Marine mammal tourism in the Bay of Plenty, New Zealand: Effects, implications and management

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COASTAL MARINE
MRG
RESEARCH GROUP

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MASSEY
UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

This thesis is dedicated to *Babunia*, Genowefa Gawlak (1922-2012)
and to our little Angel

"Life is what happens while you are busy making other plans"
Allen Saunders, 1957

Abstract

Worldwide expansion of marine mammal tourism over recent decades has raised international concerns in terms of the effects of these tourism practices on the species they target. Moreover, the growth and success of the industry have often outpaced conservation planning, including in New Zealand. To illustrate, tour vessels have been operating for *ca*. 25 years in the Bay of Plenty (BOP), situated on the east coast of North Island, New Zealand. By 2010, a total of eight permits had been granted across the region. However, development of this local industry occurred without any baseline data on species occurrence, distribution, habitat use or behaviour.

This study sought to assess the historical occurrence of the marine mammal species off the BOP and determine their spatial and temporal distribution. Current distribution, density and group dynamics were examined for common dolphins (*Delphinus* sp.) and New Zealand fur seals (*Arctocephalus forsteri*), the two most frequently encountered species in the BOP and therefore, the primarily targeted species by tour operators. The extent of anthropogenic interactions with common dolphins was investigated and their effects on dolphin behaviour examined. The number of common dolphin individuals closely interacting with tour vessels was estimated and dolphin-vessel interactions were quantified to assess repetitive encounters.

In the absence of previously undertaken systematic dedicated surveys, the present study investigated the historical spatial and temporal occurrence of dolphins, whales and pinnipeds in the BOP region. The examination of opportunistic data, collected between December 2000 and November 2010 via various platforms of opportunity including but not limited to tour vessels, identified fourteen species of dolphins, whales and pinnipeds occurring in the region. Confidence criteria in successful species identification were assigned based on observer expertise, diagnostic features of reported species and percentage of records reported by observer type. Common dolphins were the most frequently encountered species, followed by killer whales (*Orcinus orca*), bottlenose dolphins (*Tursiops truncatus*) and New Zealand fur seals, other species being infrequently encountered. A detailed examination of common dolphin habitat use revealed discrepancies with previous findings (*e*.g. higher use of shallower waters), possibly explained by inherent biases to the opportunistic dataset.

Dedicated surveys, conducted between November 2010 and May 2013, investigated the current distribution, density and habitat use of common dolphins and New Zealand fur seals. Both species exhibited a strong seasonality with contrasting occurrence in summer and autumn for common dolphins and in winter and spring for fur seals. Dolphin seasonality is suggested to be linked to movements into deeper offshore waters and/or potentially to neighbouring regions (*i.e*. the Hauraki Gulf) and most likely related to foraging opportunities. Fur seal seasonality suggests that the western BOP supports a non-breeding colony and that foraging reasons may explain the species occurrence in the region. Higher density of common dolphins and fur seals identified over the shelf break and reefs can be explained by enhanced productivity.

First application of Markov chain analyses to common dolphin within oceanic waters, allowed examination of the effects of tourism activities on common dolphins in the BOP. Dolphin foraging behaviour was significantly affected, as dolphins spent less time foraging during interactions with tour vessels and took longer to return to foraging once disrupted by vessel presence. Disruption to feeding may be particularly detrimental to common dolphins in the BOP open oceanic habitat, where prey resources are typically widely dispersed and unpredictable. While the overall level of tour operator compliance with regulations in the bay was relatively high, non-compliance was recorded with regards to swimming with calves and extended time interacting with dolphins.

Evidence of repetitive interactions between tour vessels and common dolphins were examined using photo-identification to assess potential cumulative impacts. An estimated minimum of 1,278 common dolphin individuals were identified in the region, for which the majority (86.9%) showed low levels of site fidelity (*i.e.* only one encounter). At least 61.7% of identified dolphins were exposed to tour vessel interactions. However, spatial (*i.e*. between the western and eastern sub-regions) and temporal (*i.e*. daily, seasonal and annual) cumulative exposure to tourism activities was observed for less than 10% of these individuals. This is likely explained by tour operators “handing over” groups or returning to areas preferentially frequented by dolphins (*i.e.* presumed foraging hotspots). Due to the opportunistic methods used for photo-identification, these results are indicative only of the absolute minimum of repeated interactions common dolphins may face in the region.

The present thesis represents the first comprehensive assessment of marine mammal tourism in the BOP. It offers important contributions to research and conservation in this area via the critical assessment of historical occurrence of marine mammals in the region. This thesis also provides comprehensive and detailed insights into common dolphin and New Zealand fur seal temporal and spatial distribution in the area. This can serve management agencies to implement efficient conservation plans. While identifying that tourism operations significantly affect common dolphin behaviour and repetitive interactions result in cumulative exposure, this thesis supports adaptive management and further long-term monitoring of marine mammal species in general, and in the BOP region more specifically.

Acknowledgments

This project would not have been possible without the help and support of lots of people I would like to acknowledge here.

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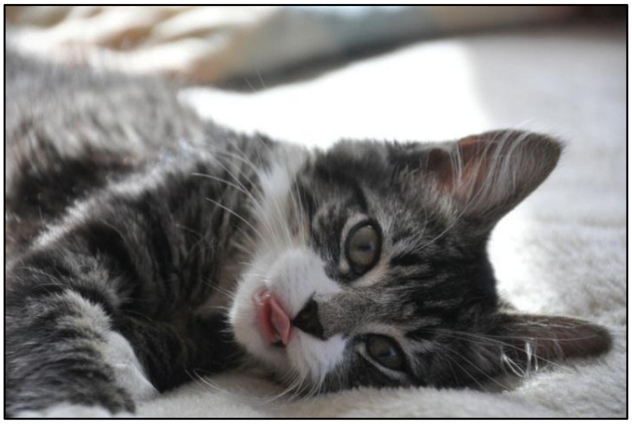

THANK YOU ALL!!!

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List of abbreviations

AIC	Akaike's Information Criteria
ANOVA	Analysis of Variance
Apr	April
Aug	August
BOP	Bay of Plenty
ca.	*circa*, approximately
CI	Confidence Interval
Chl-a	Chlorophyll-a concentration
Dec	December
df	Degree of freedom
E	East
e.g.	*exempli gratia*, for example
ENSO	El Niño Southern Oscillation
ER	Encounter Rate
ESRI	Environmental Systems Research Institute
et al.	*et alii*, and others
etc	*et caetera*, and other similar things
Feb	February
FOR	Foraging
GAM	Generalised Additive Model
GIS	Geographic Information System
gp	Group
GPS	Global Positioning System
h	Hours
hp	Horse power
IDW	Inverse Distance Weighted
i.e.	*id est*, in other words
IQR	Interquartile Range
ind	Individual(s)
IUCN	International Union for Conservation of Nature
Jan	January
Jul	July
Jun	June
KDE	Kernel Density Estimates
km	Kilometre
kts	Knots
Log	Logarithm
m	Metre
Mar	March
mg	Milligram
MGET	Marine Geospatial Ecology Tools
MIL	Milling
min	Minute
MMPA	Marine Mammals Protection Act

MMPR	Marine Mammals Protection Regulations
N	North
NE	North East
NIWA	National Institute of Water and Atmospheric Research
Nov	November
OCR	Overall Confidence Rate
P	Periodicity
p	Probability
pers. comm.	Personal communication
pers. obs.	Personal observation
photo-ID	Photo-identification
RES	Resting
S	South
SD	Standard Deviation
SE	Standard Error
Sep	September
SLR	Single-Lens Reflex
RV	Research vessel
Sep	September
SOC	Socialising
SST	Sea Surface Temperature
sp.	Unknown species of a genus
spp.	Two or more unknown species within the genus
SR	Sighting Rate
TER	Trip Encounter Rate
TL	Time Lag
TRA	Travelling
TV	Tour vessel(s)
USA	United States of America
US$	US Dollars
VIF	Variation Inflation Factors
W	West
WGS	World Geodetic System
°	Degree
°C	Degree Celsius

Author's declaration

All the photographs and figures have been taken and created by the author unless the source has been specifically acknowledged.

Anna Maria Meissner

July 2015

Meissner.

Preface

The current study, and more specifically Chapter 4 of this thesis, form part of a tendered contract commissioned by the Department of Conservation, former East Coast Bay of Plenty conservancy. The department initiated this research in direct response to concerns raised by the local dolphin tour industry, since operators themselves were opposed to the issuing of further permits within the region due to concerns over sustainability. With a moratorium on further dolphin tourism activities within the region requested by the operators, the department initiated a three year study. As part of the consultation for this study, operators were directly engaged by both the department and Massey University to discuss all aspects of the proposed research. Dialogue concerning the scope of research to be undertaking, including but not limited to the assessment of current compliance levels, took place at the outset of the study and involved Massey University, Department of Conservation and all operators with the ECBOP region. In addition, annual progress reports and presentations were delivered to the operators, via the department in order to keep all stakeholders informed on the progress of the research.

In the framework of this study and in agreement with the Department of Conservation contract (Appendix 1), some of the data presented here were collected aboard tour vessels operating in the Bay of Plenty. Access to the tour vessels for the specific purpose of the predetermined research remit was agreed between all stakeholders including but not limited to the Department of Conservation and the tour operators at the outset of research project. Operators invited the Principle Investigator (Anna M. Meissner) and associated research assistants to board their platforms with the express intent of collecting data with respect to the predetermined research remit. On a daily basis, permission to board each tour vessel was further discussed between the observers (Anna M. Meissner and/or the research assistants) and the tour operators. Furthermore, an introduction of the onboard researchers to the patrons was undertaken along with a brief dialogue about the data collection being undertaken and the overarching purpose of the study.

Publications and presentations

The following publications and presentations have been produced during this PhD, as a result of the research presented in this thesis:

Publications in peer-reviewed journals

Meissner, A. M., Christiansen, F., Martinez, E., Pawley, M. D. M., Orams, M. B. and K. A. Stockin. 2015. Behavioural effects of tourism on oceanic common dolphins, *Delphinus* sp., in New Zealand: The effects of Markov analysis variations and current tour operator compliance with regulations. *PLoS One*: e0116962.

Administrative reports, followed by annual meetings with the Department of Conservation and tour operators from the Bay of Plenty

Meissner, A. M., Orams, M. B., Martinez, E. and K. A. Stockin. 2014. Effects of commercial tourism activities on bottlenose and common dolphin populations in East Coast Bay of Plenty waters. *Final internal report to the Department of Conservation, East Coast Bay of Plenty Conservancy, New Zealand*. 117p.

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Meissner A. M., Stockin K. A, 2011. Impacts of commercial tourism activities on bottlenose and common dolphin populations in East Coast Bay of Plenty waters. *Internal report to the Department of Conservation, East Coast Bay of Plenty Conservancy, New Zealand*. 29p.

