New York and London.

Weng, J. S., Lee, M. A., Liu, K. M., Hsu, M. S., Hung, M. K., & Wu, L. J. (2015). Feeding ecology of juvenile yellowfin tuna from waters southwest of Taiwan inferred from stomach contents and stable isotope analysis. *Marine and Coastal Fisheries*, *7*(1), 537–548.

Wharton, S. (2015). *Investigating the Bottlenose Dolphins in the Swan Canning Riverpark using two research methods: A comparison between citizen science and* *professional science* (Honour's thesis). Murdoch University, Western Australia.

Whitehead, H. (2001). Analysis of animal movement using opportunistic individual identifications: application to sperm whales. *Ecological Society of America*, *82*(5), 1417–1432.

Whitehead, H., & Mann, J. (2000). Female reproductive stratergies of cetaceans: life histories and calf care. In *Cetacean societies* (pp. 219–246). University of Chicago Press, Chicago.

Wieland, M., Jones, A., & Renn, S. C. P. (2010). Changing durations of southern resident killer whale (Orcinus orca) discrete calls between two periods spanning 28 years. *Marine Mammal Science*, *26*(1), 195–201.

Wiggins, A., & Crowston, K. (2011). From conservation to crowdsourcing: A typology of citizen science. In *Proceedings of the Fourty-fourth Hawai'I International Conference on System Science* (pp. 1–10). Koloa, HI.

Wiggins, A., Newman, G. J., Stevenson, R. D., & Crowston, K. (2011). Mechanisms for data quality and validation in citizen science. In *e-Science Workshops, 2011 IEEE Seventh International Conference on* (pp. 14-19). Stockholm, SE.

Wiley, R. H. (2006). Signal Detection and Animal Communication. *Advances in the Study of Behavior*, *36*, 217–247.

Williams, J. A., Dawson, S. M., & Slooten, E. (1993). The abundance and distribution of bottlenosed dolphins (*Tursiops truncatus*) in Doubtful Sound, New Zealand. *Canadian Journal of Zoology*, *71*(10), 2080–2088.

Williams, T. M., Friedl, W. A., Fong, M. L., Yamada, R. M., Sedivy, P., & Haun, J. E. (1992). Travel at low energetic cost by swimming and wave-riding bottlenose dolphins. *Nature*, *355*(6363), 821–823.

Wilson, B., Thompson, P., & Hammond, P. S. (1997). Habitat use by bottlenose dolphins: seasonal distribution and stratified movement patterns in the Moray Firth, Scotland. *Journal of Applied Ecology*, *34*(6), 1365–1374.

Wilson, D. R. B. (1995). *The ecology of bottlenose dolphins in the Moray Firth, Scotland: A population at the northern extreme of the species' range* (Doctoral dissertation). University of Aberdeen, United Kingdom.

Wisniewska, D. M., Johnson, M., Teilmann, J., Siebert, U., Galatius, A., Dietz, R., &

Madsen, P. T. (2018). High rates of vessel noise disrupt foraging in wild harbour porpoises (*Phocoena phocoena*). *Proceedings of the Royal Society B: Biological Sciences*, *285*(1872), 20172314.

Wiszniewski, J., Brown, C., & Möller, L. M. (2012). Complex patterns of male alliance formation in a dolphin social network. *Journal of Mammalogy*, *93*(1), 239–250.

Wood, S. A., Guerry, A. D., Silver, J. M., & Lacayo, M. (2013). Using social media to quantify nature-based tourism and recreation. *Scientific Reports*, *3*, 2976.

Würsig, B., & Pearson, H. C. (2015). Dolphin Societies: Structure and Function. In D. L. Herzing & C. M. Johnson (Eds.), *Dolphin Communications and Cognition: Past, Present, and Future*. (pp. 77–105). MIT Press, Cambridge, Massachusetts.

Würsig, B., Thewissen, J. G. M., & Kovacs, K. M. (Eds.). (2017). *Encyclopedia of marine mammals*. Academic Press.

Würsig, B., Wells, R. S., Norris, K. S., & Würsig, M. (1994). A spinner dolphin's day. In K. S. Norris, B.,Würsig, R. S. Wells, & M. Würsig (Eds.), *The Hawaiian spinner dolphin* (pp. 65-102). University of California Press, Berkeley, USA.