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Meissner A. M, Ransijn, J. and K. A. Stockin. 2013. First insight into epidermal conditions affecting common dolphins (*Delphinus* sp.) in the Bay of Plenty, New Zealand. *20th Biennial Conference on the Biology of Marine Mammals, Dunedin*. [Poster]

Chapter 1

General Introduction

The research vessel *Aronui Moana* anchored at Mayor Island, Bay of Plenty, New Zealand.

1.1 Introduction

Whether for the purpose of scientific understanding, commercial exploitation or conservation management, interest in marine mammals has grown significantly over recent decades (*e.g.* Forestell, 2008; Jefferson *et al*., 2008). However, access to marine mammals is often challenging given species live permanently (*e.g.* cetaceans) or partially (*e.g.* pinnipeds) in aquatic environments (Forcada, 2009). Consequently, depending on species life cycle and distribution, the amount of interaction between humans and marine mammals is highly variable. Indeed, observation of coastal resident species, such as bottlenose dolphins (*Tursiops* spp.) or killer whales (*Orcinus orca*), is facilitated by the proximity of their habitat to the coastline and human habitation and use of that coastline. Interactions between human and marine mammals have enhanced our knowledge of those species, but have also resulted in exacerbated risks from, for example, pollution (Borrell *et al.*, 2006; Fair *et al.*, 2010; Stockin *et al.*, 2010), vessel collision (Fertl, 1994; Wells and Scott, 1997; Visser, 1999b; Stone and Yoshinaga, 2000; Wells *et al.*, 2008; Dwyer *et al.*, 2014a), interactions with commercial fisheries (*i.e.* by-catch and/or competition, VanWaerebeek *et al.*, 1997; Friedlaender *et al.*, 2001; Kiszka *et al.*, 2008; Bearzi *et al.*, 2010) and/or tourism (Lusseau, 2003a; Bejder *et al.*, 2006b; Christiansen *et al.*, 2010).

Conversely, encounters with pelagic offshore species (*i.e.* false killer whales, *Pseudorca crassidens*, striped dolphins, *Stenella coeruleoalba*) are more limited compared with coastal dwelling populations, given that offshore areas are typically less frequented by humans and owing to spatio-temporal constraints driven by data collection in the field (Robbins and Mattila, 2000; Kiszka *et al.*, 2004; McClellan *et al.*, 2014). While these pelagic offshore species are potentially less vulnerable to human disturbance, our knowledge is typically more restricted owing to temporal, geographic and budgetary restrictions centred around research (Mannocci *et al.*, 2015). In such cases, data provided via opportunistic means, whether that is historical whaling (Gregr *et al.*, 2000; Flinn *et al.*, 2002; Torres *et al.*, 2013), strandings or opportunistic sightings (Camphuysen, 2004; Siebert *et al.*, 2006; Pikesley *et al.*, 2012), often represent the only data available for some species and populations.

1.2 Challenges and implications of marine mammal data collection

Knowledge of marine mammals (*e.g.* distribution, habitat use, abundance or behaviour) has extensively relied on a range of methods and approaches to data collection (Evans and Hammond, 2004). Depending on the species, resource availability and purpose, data can be collected using land-based observations (Harzen, 1998; Carretta *et al.*, 2000; Lundquist *et al.*, 2013), aerial (Dohl *et al.*, 1986; Forney *et al.*, 1995; Carretta *et al.*, 2000; Hammond *et al.*, 2002; Hodgson *et al*., 2013; Becker *et al.*, 2014) or boat-based platforms (Cañadas and Hammond, 2008; Hammond *et al.*, 2013; Douglas *et al.*, 2014), from which surveys can be carried out. In addition, other methods include underwater observations (Bräger *et al.*, 1999; Miles and Herzing, 2003; Cusick and Herzing, 2014) or acoustic recordings (Filatova *et al.*, 2006; McDonald, 2006; Simon *et al.*, 2010). Regardless of the platform used, data are either collected via rigorous scientific protocol, *i.e.* through dedicated research surveys and standardised methods, or alternatively via opportunistic means, *i.e.* various sources and platforms, which may range from public sightings to data collected by researchers in a non-systematic manner.

Research platform type and study design greatly influence the level of information that can be inferred from a dataset (Robbins and Mattila, 2000; Evans and Hammond, 2004). While less concern typically arises from data collected within the framework of dedicated surveys using systematic standardised methods, some studies must rely on opportunistic datasets, including those collected from platforms of opportunity (Scott and Chivers, 1990; Fiedler and Reilly, 1994; Williams *et al.*, 2006a; Macleod *et al.*, 2009; Cotté *et al.*, 2010). Typically, such platforms may result in inaccuracies or bias that must been accounted for in the methodology and/or analysis of the study. Regardless of platform type, if data are collected opportunistically or if the study design is not appropriate for the research question, inaccuracies or biases are likely and must be addressed (Hauser *et al.*, 2006). For instance, data may be restricted in time and space (Redfern *et al.*, 2006; Wall *et al.*, 2006; Kiszka *et al.*, 2007b; Cotté *et al.*, 2009; Palacios *et al.*, 2012) or concerns expressed regarding the reliability or validity of data recorded (*e.g.* species identification, group size and composition, Evans and Hammond, 2004; Hauser *et al.*, 2006; Barlow and Forney, 2007; Martinez and Stockin, 2011; Moura *et al.*, 2012; Hupman *et al.*, 2014).

Opportunistic data are collected from a wide range of platforms. For example, ferries and cruise ships have extensively been used as they offer the advantage of covering large areas and crossing offshore waters (*e.g.* Scott and Chivers, 1990; Fiedler and Reilly, 1994; Cotté *et al.*, 2010), often inaccessible to traditional research platforms. Fishing vessels have also been used to estimate by-catch (*e.g.* Vinther, 1999; Rogan and

Mackey, 2007; Fernandez-Contreras *et al.*, 2010), as have tour boats to assess ecological questions concerning species targeted for tourism (*e.g.* Azzellino *et al.*, 2008a; Wiseman *et al.*, 2011).

The primary purpose of whale/dolphin watching tourism is to get a close encounter with marine mammals (Orams, 2000). For this reason, a large proportion of opportunistic data originates from commercial tour vessels. Search effort (in time or distance) is therefore dedicated to finding cetaceans, with greater probability to encounter marine mammals than from aboard other platforms of opportunity. Moreover, skippers and crew usually record some degree of information regarding the encounter (*i.e.* GPS location, time, species, group size and composition), assuming these are not already required to be reported to management authorities (Martinez and Stockin, 2011). Finally, although taken opportunistically, photographs and/or video are also typically collected by crew, often allowing species identification, group size and/or composition to be confirmed or giving access in some cases for individual identification (Dwyer *et al.*, 2014a; Zaeschmar *et al.*, 2014). Consequently, given the large expansion of this industry world-wide, tour vessels often provide inexpensive logistical support to study various aspects of cetacean ecology (Robbins and Mattila, 2000; Azzellino *et al.*, 2008b; Wiseman *et al.*, 2011).

1.3 Marine mammal-watching in the tourism industry

1.3.1 Marine mammal tourism world-wide

Nature-based marine activities, and more specifically marine wildlife experiences, have become the subject of tourism attention over the past few decades (Higham and Lück, 2008b). Viewing whales in the wild started in the 1950s with observing gray whales, *Eschrichtius robustus*, in San Diego, California, USA (Hoyt, 2009). Following the rising demand and success of these interactions, traditional whale-watching activities have evolved and, today, satisfy a large variety of expectations. For example, marine mammal based tourism encompasses any form of commercial activities of viewing, swimming with, listening to and/or feeding marine mammals (Parsons *et al.*, 2006; Carlson, 2012). The traditional and popular whale-watching activities involve trips out at sea but opportunities also include observations from land and the air (Hoyt and Iñíguez, 2008).

The marine mammal tourism industry experienced a remarkable expansion in only a few years, as it spread to other parts of the world in the late 1980s (Hoyt, 2009). For instance, whale-watching tours operated in 31 countries and territories in 1991 (Hoyt, 2001), became available in 87 countries and territories by 1998 (Hoyt, 2001) and had further expanded to 119 countries by 2008 (Figure 1.1, O'Connor *et al.*, 2009). Simultaneously, the number of tourists expanded at a rapid rate, with an estimated four million tourists in the early 1990s (Hoyt, 2001), more than nine million in 1998 (Hoyt, 2001) and over 13 million in 2008 (O'Connor *et al.*, 2009), with some countries surpassing one million marine mammal tourists per annum (*e.g.* USA, Canada, Canary Islands and Australia, Hoyt, 2001; O'Connor *et al.*, 2009). As a consequence, marine mammal based tourism activities represent a significant economic component of the ecotourism industry sector (Hoyt, 2001; O'Connor *et al.*, 2009). For example, the industry was estimated to have generated over US$1 billion in total in 1998 (Hoyt, 2001) and over double that amount 10 years later (O'Connor *et al.*, 2009). In response to the growing demand and given the economic potential, it is believed that the industry will continue to expand (Cisneros-Montemayor *et al.*, 2010).

In the history of marine mammal exploitation, marine mammal tourism has often been positively considered compared to lethal whaling activities (Parsons and Draheim, 2009; Draheim *et al.*, 2010; Chen, 2011). Moreover, watching free ranging dolphins is becoming a popular alternative to viewing dolphins in captivity (Hughes, 2001; Luksenburg and Parsons, 2014). As such, the tourism industry is perceived to have some conservation benefits including wildlife management, tourist education and research support (Higginbottom and Tribe, 2004; Krüger, 2005; Section 1.2).

Figure 1.1: Map of countries participating in marine mammal tourism activities in 2008, displayed in black (Source: O'Connor *et al.*, 2009).

Although species targeted by tourism activities are typically the most prevalent and/or reliably found in a region, the vast majority of all marine mammal species are targeted by tourism activities (Hoyt, 2001). This includes baleen whales, dolphins, porpoises, pinnipeds and other marine mammal species such as polar bears (*Ursus maritimus*) (Lemelin, 2006; Parsons *et al.*, 2006; Hoyt, 2009). Additionally, some of these targeted species are endangered (*e.g.* blue, *Balaenoptera musculus*, and northern right whales, *Eubalaena glacialis*, Hector’s dolphins, *Cephalorhynchus hectori hectori*, and the Mediterranean monk seal, *Monachus monachus*).

1.3.2 Marine mammal tourism in New Zealand

The whale and dolphin watching industry in the Oceania, Pacific Islands and Antarctica regions has matched the global trend and is led today by significant industries in Australia and New Zealand (O'Connor *et al.*, 2009). In New Zealand, marine mammal tourism was first established in 1987 in Kaikoura (Constantine, 1999; Orams, 2004) (Figure 1.2). Similar to the rest of the world, New Zealand has experienced a spectacular expansion with an annual growth averaging 9%, with an estimated 230,000 to *ca.* 550,000 international and domestic tourists participating in tours between 1998 and 2008 (O'Connor *et al.*, 2009). Indeed, New Zealand has earned an international reputation as a marine mammal tourism destination owing to the outstanding diversity of marine mammal species occurring in its waters (Suisted and Neale, 2004).