Würsig, B., & Würsig, M. (1979). Behavior and ecology of the bottlenose dolphin, *Tursiops truncatus*, in the South Atlantic. *Fishery Bulletin*, *77*(2), 399–412.

Xue, Y., Davies, I., Fink, D., & Gomes, C. P. (2016). Avicaching: A two stage game for bias reduction in citizen science. In *Proceedings of the 2016 International Conference on Autonomous Agents & Multiagent Systems* (pp. 776–785).

Yorzinski, J. L. (2014). Peafowl antipredator calls encode information about signalers. *The Journal of the Acoustical Society of America*, *135*(2), 942–952.

Yoshimura, N., & Hiura, T. (2017). Demand and supply of cultural ecosystem services: Use of geotagged photos to map the aesthetic value of landscapes in Hokkaido. *Ecosystem Services*, *24*, 68–78.

Zaeschmar, J. R. (2014). *False killer whales (Pseudorca crassidens) in New Zealand Waters* (Master's thesis). Massey University, New Zealand.

Zaeschmar, J. R., Visser, I. N., Fertl, D., Dwyer, S. L., Meissner, A. M., Halliday, J., … Stockin, K. A. (2014). Occurrence of false killer whales (*Pseudorca crassidens*) and their association with common bottlenose dolphins (*Tursiops truncatus*) off northeastern New Zealand. *Marine Mammal Science*, *30*(2), 594–608.

# Appendix 1.1

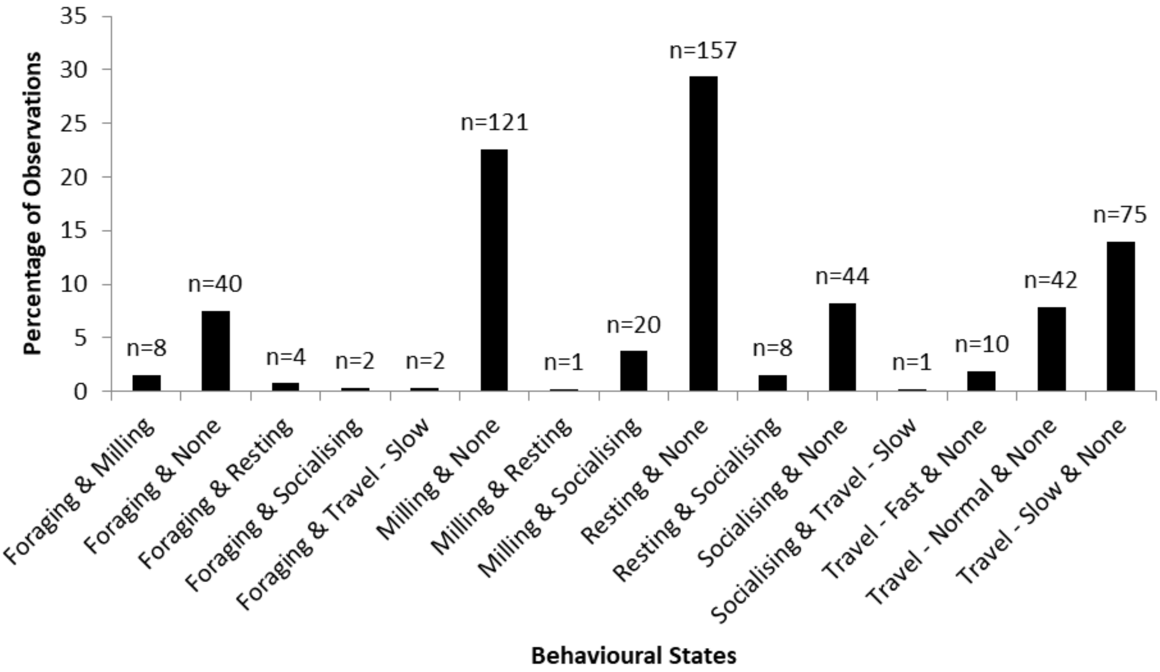
Review of citizen science websites dedicated to cetacean research.