With almost half the world's cetacean species and nine species of pinnipeds either resident in or migrating through New Zealand waters (Suisted and Neale, 2004), marine mammal based tourism in New Zealand is extremely diversified. Activities range from viewing oceanic species such as common dolphins (*Delphinus* sp.) or sperm whales

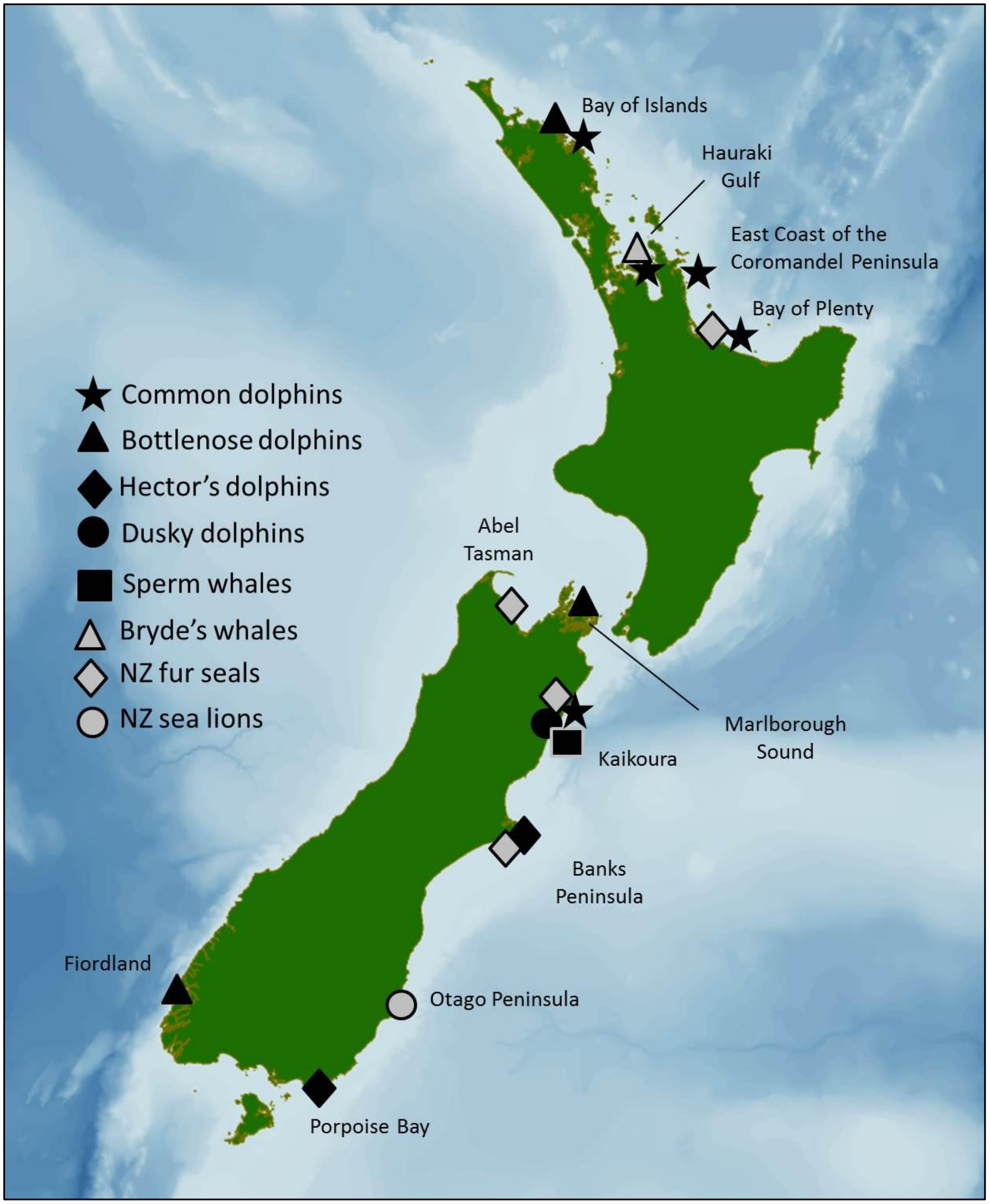

Figure 1.2: Marine mammal species targeted by commercial tourism activities and their locations in New Zealand.

(*Physeter macrocephalus*) (Richter *et al.*, 2006; Stockin *et al.*, 2008a; Meissner *et al.*, 2015) to swimming with endemic Hector's dolphins (Martinez *et al.*, 2011) or New Zealand fur seals (*Arctocephalus forsteri*, Cowling *et al.*, 2014). The main focal species include dusky dolphins (*Lagenorhynchus obscurus*, Lundquist *et al.*, 2012) and sperm whales (Richter *et al.*, 2006) in Kaikoura, bottlenose dolphins (*T. truncatus*) in the Bay of Islands and Fiordland (Constantine, 2001; Lusseau, 2003a), common dolphins off the northeast coast of the North Island (Neumann and Orams, 2006; Stockin *et al.*, 2008a; Meissner *et al.*, 2015) and Hector's dolphins off Banks Peninsula and Porpoise Bay (Bejder *et al.*, 1999; Martinez *et al.*, 2011; Figure 1.2). Additionally, New Zealand fur seals have also been the focus of regular commercial tourism interactions since the recent recolonisation of some breeding sites in the South Island (Boren *et al.*, 2001).

A range of concerns have been voiced over effects of this industry upon targeted populations within New Zealand including Hector's, common, dusky and bottlenose dolphins (*e.g.* Constantine, 2001; Lusseau, 2003a; Neumann and Orams, 2006; Stockin *et al.*, 2008a; Martinez, 2010; Lundquist *et al.*, 2012), sperm whales (Richter *et al.*, 2006) as well as for New Zealand fur seals (Boren *et al.*, 2002). In an attempt to mitigate these effects, guidelines and regulations have been introduced, for which New Zealand has been considered an international leader (Orams, 2004).

In New Zealand, all marine mammal species have been protected since 1978 under the Marine Mammals Protection Act (MMPA, 1978). In 1990, the Marine Mammals Protection Regulations (MMPR) were introduced to provide a regulatory framework for whale-watching activities and to regulate human behaviour around marine mammals in general. These regulations were consolidated in 1992 (Marine Mammals Protection

Regulations, 1992), following the expansion of commercial dolphin-based activities and a commensurate increase in the interactions with recreational vessels. The Department of Conservation is responsible for administrating the MMPA and MMPR and do so through a permit system and via monitoring of permitted marine mammal tour vessels.

Since the first permit was issued in the late 1980s (Orams, 2004), permits to watch and/or swim with marine mammals in New Zealand have increased. In 1999, out of 14 Department of Conservation conservancies covering the North and South Island, marine mammal tourism had become well established in 10 of them, with 74 permits granted nationwide (Constantine, 1999). This number increased to 90 in 2005 (International Fund for Animal Welfare, 2005) and to 112 in 2011 (Department of Conservation, pers. comm.), with new permit applications currently awaiting approval.

1.3.3 Marine mammal tourism in the Bay of Plenty region

Situated on the east coast of the North Island, the Bay of Plenty (BOP) is second only to the Bay of Islands as the busiest destination for cetacean-watching in the North Island (O'Connor *et al.*, 2009). This industry is supported by a diversity and abundance of marine mammal species occurring in the area (Gaborit-Haverkort and Stockin, 2011), likely influenced by the bathymetry and oceanographic conditions of the region. Indeed, the western part of the region, characterised by a wide continental shelf margin and typically used by coastal resident species (Gaborit-Haverkort and Stockin, 2011). This contrasts with the eastern sub-region, featuring oceanic waters close to the coastline and visited by pelagic migrant or visiting species (Gaborit-Haverkort and Stockin, 2011).

Such biodiversity has particularly encouraged the development of a flourishing tourism industry in the region over the past few decades.

While the exact starting date remains unknown, commercial dolphin-based operations in the region commenced in the early 1990s (Butler, pers. comm.), before the first commercial permit was granted in 1994 (Cowling *et al.*, 2013). In 2001, two vessels were permitted to operate from Tauranga (37.6878°S and 176.1651°E) and a further two from Whakatane (37.5700°S 177.0050°E) (Figure 1.3, Neumann, 2001b). By 2010, there were a total of eight permits across the region, allowing 10 vessels to operate, of which seven were based from Tauranga and the remaining three from Whakatane.

Entrepreneurship and the potential for economic benefits can explain the expansion of marine mammal tourism in the BOP. However, the lack of addressing the effects of tourism on species occurring in the region can potentially result in negative impacts and may create an unsustainable situation (Parsons, 2012). Failing to anticipate the success and expansion of marine mammal tourism in the region and facing an absence of baseline data, the Department of Conservation established a moratorium in 2010, preventing any further permit to be approved for the BOP until the completion of two commissioned studies on the potential effects of tourism activities on New Zealand fur seals and common dolphins (Cowling *et al.*, 2014; Meissner *et al.*, 2014; Chapter 4). Assessing marine mammal behaviour in relation to tourism operations and examining the compliance of tour operators with regulations can minimise potential effects and ensure tourism activities are ecologically sustainable in the region. However, in order to identify and mitigate effects of human activities on specific species in a given location, further knowledge about their spatial and temporal distribution is necessary (Cañadas *et al.*, 2005; Macleod *et al.*, 2009), yet often still overlooked.

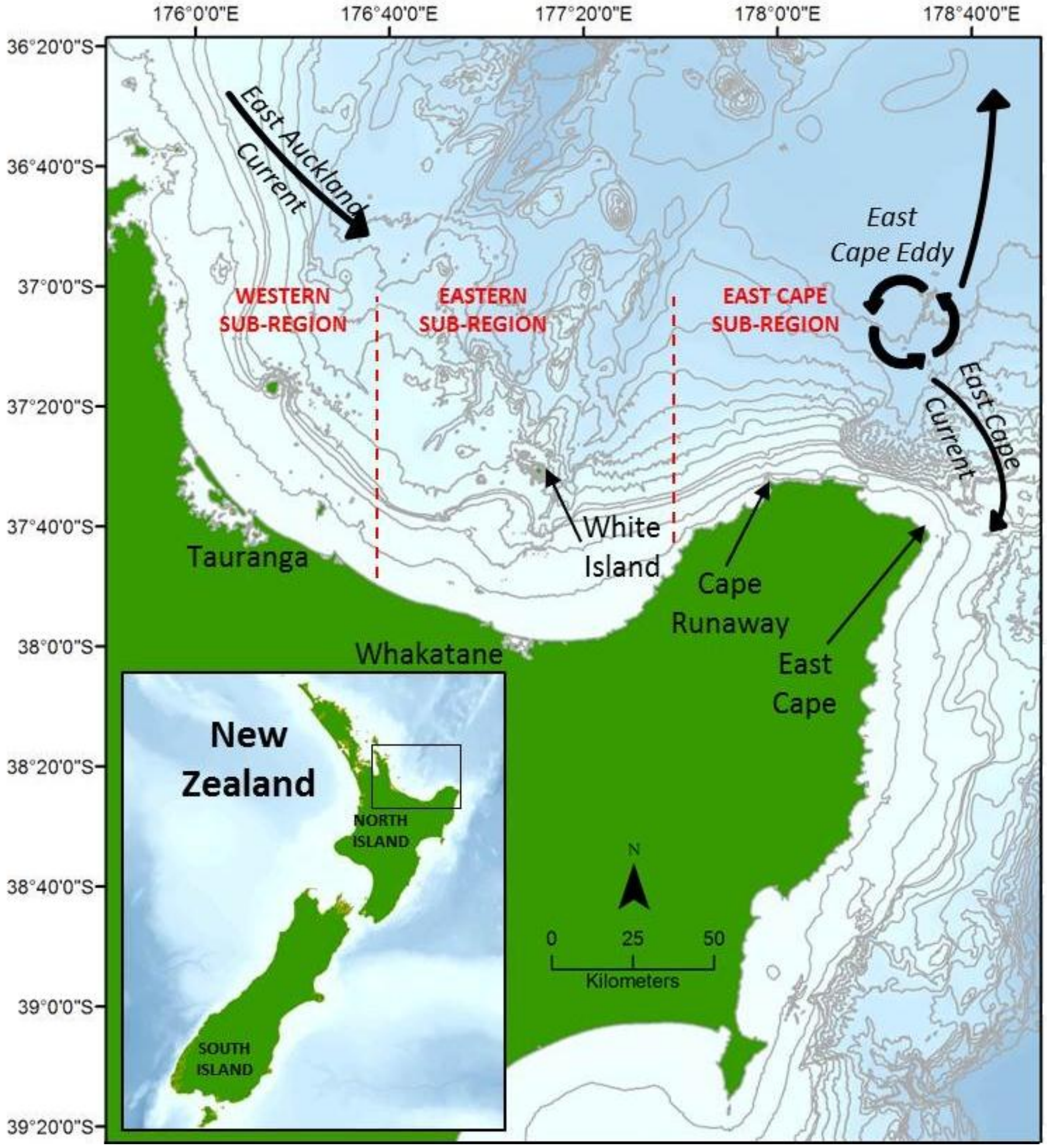

Figure 1.3: Location of the Bay of Plenty and places referred to in this chapter in relation to the North and South Island of New Zealand. The approximate position of hydrographic features is indicated. Bathymetry is depicted with darker shades of blue representing deeper waters and isobaths in 50m increment, bathymetry data courtesy of NIWA (CANZ, 2008).

1.4 Importance of marine mammal distribution studies

Wildlife tourism has previously contributed to the conservation of targeted animals (Orams, 1994; Higginbottom *et al.*, 2001; Zeppel and Muloin, 2007). For this, the industry has to provide some baseline knowledge of species distribution or behaviour to assist with their conservation. For example, understanding how given species use their habitat provides a strong basis to implement conservation plans and mitigate potential anthropogenic impacts upon targeted populations (Hooker *et al.*, 1999; Cañadas *et al.*, 2002; Guisan *et al.*, 2006). Moreover, identifying the relationship between species distribution and physiographic variables of their environment is also of great importance for the tourism industry in order to predict marine mammal occurrence in space and time (Lambert *et al.*, 2010).

Marine mammal distribution and density largely reflect oceanographic and physiographic features of the environment (Huntley *et al.*, 2000; Worm *et al.*, 2005) given that those processes influence the distribution and availability of their prey (Irvine *et al.*, 1981; Selzer and Payne, 1988; Ballance, 1992; Croll *et al.*, 1998; Davis *et al.*, 1998; Cañadas *et al.*, 2002; Davis *et al.*, 2002; Forcada, 2009). Therefore, when prey data are unavailable, marine mammal distribution can alternatively be investigated via the examination of physical and/or biological components of the marine environment, such as water depth, distance to shore, slope gradient, sea surface temperature (SST) and/or chlorophyll-a concentration (Chl-a) (*e.g.* Notarbartolo Di Sciara *et al.*, 1993; Davis *et al.*, 1998; Cañadas *et al.*, 2002; Lopez *et al.*, 2004; Laran and Drouot-Dulau, 2007; Azzellino *et al.*, 2008a; Macleod *et al.*, 2008). The influence of ecological factors on species can be investigated by modelling techniques (Guisan and Thuiller, 2005;

Guisan *et al.*, 2006; Redfern *et al.*, 2006), allowing not only the identification of habitat use but also providing the ability to understand and predict changes in species distribution over time.

The ecology of marine mammals in the BOP has so far only concentrated on research focusing on common dolphins, and with the vast majority conducted along the east coast of the Coromandel Peninsula, *ca.* 100km northwest the central BOP (Neumann, 2001a, c; Neumann *et al.*, 2002; Neumann and Orams, 2003, 2006; Meissner *et al.*, 2015). To a lesser extent, New Zealand fur seals have been studied within BOP waters (Cowling *et al.*, 2014), although primarily only in relation to behaviour, following concerns over potential tourism effects. Consequently, a broader understanding of marine mammal biodiversity and ecology within the larger BOP region remains lacking, yet is crucial in order to implement appropriate conservation and management initiatives (Hooker and Gerber, 2004; Cañadas *et al.*, 2005; Cañadas and Vazquez, 2014). This is of particular importance off Tauranga, where most recent growth of the tourism industry has occurred.

1.5 The study area

The BOP (37.0600°S; 175.5800°E and 37.6000°S; 178.5700°E), situated on the north east coast of the North Island, New Zealand (Figure 1.3), is an oceanic habitat with water depths generally reaching 200m within 35km of the coastline (Park, 1991). Spanning *ca.* 200km of shoreline (Park, 1991), the bay opens to the Pacific Ocean in the North and can be divided into three major sub-regions: the western (west of 176.3500°E), the eastern (176.3500 to 177.4000°E) and the East Cape sub-region (east of 177.4000°E, Figure 1.3). From a bathymetric perspective, the western and eastern sub-regions are characterised by a relatively wide continental shelf, which extends up to 35km (Figures 1.3 and 1.4, Park, 1991). The continental shelf is relatively smooth in terms of bathymetry (slope <1°), with only a few reefs or shoals associated with steep bathymetry (slope >1°, Figure 1.4, Park, 1991). However, in the vicinity of Cape Runaway and East Cape, the shelf narrows to 8km, with steeper slopes and deeper waters found closer to the shore (Park, 1991, Figure 1.4).

The BOP is also characterised by complex hydrographic features, dominated by the East Auckland Current, which follows the coastline south-eastward and transports relatively warm and saline subtropical water (Sharples, 1997; Stanton *et al.*, 1997; Tilburg *et al.*, 2001). The strength and position of the East Auckland Current varies substantially in time depending on offshore winds (Sharples, 1997; Stanton *et al.*, 1997; Tilburg *et al.*, 2001). While some of this flow seasonally approaches the BOP slope, and potentially the shelf, another part of the flow feeds the East Cape Eddy, north of East Cape (Stanton *et al.*, 1997, Figure 1.3). The flow further generates the East Cape Current (Stanton *et al.*, 1997; Tilburg *et al.*, 2001, Figure 1.3).

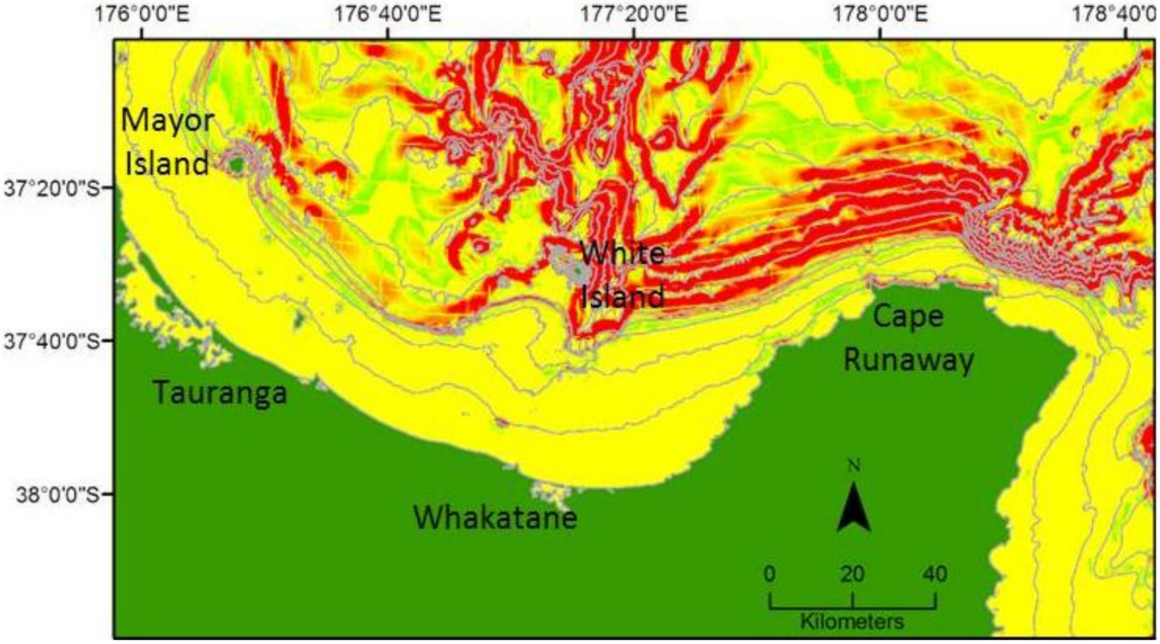

Figure 1.4: Bathymetry slope map of the Bay of Plenty, New Zealand. Smooth slopes (<1°) are indicated in yellow, steeper slopes (1-2°) in green and the steepest ones (>2°) in red.

1.6 The study species

Marine mammal tourism in the BOP is supported by a wide range of marine mammal species occurring in the region, some of which qualify as resident (common dolphins and New Zealand fur seals), seasonal (bottlenose dolphins and killer whales) and potentially offshore resident (pilot, *Globicephala* spp., and beaked whales, *Ziphiidae*, Gaborit-Haverkort and Stockin, 2011). Other species, opportunistically encountered in the region, have been categorised as seasonal migrants (*e.g.* humpback, *Megaptera novaeangliae*, sperm, minke, *Balaenoptera acutorostrata*, southern right whales, *Eubalaena australis*) or visitors (Bryde's, *B. edeni*, blue, fin, *B. physalus*, sei, *B. borealis*, and false killer whales, *Pseudorca crassidens*) (Gaborit-Haverkort and Stockin, 2011). While all species can potentially be encountered by commercial operators, tourism activities in the BOP relies on the predictable occurrence and movements of marine mammals (Lambert *et al.*, 2010) and therefore on the most frequently encountered species, *i.e.* common dolphins (Meissner *et al.*, 2015; Chapter 4) and New Zealand fur seals (Cowling *et al.*, 2014). Consequently, an examination of current knowledge pertaining to distribution, seasonality, habitat use and conservation status of these two key species is provided hereafter.