| Main Organisation | Purpose | Location | Website Domain |
|---|---|---|---|
| Murdoch University | Marine animal monitoring | Western Australia | http://mucru.org/our-research/research-projects/citizen-science-coastal-walkabout/ |
| Whale Alert | Reduce ship strike | West Coast, USA | http://www.whalealert.org/ |
| Dolphin Research Institute | Cetacean monitoring | Victoria, Australia | http://www.dolphinresearch.org.au/research/ |
| E3C | Cetacean monitoring | South Africa | https://seasearchafrica.wordpress.com/2016/03/29/mapping-dolphin-distribution-using-citizen-science/ |
| Seawatch Foundation | Cetacean monitoring | United Kingdom | http://www.seawatchfoundation.org.uk/become-a-sea-watch-observer/ |
| River Guardians | Indo-Pacific Bottlenose dolphin monitoring | Swan River, Australia | http://www.riverguardians.com/projects/dolphin-watch/how-can-i-get-involved |
| Gotham Whale | Cetacean monitoring | New York, USA | http://www.gothamwhale.org/ |
| UK Natural History Museum | Cetacean stranding records | United Kingdom | http://www.nhm.ac.uk/take-part/citizen-science/uk-whale-and-dolphin-strandings.html |
| Match My Whale | Humpback whale | Australia | http://www.matchmywhale.org/ |

| Main Organisation | Purpose | Location | Website Domain |
|---|---|---|---|
| | monitoring | | |
| Pacific Whale Foundation | Humpback whale monitoring | Maui, USA | http://www.pacificwhale.org/content/732-humpback-whales-sighted-during-great-whale-count-2016 |
| Carib Tails | Humpback whale monitoring | Caribbean | http://www.caribtails.org/home.html |
| Alaska Whale Foundation | Cetacean monitoring | Global | http://www.whalemapp.org/ |
| Northeast Pacific Minke Whale Project | Monitoring minke whales | Salish Sea, Canada/USA | http://www.northeastpacificminke.org/citizen-science-project.html |
| Wild Whales | Cetacean and sea turtle monitoring | British Columbia, Canada | http://wildwhales.org/sightings-network/about-wild-whales/ |