1.6.1 Common dolphins

Common dolphins (*Delphinus* spp.) belong to the delphinid subfamily of *Delphinidae* (Leduc *et al.*, 1999). The global taxonomic status of common dolphins remains uncertain. Based on morphological (Heyning and Perrin, 1994; Murphy *et al.*, 2006) and genetic differences (Rosel *et al.*, 1994; Natoli *et al.*, 2006; Amaral *et al.*, 2007), two species of common dolphins are currently recognised: the short-beaked (*D. delphis*) and the long-beaked common dolphin (*D. capensis*), which appear genetically isolated (Heyning and Perrin, 1994; Rosel *et al.*, 1994). Both species are thought to have recently diverged (Kingston and Rosel, 2004) and sympatric occurrence exists across the species home range (Heyning and Perrin, 1994; Rosel *et al.*, 1994).

Due to their wide distribution, several geographical variants of *Delphinus* have been described as subspecies (Hershkovitz, 1966; Heyning and Perrin, 1994). However, only the very-long-beaked subspecies (*D. c. tropicalis*) endemic of the Indian Ocean, has been confirmed (Jefferson and Van Waerebeek, 2002), although ongoing taxonomic debate concerning the genus *Delphinus* continues (Amaral *et al.*, 2007, 2012a, 2012b). In the South Pacific, while studies confirmed evidence for the short-beaked form in southern Australian waters (Bell *et al.*, 2002; Bilgmann, 2007), the taxonomic status of the species in New Zealand waters has not been entirely clarified (Stockin *et al.*, 2014). As such, New Zealand common dolphin hereafter is referred to as *Delphinus* sp.

1.6.1.1 Distribution

Common dolphins occur in warm-temperate to tropical waters worldwide typically from approximately 60°N in the Atlantic and 45°N in the Pacific to 50°S (Jefferson *et al.*, 1993; Pollock *et al.*, 2000; Hammond *et al.*, 2008a, b; Cañadas *et al.*, 2009; Becker *et al.*, 2014, Figure 1.5). The accurate distribution of each species remains uncertain due to past taxonomic confusion (Rice, 1998) and difficulties distinguishing species in the field (Hui, 1979; Forney *et al.*, 1995; Becker *et al.*, 2014).

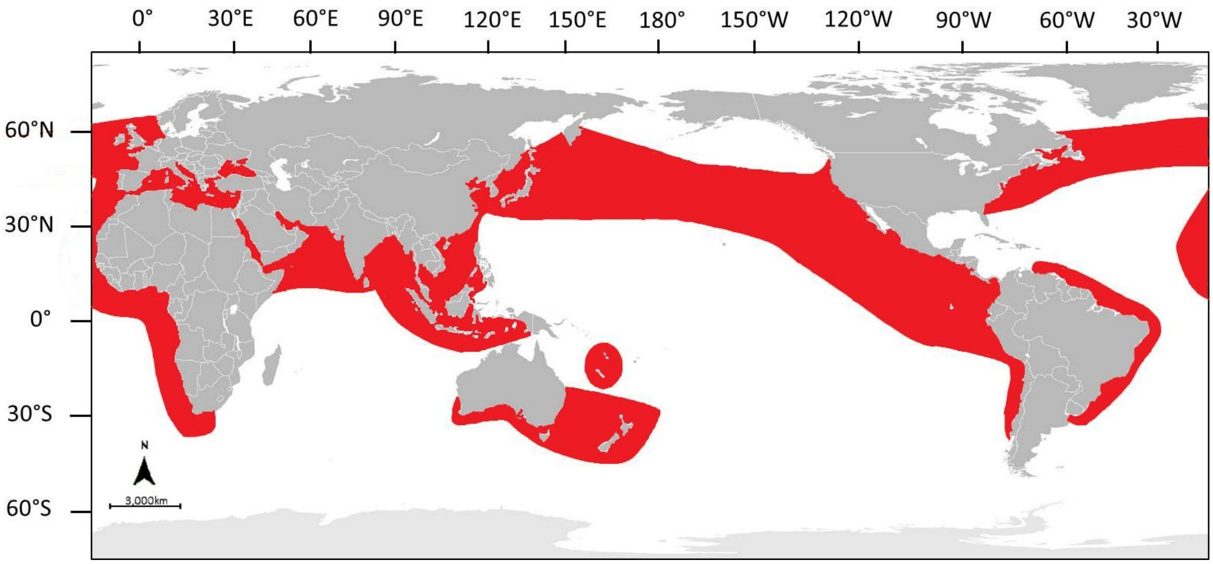

Figure 1.5: Global distribution of common dolphins, genus *Delphinus*, displayed in red (modified from Hammond *et al.*, 2008a, b).

In the western Atlantic, common dolphins occur off Canada and North America (*e.g.* Selzer and Payne, 1988; Jefferson *et al.*, 2009; Lawson *et al.*, 2009; Goyert *et al.*, 2014) to South America (*e.g.* Di Beneditto *et al.*, 2001; Jefferson *et al.*, 2009; Oviedo *et al.*, 2010; Tavares *et al.*, 2010). However, their distribution appears to be discontinuous, presumably related to SST (Cañadas *et al.*, 2009), as they appear absent from the tropical waters (Jefferson *et al.*, 2009) and some areas in the central North Atlantic where cold temperatures have been recorded (Cañadas *et al.*, 2009).

In the eastern Atlantic, common dolphins are reported from the European (*e.g.* Silva, 1999; Hammond *et al.*, 2002; Lopez *et al.*, 2004; Kiszka *et al.*, 2007b; Certain *et al.*, 2008; Macleod *et al.*, 2008, 2009; Lambert *et al.*, 2010; Pierce *et al.*, 2010; Robinson *et al.*, 2010) to west African coasts (*e.g.* Perrin, 2008; Pinela *et al.*, 2008, 2011; Weir, 2010; Perrin and Van Waerebeek, 2012; Weir *et al.*, 2012; Sohou *et al.*, 2013; Segniagbeto *et al.*, 2014), including the Mediterranean and Black Sea (*e.g.* Notarbartolo Di Sciara *et al.*, 1993; Bearzi *et al.*, 2003, 2011; Gannier, 2005; Cañadas and Hammond, 2008; Dede and Tonay, 2010).

The genus is also present in the Red Sea and the Indian Ocean (*e.g.* Rudolph *et al.*, 1997; Ballance and Pitman, 1998; Jayasankar *et al.*, 2008, 2009; Eyre and Frizell, 2012; Mohsenian *et al.*, 2014) and has been observed off the South African coast (*e.g.* Cockcroft and Peddemors, 1990; Young and Cockcroft, 1994; Samaai *et al.*, 2005; Best *et al.*, 2009; Ambrose *et al.*, 2013).

Common dolphins are present in the Pacific Ocean from North America (*e.g.* Fiedler and Reilly, 1994; Ford, 2005; Carretta *et al.*, 2007; Becker *et al.*, 2014; Smultea and Jefferson, 2014) to Chile (*e.g.* Van Waerebeek *et al.*, 1997; Bernal *et al.*, 2003; Mangel *et al.*, 2010), from the Sea of Okhotsk to Korea (*e.g.* Ohizumi *et al.*, 1998; Ahn *et al.*, 2014; Kanaji *et al.*, 2014) and within Indonesian waters (*e.g.* Rudolph *et al.*, 1997).

In the South Pacific, information on common dolphin distribution is limited. Strandings, incidental captures or biopsies have usually provided information in terms of common dolphin occurrence and geographical range in New Caledonia (*e.g.* Borsa, 2006) and South Australia (*e.g.* Kemper *et al.*, 2005; Ross, 2006; Bilgmann *et al.*, 2008; Hamer *et al.*, 2008; Möller *et al.*, 2011). However, a recent assessment of common dolphin distribution was provided for coastal waters of the Gulf St Vincent, South Australia (*e.g.* Filby *et al.*, 2010).

Besides knowledge inferred from by-catch (Meynier *et al.*, 2008b; Stockin *et al.*, 2009b), common dolphin encounters in New Zealand have also been reported via specific studies on human-dolphin interactions in the Bay of Islands (Constantine and Baker, 1997), the Hauraki Gulf (Stockin *et al.*, 2008a) and the east coast of the Coromandel Peninsula (Neumann and Orams, 2006). Encounters in the South Island have also been documented (Bräger and Schneider, 1998; Clement and Halliday, 2014) but their habitat remains unclear (Clement and Halliday, 2014). Dwyer (2014) provided the first fine scale examination of common dolphin distribution and habitat use in the Hauraki Gulf. However, knowledge of common dolphin distribution in the BOP is yet to be investigated, with an obvious need to understand the species distribution in oceanic regions other than just the east coast of the Coromandel Peninsula (Neumann, 2001).

1.6.1.2 Seasonality

Seasonal changes in common dolphin distribution have been reported in various regions and have usually been identified as inshore-offshore movements. For instance, common dolphins typically move offshore in winter and inshore during the summer in the southwestern Mediterranean (Cañadas and Hammond, 2008). The opposite trend is described in the northeastern Atlantic, where common dolphins are more abundant in offshore waters (200-2,000m) during summer (Lopez *et al.*, 2004; Cañadas *et al.*, 2009; Silva *et al.*, 2014) but move towards shallower waters of the continental shelf during winter (Pollock *et al.*, 2000; Macleod *et al.*, 2009). Similarly, common dolphin distribution extends further offshore and northwards in the northeastern Pacific off the Californian coast, with higher densities in summer compared to winter (Carretta *et al.*, 2000; Becker *et al.*, 2014). Such seasonal shifts are suggested to follow migration movements of prey species (Selzer and Payne, 1988; Cañadas and Hammond, 2008; Jefferson *et al.*, 2009; Oviedo *et al.*, 2010). For example, shifts to offshore waters have been linked with the movements of anchovies (*Engraulis encrasicolus*) in the Atlantic and displacement of sardines (*Sardina pilchardus*) in both the southwestern Mediterranean and off the southeast coast of South Africa (Cockcroft and Peddemors, 1990; Cañadas *et al.*, 2002; Cañadas and Hammond, 2008).

In New Zealand waters, and more specifically off the east coast of the Coromandel Peninsula, common dolphins have also been observed to perform a seasonal shift occurring closer to shore in summer and moving further offshore in winter, presumably linked to changes in SST and more specifically movements of the East Auckland Current (Neumann, 2001c). A similar pattern is also evident in the Hauraki Gulf, where common dolphins are found in shallower waters during the summer months (Stockin *et al.*, 2008b; Dwyer, 2014).

1.6.1.3 Habitat use

Common dolphins are typically considered pelagic (Gaskin, 1992), occurring in deep waters (200-2,000m) beyond the continental slope in the Mediterranean (Azzellino *et al.*, 2008a), North Atlantic (Hooker *et al.*, 1999; Lopez *et al.*, 2004; Silva *et al.*, 2014) and Pacific (Carretta *et al.*, 2000). However, the genus is also found in shallow waters over the continental shelf in the Atlantic (Di Beneditto *et al.*, 2001; Certain *et al.*, 2008; Jefferson *et al.*, 2009; Macleod *et al.*, 2009; Oviedo *et al.*, 2010; Robinson *et al.*, 2010) and Pacific (Stockin *et al.*, 2008b; Filby *et al.*, 2010, Dwyer, 2014). They also inhabit shallow waters of the continental slope in the Atlantic (Selzer and Payne, 1988; Kiszka *et al.*, 2007b; Pierce *et al.*, 2010) and the Mediterranean (Notarbartolo Di Sciara *et al.*, 1993).

In some areas, occurrence of common dolphins is reported in both deep and shallow waters (Cañadas and Hammond, 2008; Jefferson *et al.*, 2009; Becker *et al.*, 2014) and has been explained by differences in prey availability and feeding habits (Cañadas *et al.*, 2002; Cañadas and Hammond, 2008). Alternatively, given that sightings often refer to the entire *Delphinus* genus (Becker *et al.*, 2014), it has been suggested that differences in habitat use are linked to habitat partitioning between the short- and long-beaked forms (Heyning and Perrin, 1994; Jefferson *et al.*, 2009).

Behavioural aspects, and more specifically foraging behaviour, also seem to explain common dolphin use areas with prominent bathymetry such as the continental slope, shelf break or canyons (Hui, 1979, 1985; Selzer and Payne, 1988; Hooker *et al.*, 1999; Oviedo *et al.*, 2010). Such features provide foraging opportunities with higher prey resource enriched by local upwellings and concentrated by the steep bathymetry. Likewise, correlations have been made between common dolphin occurrence and highly productive areas such as waters influenced by upwellings (Au and Perryman, 1985; Selzer and Payne, 1988; Cañadas and Hammond, 2008; Jefferson *et al.*, 2009; Silva *et al.*, 2014), or between dolphin distribution and SST (Cañadas *et al.*, 2005, 2009; Cañadas and Hammond, 2008) or chlorophyll concentrations (Cañadas and Hammond, 2008; Moura *et al.*, 2012). However, it is more likely that those oceanographic features affect dolphins subsequently, while first influencing dolphin prey species (Cañadas and Hammond, 2008; Cañadas *et al.*, 2009).

Social organisation appears to also influence common dolphin habitat use (Cañadas and Hammond, 2008). For instance, groups containing calves showed a tendency for higher density towards shallower waters in the Mediterranean and were partly explained by foraging strategies of lactating females feeding on highly nutritive prey (Cañadas and Hammond, 2008). Similarly, in the Hauraki Gulf, nursery groups were primarily reported in shallower waters (Stockin *et al.*, 2008b), although a recent study reported groups containing neonates in deeper waters in areas of decreased slope (Dwyer, 2014).

1.6.1.4 Conservation status

Common dolphins are protected by various international and national legislation (Murphy *et al.*, 2013). On a global scale, short-beaked common dolphins are listed as “least concern” by the International Union for Conservation of Nature (IUCN, Hammond *et al.*, 2008b). However, the IUCN classified the Mediterranean common dolphins as “endangered” in 2003, after the population in the eastern Ionian Sea was discovered to be in decline (Bearzi *et al.*, 2005). Although the worldwide population is not considered to be under threat, factors affecting the Mediterranean population of common dolphin, *i.e.* fisheries by-catch, depletion of food resources caused by overfishing and pollution (Bearzi *et al.*, 2003), potentially pose similar threats to other populations.

In New Zealand, common dolphins are exposed to fisheries by-catch (Stockin *et al.*, 2009b; Thompson *et al.*, 2013), pollution (Stockin *et al.*, 2007) and anthropogenic activities including tourism activities (Neumann and Orams, 2006; Stockin *et al.*, 2008a; Meissner *et al.*, 2015). However, under the New Zealand Threat Classification System (Townsend *et al.*, 2008), this species remains currently classified as “not threatened” (Baker *et al.*, 2010). This is despite a lack of data on dolphin abundance and rigorous assessment of mortality of this species within New Zealand waters.

1.6.2 New Zealand fur seals

New Zealand fur seals belong to the pinniped subfamily of *Otariidae*. Before the colonisation of New Zealand by Polynesians, fur seals occurred in the North and South Island, as well as on offshore and sub-Antarctic islands (Lalas and Bradshaw, 2001; Baird, 2011). However, the species was decimated from north to south by hunting after Māori arrived in New Zealand (Lalas and Bradshaw, 2001), with the breeding range eventually confined to the southwestern part of the South Island (Lalas and Bradshaw, 2001; Baird, 2011). The subsequent colonisation of New Zealand by Europeans marked the beginning of an intense and unregulated sealing industry in the South Island and offshore islands, bringing the species close to extinction (Lalas and Bradshaw, 2001).

1.6.2.1 Distribution

The species is present in southern and western Australia, and on offshore islands on the east coast of Australia (*e.g.* Goldsworthy and Shaughnessy, 1994; Arnould *et al.*, 2000; Harcourt, 2001; Shaughnessy and McKeown, 2002; Shaughnessy *et al.*, 2010; Campbell *et al.*, 2014, Figure 1.6). Limited gene flow seems to occur between both Australian and New Zealand populations (*e.g.* Lento *et al.*, 1994, 1997; Berry *et al.*, 2012).

Since their total protection in 1978 under the MMPA (1978), New Zealand fur seals have increased in numbers and their range has expanded northward along the New Zealand coasts and on the offshore and sub-Antarctic islands (*e.g.* Crawley and Wilson, 1976; Carey, 1998; Lalas and Bradshaw, 2001), dispersing as far North as the Three Kings Islands (*e.g.* Crawley and Wilson, 1976; Cawthorn, 1981; Baird, 2011). Fur seals have been recolonising marine coastal habitats mainly in the South Island (*e.g.* Lalas and Harcourt, 1995; Taylor *et al.*, 1995; Bradshaw *et al.*, 2000b; Boren *et al.*, 2006b). However, as the population is recovering, breeding colonies have been reestablished in the south of the North Island (*e.g.* Dix, 1993). On the west coast, breeding colonies have been reported off Taranaki (Miller and Williams, 2003). Recently, pups have also been sighted further north, in the Waikato region (Bouma *et al.*, 2008). On the east coast, seals have been visiting the BOP since the late 1970s, with evidence of recolonisation since the 1990s (Cowling *et al.*, 2013). A breeding colony has since reestablished in the eastern part of the region since the mid-2000s (Cowling *et al.*, 2014).

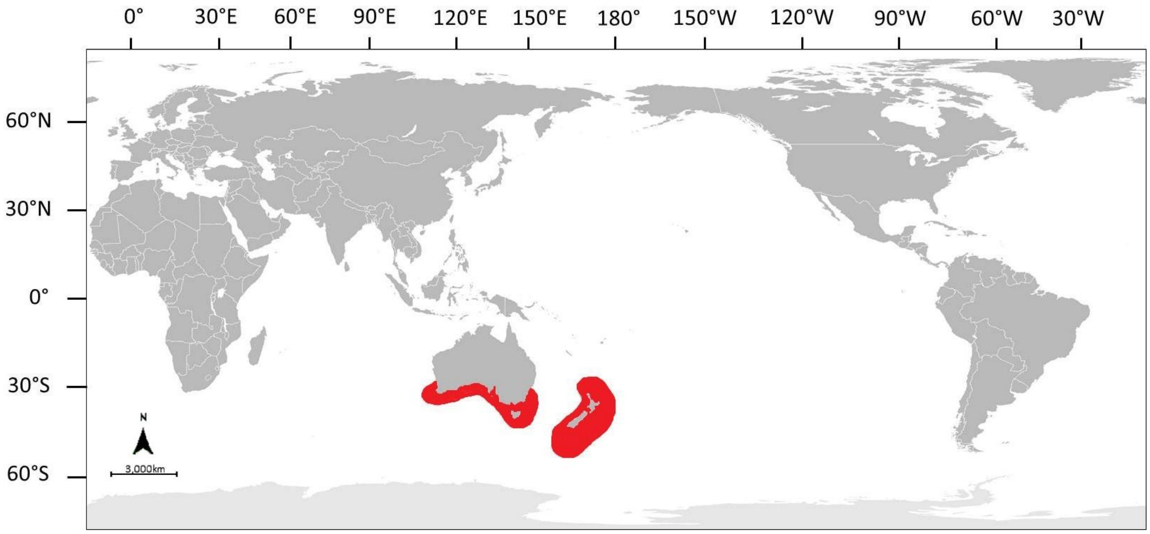

Figure 1.6: Global distribution of New Zealand fur seals (*Arctocephalus forsteri*).

1.6.2.2 Seasonality

Seasonal variation in fur seal distribution is observed and determined by animal gender and maturity (Baird, 2011). In New Zealand, adult males arrive at breeding colonies from late October to establish their territories (Crawley and Wilson, 1976). Females arrive in November and pupping occurs between mid and late December (Lalas and Harcourt, 1995; Boren, 2005). Males typically leave colonies by February (Crawley and Wilson, 1976) and disperse to non-breeding haul out sites (Bradshaw *et al.*, 1999a), with higher densities recorded in July-August (Crawley and Wilson, 1976). Conversely to males, females remain at the breeding colonies for *ca.* 10 months until August-September (Crawley and Wilson, 1976), when pups are weaned, alternating pupping and short foraging trips at sea.

1.6.2.3 Habitat use

New Zealand fur seals alternate foraging trips at sea and breeding periods ashore, typically during austral summer (Miller, 1975; Crawley and Wilson, 1976; Goldsworthy and Shaughnessy, 1994). Terrestrial habitats include a variety of rocky coastlines with the preferred areas determined by direct access to the sea (Crawley and Wilson, 1976). Breeding colonies require sheltered areas from heat, heavy sea and predators, as well as an easy access to the water or some cooling pools (Crawley and Wilson, 1976; Bradshaw *et al.*, 1999b). Both types of colonies are further determined by the availability and distribution of prey resources (Boyd, 1991; Bradshaw *et al.*, 2000a) and human disturbance (Taylor *et al.*, 1995).