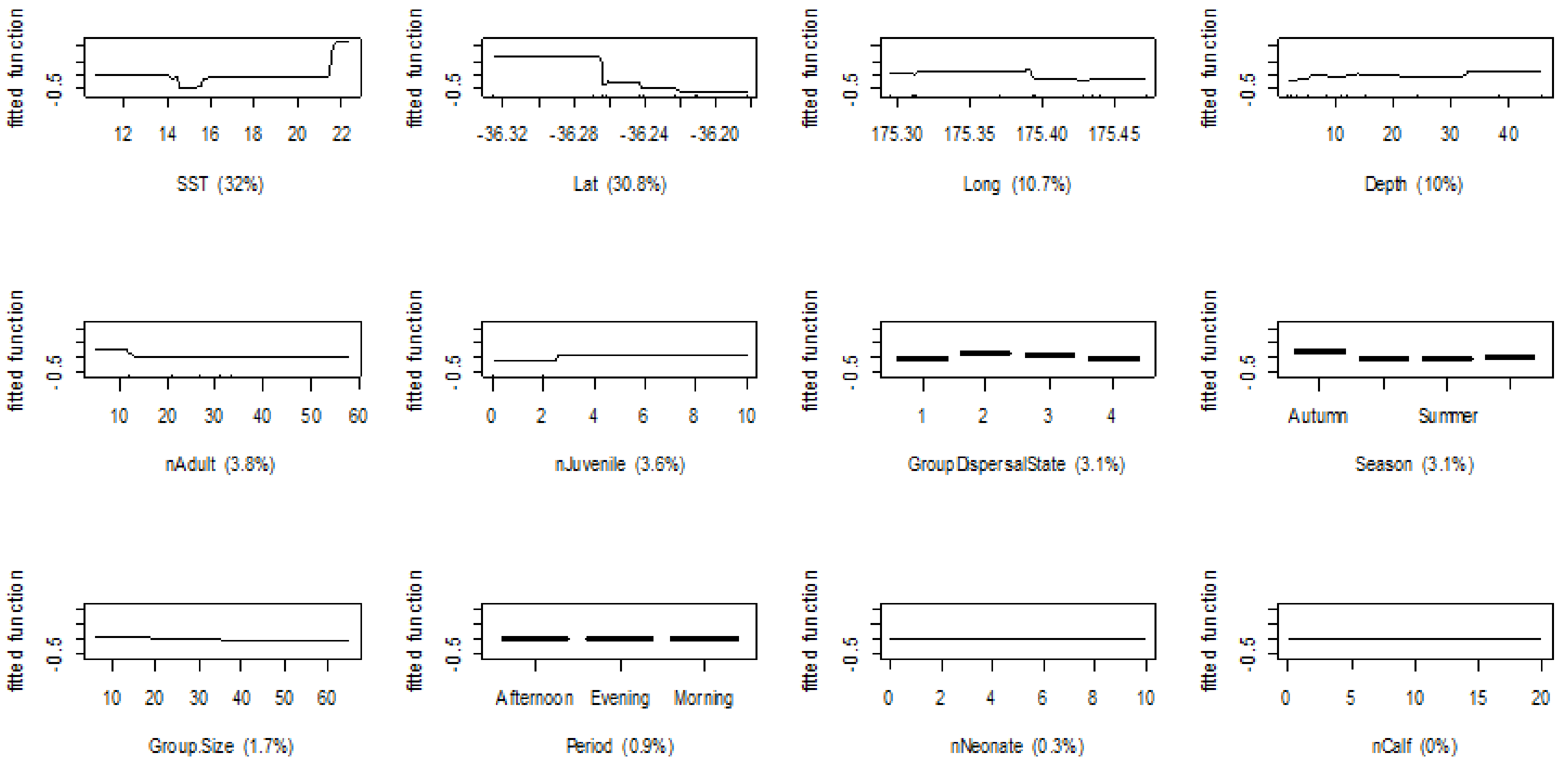
# Appendix 3.1

A complete behavioural budget for bottlenose dolphins at Great Barrier Island, New Zealand, including combined behaviours.