Marine habitat choice varies seasonally. Close to the breeding season, fur seals typically forage over the continental shelf and slope, in depths shallower than 200m and up to *ca.* 30km offshore (Sinclair and Wilson, 1994; Harcourt *et al.*, 2002). Outside the breeding season, foraging trips increase in duration as animals travel beyond the continental slope (Sinclair and Wilson, 1994; Harcourt, 2001; Harcourt *et al.*, 2002; Baylis *et al.*, 2008, 2012). The seasonal shift in habitat corresponds to subsequent shift in diet, inferred from the difference in diving profile between the warm (*i.e.* summer and autumn) and the cold season (*i.e.* winter and spring). Indeed, during summer, fur seals are found to perform short, shallow and nocturnal dives (Mattlin *et al.*, 1998; Harcourt *et al.*, 2002), suggesting prey species may include pelagic and vertical migrating species. Conversely, seals dive deeper (>150m) and longer in winter (Mattlin *et al.*, 1998; Harcourt *et al.*, 2002), suggesting that they feed on benthic, demersal and pelagic species (Harcourt *et al.*, 2002). However, it is worth highlighting that most of foraging research on New

Zealand fur seals has focused on lactating females (Sinclair and Wilson, 1994; Mattlin *et al.*, 1998; Harcourt *et al.*, 2002). Foraging distribution, *i.e.* distribution at sea, may therefore be potentially different for males or juveniles (Baird, 2011), owing to their different physiological constraints and energetic requirements (Page *et al.*, 2005). This is indeed supported by analysis of scats and regurgitates indicating a wider use of deeper waters than the foraging study of lactating fur seals (Fea *et al.*, 1999).

1.6.2.4 Conservation status

On a global scale, New Zealand fur seals are listed as “least concern” by the IUCN (Goldsworthy and Gales, 2008) and at a national scale, they are considered as “not threatened” (Baker *et al.*, 2010) under the New Zealand Threat Classification System (Townsend *et al.*, 2008). With the subsequent recolonisation of the fur seal population, the effect of the species on the marine environment and on human activities (*i.e.* interactions and/or conflicts with fisheries, Lalas and Bradshaw, 2001) has gradually lead to an increasing interest from scientists, conservationists, the tourism and fishing industries since the late 1990s (Boren *et al.*, 2002, 2006a; Page *et al.*, 2004; Goldsworthy and Page, 2007).

Besides natural mortality, New Zealand fur seals are vulnerable to human-induced sources of mortality including entanglement in fishing gear (Baird, 2005; Boren *et al.*, 2006a; Abraham *et al.*, 2010). Most importantly, there is a great concern over incidental by-catch of New Zealand fur seals by trawl operations for hoki (*Macruronus novaezelandiae*), squid (*Nototodarus* spp.) and southern blue whiting (*Micromesistius australis*) around the coastline of the South Island and the offshore islands (Abraham *et* *al.*, 2010). Most of the fisheries that reported incidental captures occur in waters around the continental shelf which, around much of the South Island and offshore islands, slopes to deep waters relatively close to shore, and thus in proximity of breeding colonies and haul out sites (Baird, 2011). For instance, the area targeted by trawl operation for hoki on the west coast of the South Island are *ca.* 100km from the breeding colonies (Sinclair and Wilson, 1994) between June and September (Baird, 2005). Therefore, by-catch most likely affects pregnant or lactating females, which have dependent pups ashore. The loss of mature females can consequently to slow down the recovery of fur seal population.

Incidental captures in commercial fisheries has been quantified for larger fisheries (Baird, 2005). However, interactions between fur seals and small fisheries within inshore waters remain poorly documented (Baird, 2011), although these practices contribute to about half of the annual trawl effort (Smith and Baird, 2009). Similarly to common dolphins, abundance of New Zealand fur seals remains unknown, with only an approximate estimation of 100,000 individuals (Harcourt, 2001). The lack of knowledge relating to the population abundance and extent of the incidental mortality due to fishery activities is of concern as it precludes the ability to assess any potential future decline in the population.

1.7 Thesis rational

Conservation efforts and management actions for marine mammals are largely focused on coastal areas (Hooker and Gerber, 2004; Correia *et al.*, 2015; Mannocci *et al.*, 2015), highly motivated by the perceived gravity of the threats (*e.g.* ship collisions, Laist *et al.*, 2001; pollution, Aguilar *et al.*, 2002; fisheries by-catch, Read, 2008; Hammond *et al.*, 2013; Whitty, 2015) and prioritised according to the species status (Hooker and Gerber, 2004; Pompa *et al.*, 2011; Dwyer *et al.*, 2014b). For instance, the rapid decline in the Mediterranean short-beaked common dolphin population (Bearzi *et al.*, 2003) and the species reclassification as endangered in the IUCN Red List (Hammond *et al.*, 2008b), resulted in the development of protective measures (Notarbartolo Di Sciara, 2002). Similarly, following concerns over the incidental by-catch of harbour porpoises (*Phocoena phocoena*) in the North Sea (Tregenza *et al.*, 1997; Vinther, 1999), conservation plans and mitigation strategies have been implemented (Reijnders *et al.*, 2009). Likewise, scientific research has often, if not always, evaluated effects of tourism activities on marine mammal behaviour after operations were well established and given priority to species most frequently encountered by tour operators (*e.g.* Constantine, 2001; Christiansen *et al.*, 2010; Scarpaci *et al.*, 2010; Lundquist *et al.*, 2013; Filby *et al.*, 2014) .

The BOP is second only to the Bay of Islands as the busiest destination for cetacean watching in the North Island (O'Connor *et al.*, 2009) with a tourism industry growing for the last 25 years. Despite this, marine mammal conservation has been given attention only recently. That has translated into a moratorium on further commercial permits and two commissioned studies aiming at evaluating the effects of vessel interactions on the behaviour of New Zealand fur seals and common dolphins (Cowling *et al.*, 2014; Meissner *et al.*, 2014). However, in the absence of baseline information, identifying factors responsible of changes in species abundance, distribution or behaviour and minimising effects upon populations can be challenging (Bearzi *et al.*, 2003).

There was, therefore, an urgent need to evaluate the composition of the marine mammal community in the BOP and assess their spatial and temporal distribution. Despite a broader lack of dedicated scientific surveys, the use of existing opportunistic datasets was considered important. However, identifying and evaluating biases associated with those data was first required, before investigating historical occurrence and distribution of the species.

In order to assess the extent of potential human interactions with common dolphins and New Zealand fur seals in space and time, a comprehensive understanding of the relationship between the species and their habitat was required (*i.e.* a sound knowledge of species distribution, habitat use and behavioural budget activity, Hooker and Gerber, 2004; Cañadas *et al.*, 2005; Cañadas and Vazquez, 2014). Dedicated surveys were consequently conducted to describe the spatial and temporal distribution of common dolphins and New Zealand fur seals in the region.

To fulfil the contract for the Department of Conservation, there was an urgency to evaluate the level of vessel traffic and interactions with common dolphins and investigate their behavioural response. Finally, the potential for cumulative tourism exposure was examined while assessing dolphin site fidelity and identifying individuals exposed to repetitive interactions with tour vessels.

1.8 Thesis structure

This thesis comprises four research chapters (Chapters 2 to 5) complemented by a general introduction (Chapter 1) and discussion (Chapter 6). The research chapters have been written in publication format, representing a manuscript that is either published

(Chapter 4) or in preparation for publication (Chapters 2, 3 and 5). In addition, Chapter 4 formed part of the commissioned report for the Department of Conservation, East Coast Bay of Plenty Conservancy (Meissner *et al.*, 2014). Consequently, the format of this thesis results in some unavoidable repetitions, especially in terms of the methods applied and description of the study site. However, effort was made to limit duplication where possible. The outline of each chapter is as follows:

Chapter 1 provides background information on methods used for marine mammal data collection including a brief description of their uses and limitations. Given that commercial whale/dolphin watching platforms provide substantial information available to marine mammal knowledge, an overview of the marine mammal tourism industry at an international, national and regional scale is further provided. This chapter further stresses the importance of identifying environmental factors related to species distribution in order to implement effective conservation initiatives. Finally, the chapter introduces the study area as well as the two species most targeted by tourism activities in the BOP, the common dolphin and the New Zealand fur seal. Aspects of their distribution, seasonality, habitat use and conservation status are discussed with respect to the current literature available. The chapter was written by A.M. Meissner and improved by edits and suggestions provided by K.A. Stockin, E. Martinez and M.B. Orams.

Chapter 2 evaluates the use of historical opportunistic data by assessing their reliability to provide the first quality assured insights into the historical occurrence of marine mammal species encountered within the wider BOP. Data for this chapter were collected between 1974 and 2014 by various observers (*i.e.* fishermen, tour operators, researchers) aboard platforms of opportunity and kindly provided by G. Butler, C. Fines,

M. Fitzpatrick, C. Schweder-Goad and R. Tully. Analyses were performed by A.M. Meissner. Assistance with spatial analysis and statistics was provided by C.D. Macleod, M.D.M. Pawley, G. Pierce and J. Roberts. The chapter was written by A.M. Meissner and improved by edits and suggestions provided by K.A. Stockin, E. Martinez and M.B. Orams.

Chapter 3 examines common dolphin and fur seal distribution, density and group dynamics at a fine geographical scale in the western BOP sub-region, where the majority of tourism operations occur. This provides the first comprehensive baseline information to help with management and conservation plans. Data were collected year-round between November 2010 and May 2013 during surveys aboard an independent research vessel and four opportunistic platforms of observation. Habitat use for the species was examined in relation to temporal and spatial scales using a Geographic Information System (GIS). Density rates were calculated and kernel estimate maps created. Data collection and analysis for this chapter were performed by A.M. Meissner. Statistical advice was provided by M.D.M. Pawley. Suggestions on some aspects of density analysis were kindly provided by D. Clement and S.L. Dwyer. The chapter was written by A.M. Meissner and improved by edits and suggestions provided by K.A. Stockin, E. Martinez and M.B. Orams.

Chapter 4 investigates the effects of tourism activities on common dolphin behaviour. For the first time, level of vessel traffic and interactions, including commercial and recreational viewing and swimming activities, were assessed. Variations in the dolphin responses to vessel interaction were examined by innovatively applying two approaches of Markov chain analysis. Compliance of tourism operations with regards to permit conditions and to the MMPR (1992) was also evaluated in the framework of the commissioned contract for the Department of Conservation. Data for this chapter were primarily collected by A.M. Meissner during fieldwork conducted in the western BOP sub-region between November 2010 and May 2013. Data analyses, advised by F. Christiansen, E. Martinez and M.D.M Pawley, were performed by A.M. Meissner. The chapter was written by A.M. Meissner and improved by edits and suggestions provided by K.A. Stockin, F. Christiansen, E. Martinez, M.D.M Pawley and M.B. Orams. This chapter is a reformatted version of an unpublished report to the Department of Conservation, co-authored with E. Martinez, M.B. Orams and K.A. Stockin, and a peer-reviewed article published in *PLoS One* co-authored by F. Christiansen, E. Martinez, M.D.M Pawley, M.B. Orams and K.A. Stockin.