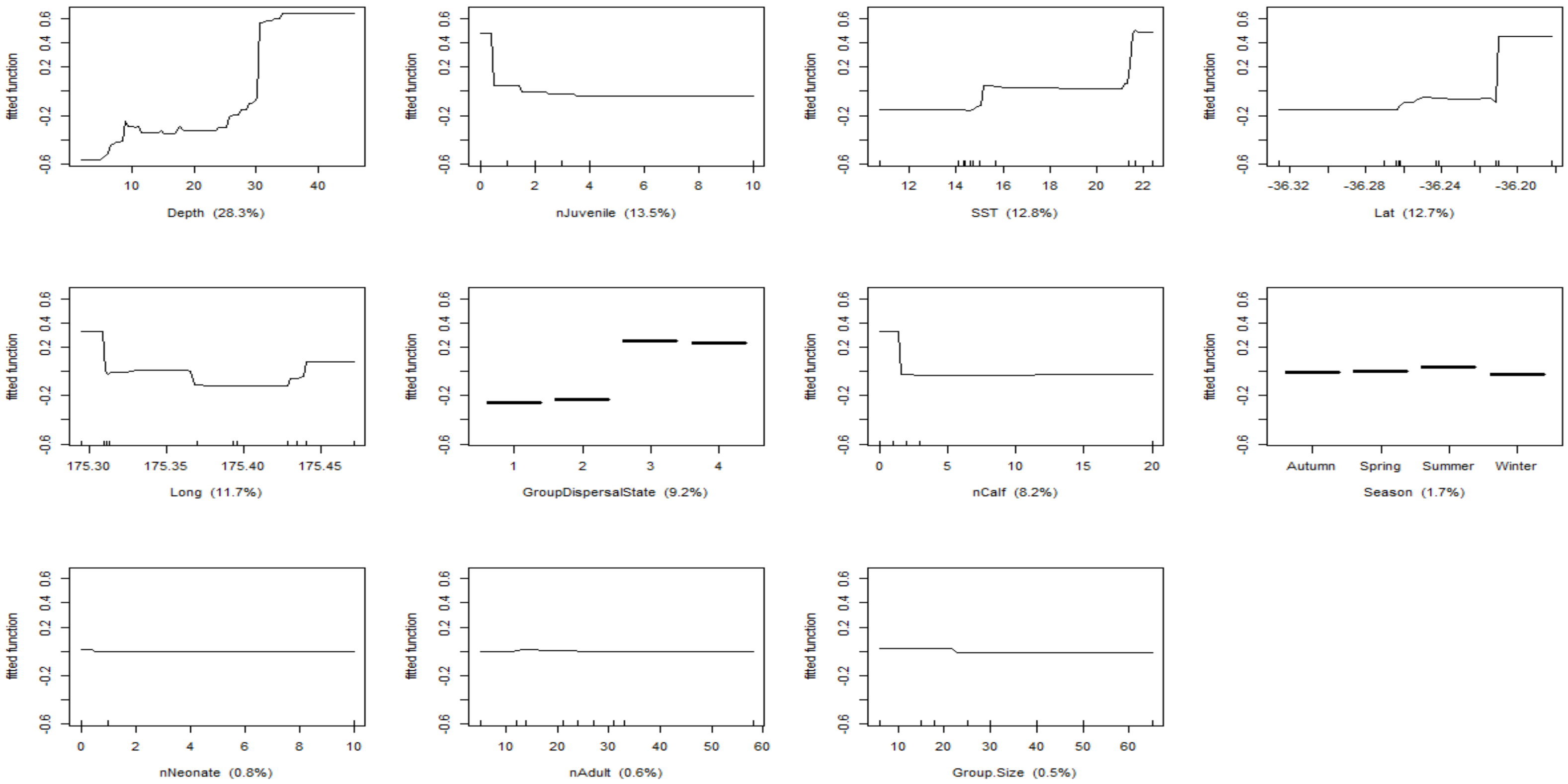
## Appendix 3.2

Partial dependence plots which visualise the effect of each variable on the model response for the behavioural state travel – slow.



# Appendix 3.3

Partial dependence plots which visualise the effect of each variable on the model response for the behavioural state travel – normal/fast.



## Appendix 4.1

Review of mean (standard deviation) whistle rates for bottlenose dolphins. The shaded rows represent median values rather than means, SE = Standard error reported instead of standard deviation

| Location | Species | Number of whistles per minute | Number of whistles per minute per dolphin | Reference |
|---|---|---|---|---|
| GBI, New Zealand | *Tursiops truncatus* | 26.84(SE=1.02) | 0.50 (0.53) | Present study |
| GBI, New Zealand | *Tursiops truncatus* | - | 0.38 | Present study |
| Bay of Islands, New Zealand | *Tursiops truncatus* | - | 0.37 | Snell 2000 |
| Bay of Islands - Boats | *Tursiops truncatus* | - | 0.21 | Snell 2000 |
| Sardinia, Italy | *Tursiops truncatus* | 2.24 (SE=0.29) | - | Lopez & Shirai 2009 |
| Sado Estuary, Portugal | *Tursiops truncatus* | - | 0.28 (0.54) | dos Santos et al. 2005 |
| Patos Lagoon estuary, Brazil | *Tursiops truncatus* | - | 0.8 (-) | Azevedo et al. 2007 |
| Sarasota Bay, USA | *Tursiops truncatus* | 1.89 (SE=0.10)-5m | - | Cook et al. 2004 |
| Isla del Coco, Costa Rica (Foraging) | *Tursiops truncatus* | - | 2.7 (0.7) | Acevedo-Guitierrez & Steindessen 2004 |
| Isla del Coco, Costa Rica (Non-foraging) | *Tursiops truncatus* | - | 0.4 (0.08) | Acevedo-Guitierrez & Steindessen 2004 |
| Wilmington, NC Intracoastal Waterway (IWC) | *Tursiops truncatus* | - | 0.13 (0.10) | Jones & Sayigh 2002 |
| Wilmington coastline (Ocean) | *Tursiops truncatus* | - | 0.2 (0.22) | Jones & Sayigh 2002 |
| South Port, NC coastline | *Tursiops truncatus* | - | 0.4 (0.10) | Jones & Sayigh 2002 |

| Location | Species | Number of whistles per minute | Number of whistles per minute per dolphin | Reference |
|---|---|---|---|---|
| Sarasota, FL inshore waters | *Tursiops truncatus* | - | 0.1 (0.07) | Jones & Sayigh 2002 |
| New South Wales, Australia | *Tursiops aduncus* | - | 0.75 (2.68) | Hawkins and Gartside 2010 |

# Appendix 4.2

Review of mean (SD) bottlenose dolphin whistle parameters. The shaded rows represent median values rather than means, - = values not reported, SE = Standard error reported instead of standard deviation.

| Location | Species | Number of Samples | Duration (ms) | Mean (kHz) | Min (kHz) | Max (kHz) | Range (kHz) | Start (kHz) | End (kHz) | Range of inflection points | Mean no. inflection points | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Great Barrier Island, New Zealand | T. truncatus | 7605 | 836 (520) | 11.01 (2.43) | 7.87 (2.37) | 14.23 (3.31) | 6.35 (3.17) | 9.63 (3.04) | 11.65 (4.2) | 0-18 | 1.41 (1.58) | Present study |
| Great Barrier Island, New Zealand | T. truncatus | 7606 | 732 | 10.93 | 7.74 | 14.18 | 6.22 | 9.44 | 11.31 | - | - | Present study |
| Bay of Islands, New Zealand | T. truncatus | 941 | 962 | - | 7.03 | 14.5 | 7.27 | 8.48 | 11.17 | - | - | Snell 2000 |
| Bay of Islands, New Zealand-Boats Present | T. truncatus | - | 892 | - | 7.73 | 15.37 | 7.33 | 9.39 | 11.47 | - | - | Snell 2000 |
| Milford Sound, New Zealand | T. truncatus | 865 | 1000 (620) | 11.35 (2.17) | 7.14 (1.72) | 15.90 (4.00) | 8.78 (3.89) | 9.58 (3.62) | 10.68 (4.41) | - | - | Boisseau 2004 |
| Doubtful Sound, New Zealand | T. truncatus | 865 | 860 (610) | 10.87 (2.33) | 7.16 (1.75) | 15.23 (3.98) | 8.07 (3.80) | 9.64 (3.80) | 10.38 (4.22) | - | - | Boisseau 2004 |
| Patos Lagoon estuary, Brazil | T. truncatus | 982 | 553.3 (393.9) | 8.7 (2.15) | 5.96 (2.15) | 12.21 (3.2) | 6.25 (3.34) | - | - | 0-14 | - | Azevedo et al. 2007 |
| Gandoca-Manzanillo, Costa Rica | T. truncatus | 77 | 890 (690) | - | 5.68 (2.24) | 17.61 (4.93) | - | 8.43 (3.66) | 13.15 (5.57) | 0-20 | 2.64 (3.41) | May-Collado & Wartzok 2008 |
| Bocas del Toro, Panama | T. truncatus | 74 | 1100 (740) | - | 5.34 (1.9) | 15.34 (3.65) | - | 9.1 (3.7) | 9.19 (4.27) | 0-19 | 3.78 (4.11) | May-Collado & Wartzok 2008 |
| Sardinia, Italy | T. truncatus | 600 | 621 (SE=31) | - | 7.85 (SE=0.15) | 13.09 (SE=0.22) | - | 9.07 (SE=0.17) | 11.36 (SE=0.27) | 0-22 | 1.6 (SE=0.1) | Lopez 2011 |
| Walvis Bay, Namibia | T. truncatus | 693 | 1110 (650) | - | 5.72 (1.99) | 12.88 (2.87) | 7.16 (3.24) | 8.64 (3.56) | 7.21 (3.10) | 0-20 | 1.6 (2.12) | Gridley et al. 2015 |
| Sado Estuary, Portugal | T. truncatus | 735 | 859 (396) | - | 5.4 (1.2) | 15 (±2.7) | 9.6 | 5.8 (1.8) | 12.1 (1.8) | - |  | dos Santos et al. 2005 |

| Location | Species | Number of Samples | Duration (ms) | Mean (kHz) | Min (kHz) | Max (kHz) | Range (kHz) | Start (kHz) | End (kHz) | Range of inflection points | Mean no. inflection points | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Corpus Christi, USA | T. truncatus | 617 | 690 (410) | - | 5.88 (2.65) | 11.43 (3.8) | - | 7.43 (2.44) | 8.71 (4.04) | 0-37 | 2.14 (2.97) | Wang et al. 1995 |
| Galveston, USA | T. truncatus | 811 | 750 (460) | - | 5.98 (2.3) | 11.95 (3.08) | - | 7.95 (2.88) | 9.02 (3.96) | 0-17 | 2.57 (2.62) | Wang et al. 1995 |
| South Padre Island, USA | T. truncatus | 549 | 600 (260) | - | 5.37 (1.12) | 10.33 (2.8) | - | 8.7 (2.95) | 6.4 (2.44) | 0-15 | 1.37 (1.65) | Wang et al. 1995 |
| Cardigan Bay, Wales | T. truncatus | 2357 | 670 (SE=20) | - | 6.45 (SE=0.10) | 13.25 (SE=0.21) | - | 7.89 (SE=0.18) | 11.25 (SE=0.26) | - | 2.01 (SE=0.09) | Massey 2014 |
| Mediterranean Sea | T. truncatus | 76 | 710 (400) | 9.49(2.34) | 6.42 (1.68) | 12.72 (3.95) | 6.3 (3.96) | 8.89 (3.16) | 8.61 (3.47) | - | 2.1 (2.1) | Gannier et al. 2010 |
| Cres & Lošinj islands, Croatia | T. truncatus | 579-592 | 360 (380) | - | 5.09 (2.96) | 9.82 (4.79) | - | 6.62 (3.58) | 8.73 (4.37) | 0-9 | 0.57 (1.25) | Gospic & Picciulin 2016 |
| Tropical Pacific Ocean | T. truncatus | 157 | 1400 (700) | - | 7.4 (2.2) | 17.2 (3.1) | 10 (3.5) | 11.2 (4.6) | 9 (3.7) | - | 3.7 (3) | Oswald et al. 2003 |
| Western Kyushu, Japan | T. aduncus | 515 | 370 (250) | - | 5.63 (2.21) | 9.39 (3.9) | - | 6.74 (2.82) | 8.06 (3.8) | - | 0.78 (0.88) | Morisaka et al. 2005 |
| Ogasawara Islands, Japan | T. aduncus | 247 | 440 (440) | - | 5.61 (2.06) | 12.34 (4.93) | - | 6.91 (3.12) | 10.35 (4.86) | - | 1.19 (1.5) | Morisaka et al. 2005 |
| Mikura Island, Japan | T. aduncus | 851 | 390 (330) | - | 5.98 (2.44) | 12.21 (3.2) | - | 7.17 (2.85) | 9.82 (4.18) | - | 1.22 (1.39) | Morisaka et al. 2005 |
| Plettenberg Bay, South Africa | T. aduncus | 511 | 440 (280) | - | 3.92 (1.64) | 9.62 (3.21) | - | 5.53 (2.86) | 6.98 (4.26) | - | 0.66 (0.88) | Gridley et al. 2012 |
| Zanzibar, Tanzania | T. aduncus | 1166 | 370(220) | - | 4.37 (1.35) | 12.10 (3.91) | - | 5.89 (3.08) | 11.44 (4.30) | - | 0.42 (0.77) | Gridley et al. 2012 |

# Appendix 4.3

Review of the proportion of whistle types for bottlenose dolphins. M = whistle type combined with Multi type whistles, C = Desc-asc whistle type combined with Asc-desc, Combined = combined whistle types Multi, 3-loop and Sine.

| Location | Species | Asc | Desc | Asc-desc | Desc-asc | Flat | Multi | 3-loop | Sine | Multi + 3 loop | Combined | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Great Barrier Island | T. truncatus | 27.4 | 8.8 | 19.8 | 8.8 | 3.3 | 9.5 | 5.2 | 17.2 | 14.7 | 31.9 | Present study |
| Fiordland | T. truncatus | 14 | - | 19 | - | - | - | - | 13 | 22 | - | Boisseau 2014 |
| Brazil | T. truncatus | 17.3 | 14.2 | 23.5 | 7.4 | 6.1 | - | - | - | - | 31.5 | Azevedo et al. 2007 |
| Italy | T. truncatus | 39 | 6 | 7 | 14 | 1 | - | - | 12 | 21 | - | Diaz Lopez 2011 |
| Australia | T. aduncus | 40 | 1 | 7 | C | 11 | - | - | - | - | 40 | Hawkins and Gartside 2010 |
| Australia | T. aduncus | 32 | 5 | M | M | 6 | - | - | - | - | 57 | Ward et al. 2016 |