Chapter 5 investigates the cumulative effects of tourism activities on common dolphins. This is the first attempt to use photo-identification to estimate the minimum number of individuals closely interacting with tour vessels and to quantify interactions between dolphins and vessels to assess for repetitive interactions. Site fidelity of common dolphins within the region was further investigated. Photographs were primarily collected by A.M. Meissner during fieldwork conducted in the BOP between November 2010 and May 2013 aboard an independent research vessel and several tour vessels. Assistance with the catalogue and photo-ID process was kindly provided by T. Plencner, J. Ransijn, R. Vaton and K. Hupman. Data analyses were performed by A.M. Meissner assisted by T. Plencner. The chapter was written by A.M. Meissner and improved by edits and suggestions provided by E. Martinez, M.B. Orams and K.A. Stockin.

Chapter 6 concludes by discussing the results of the research chapters in relation to each other, places these findings within the perspective of marine mammal tourism in the BOP region and provides implications in terms of management initiatives.

Chapter 2

The use and contribution of opportunistic data to infer historical occurrence of marine mammals off the Bay of Plenty, New Zealand: A critical approach

Humpback, minke, killer whales and bottlenose dolphins encountered in the Bay of Plenty, New Zealand (from top left to bottom right).

2.1 Introduction

Marine ecosystems are complex and dynamic. Temporal variability operates on short to long term scales, as illustrated by daily cycles, seasonal fluctuations or long-term global climate changes (Fiechter and Mooers, 2007; Keller *et al.*, 2015). Similarly, spatial variability can be observed on scales from several meters to thousands of kilometres, related to tides, upwelling systems or ocean gyres (Mann and Lazier, 2005; Olbers *et al.*, 2012). These physical processes largely influence biological components in the ocean, including distribution and habitat use of marine mammals (Stern, 2009; McClellan *et al.*, 2014). Assessing marine mammal distribution or monitoring populations can, therefore, be challenging and usually require extensive effort given the spatio-temporal constraints driven by data collection in the field (Robbins and Mattila, 2000; Kiszka *et al.*, 2004; Hammond *et al.*, 2006; Hauser *et al.*, 2006; Redfern *et al.*, 2006; Viddi *et al.*, 2010; Williams *et al.*, 2011; Moura *et al.*, 2012; McClellan *et al.*, 2014). However, budget restrictions, time and geographic limitations, as well as characteristics of the species in question, are frequent obstacles to such long-term systematic data collection (Kiszka *et al.*, 2004; Tepsich *et al.*, 2014). Therefore, besides traditional dedicated research surveys, where data are acquired following a scientific rigorous protocol, marine mammal research has extensively relied on opportunistic data, where sightings are collected either occasionally and/or in a non-systematic manner.

Stranding records or incidental sightings collected from land (Camphuysen, 2004; Siebert *et al.*, 2006; Pikesley *et al.*, 2012) or aboard platforms of opportunity, *e.g.*, ferries and cruise ships (Williams *et al.*, 2006a; Gómez de Segura *et al.*, 2007; Macleod *et al.*, 2009; Cotté *et al.*, 2010; McClellan *et al.*, 2014), fishing boats (Scott and Chivers, 1990; Fiedler and Reilly, 1994; Fernandez-Contreras *et al.*, 2010; Thompson *et al.*, 2013) or whale-watching vessels (MacLeod *et al.*, 2004; Azzellino *et al.*, 2008a; Wiseman *et al.*, 2011) have often constituted an opportunistic baseline of data for assessing cetacean abundance estimates, examining species distribution or providing information on their habitat use. This is especially so to inform on rare, elusive or inconspicuous species (Wiley *et al.*, 1994; Ritter and Brederlau, 1999; Ford, 2005; Williams *et al.*, 2011; Constantine *et al.*, 2014a; Tepsich *et al.*, 2014), to determine species presence in data deficient areas (Evans and Hammond, 2004; Redfern *et al.*, 2006; Williams *et al.*, 2006a; Ingram *et al.*, 2007; Viddi *et al.*, 2010; Félix and Botero-Acosta, 2011; Moura *et al.*, 2012; Correia *et al.*, 2015) or to draw attention to areas of ecological importance and implement future dedicated research (Evans and Hammond, 2004; Kiszka *et al.*, 2004; Hauser *et al.*, 2006; Williams *et al.*, 2006a; Compton *et al.*, 2007; Davidson *et al.*, 2014; McClellan *et al.*, 2014; Correia *et al.*, 2015). For instance, in response to concerns over incidental by-catch of harbour porpoises (*Phocoena phocoena*, Tregenza *et al.*, 1997; Vinther, 1999), extensive dedicated sighting surveys were conducted in the North East Atlantic to estimate species abundance and assess threat levels (Hammond *et al.*, 2002, 2006). Similarly, based on opportunistic data, Torres (2013) identified the South Taranaki Bight, New Zealand, to represent an important foraging area for blue whales (*Balaenoptera musculus*), which subsequently led to dedicated surveys confirming this hypothesis (Torres *et al.*, 2014).

While studies relying on data collected opportunistically can provide important insights on species occurrence and distribution patterns (Williams *et al.*, 2006a; Moura *et al.*, 2012; Jefferson *et al.*, 2014; McClellan *et al.*, 2014; Smultea and Jefferson, 2014), inherent biases, due to non-systematic sampling must be identified and addressed prior to data analysis and interpretation (Robbins and Mattila, 2000; Hauser *et al.*, 2006; Siebert *et al.*, 2006; Pikesley *et al.*, 2012; McClellan *et al.*, 2014). A simple and basic illustration of this relies on the correct identification of species (Evans and Hammond, 2004; Hauser *et al.*, 2006; Moura *et al.*, 2012; Cheney *et al.*, 2013), which highly depends upon biases associated with observer ability and experience, as well as platform type (Evans and Hammond, 2004; Compton *et al.*, 2007). Moreover, biases associated with opportunistic data limit their use in scientific analysis. For example, when data are not related to observation effort, abundance estimation cannot be calculated (Clapham, 1988; Kiszka *et al.*, 2004). Similarly, photo-identification undertaken using opportunistic methodology only provides access to partial interpretation (Clapham, 1988; Robbins and Mattila, 2000; Weir *et al.*, 2008; Félix and Botero-Acosta, 2011; Chapter 5). Consequently, those biases have to be accounted for in the analyses and carefully considered when interpreting results. By identifying inaccuracies associated with opportunistic data (*i.e.* under- or over-estimation of group size, inconsistency in recording mature and immature animals) while comparing their results to scientifically collected data, Hupman *et al.* (2014) recently examined the occurrence and group dynamics of killer whales (*Orcinus orca*) in the Hauraki Gulf, New Zealand, and provided further recommendations on future data collection aboard platforms of opportunity.

Situated on the east coast of North Island, New Zealand, the Bay of Plenty (BOP), is a region of great importance in terms of marine-based activities. Indeed, shipping is one of the leading industries in the region, with the largest port in the country in terms of total cargo volume located in Tauranga (Port of Tauranga, 2014, Figure 2.1). The region supports a range of important commercial and recreational fisheries (*e.g.* pure seine trawling for skipjack tuna, *Katsuwonus pelamis*, set-netting for trevally, *Pseudocaranx dentex*, and snapper, *Chrysophrys auratus*, aquaculture, game fishing, Park, 1991). Additionally, deep sea oil exploration is under development north of East Cape (Reid and van Halderen, 2013). Furthermore, the BOP is second only to the Bay of Islands as the busiest destination for cetacean watching in the North Island, New Zealand (O'Connor *et al.*, 2009; Chapter 4). All these activities have the potential to negatively affect marine mammals in areas where species habitat and human activities overlap (McClellan *et al.*, 2014). However, the existence or extent of detrimental anthropogenic activities on local populations remains unknown given that the ecology of marine mammals in the central BOP has so far not been studied. There have been only a few dedicated research studies on common dolphins, most of which have focused off the east coast of the Coromandel Peninsula (*ca.* 100km northwest of the BOP, Neumann, 2001a, c; Neumann *et al.*, 2002; Neumann and Orams, 2003, 2006; Meissner *et al.*, 2015). The only study on New Zealand fur seals (*Arctocephalus forsteri*) in BOP waters is that of Cowling *et al.* (2014), who recently completed a tourism impact study following concerns over potential effects on the local population.

Despite a broader lack of surveys within the BOP region, data on marine mammals exist in the form of incidental stranding records and opportunistic observations of marine mammals (*e.g.* Gaborit-Haverkort and Stockin, 2011; Gaborit-Haverkort, 2012). Considering the lack of robust dedicated scientific surveys within the region, the use of opportunistic datasets to investigate historical marine mammal occurrence and distribution within the area may be beneficial. However, a need to assess such data for accuracy and potential biases, alongside that of potential trends in marine mammal occurrence within the region is required. In this chapter, data collected opportunistically were therefore critically evaluated in order to extract, where possible, historical trends about the historical use of the BOP waters by marine mammals.

Specifically, this chapter aimed to offer first insights into the historical seasonality and distribution of marine mammals in the BOP waters using scrutinised standardised opportunistic data. More specifically, the objectives of this chapter were to:

- Identify and evaluate biases associated with opportunistic data available for the BOP region.
- Standardise the data in terms of species/groups of species, spatial and temporal scales.
- Provide first insights into the historical occurrence and distribution of marine mammals using the BOP waters.

2.2 Methods

2.2.1 Study area

The BOP (37.0500°S; 175.5500°E and 38.0000°S; 178.5700°E) is situated on the north east coast of the North Island, New Zealand (Figure 2.1). The region can be divided into three major sub-regions: the western, the eastern and East Cape sub-regions (Figure 1.2, Chapter 1, Section 1.5). From a bathymetric perspective, the western and eastern sub-regions are characterised by a relatively wide continental shelf, conversely to the East Cape sub-region (Park, 1991, Figure 1.2, Chapter 1, Section 1.5). The BOP is also characterised by complex hydrographic features, mainly dominated by the East Auckland Current (Chapter 1, Section 1.5).

2.2.2 Data collection and classification

2.2.2.1 Observer ability to correctly identify marine mammal to species

Marine mammal sightings were collected between 1974 and 2014 by various stakeholders aboard platforms of opportunity (Table 2.1). In the absence of supporting evidence to verify species identification (*i.e.* photographs, video or description of diagnostic characters) and owing to the potential difficulty of distinguishing species at sea and/or ambiguity between some species, observer ability to successfully identify marine mammals to correct species level was investigated and rated. “Experts” were defined as trained and/or experienced observers and included scientists, research students and officers from the Department of Conservation. “Tour operators” (*i.e.* skippers and crew) were considered observers with a good working knowledge of the species likely occurring in the region, given they specifically target marine mammals in their daily activities and approach them within close proximity (*ca.* within meters). “Mariners” were defined as observers spending large proportions of their time out at sea but whose activities were not specifically related to marine mammal observation (*i.e.* harbour masters, fishers, coastguards, ferry skippers). Their level of expertise was, therefore, considered limited for successful taxonomic identification of marine mammals. Finally, sightings for which the source was unknown or sightings reported by members of the public were classified as “non-experienced observers”. Owing to the uncertainty over the reliability of species identification, sightings related to this category were discarded from the dataset based on the presumed likelihood of species misidentification. All sightings were opportunistic only, with no information on the survey tracks, vessel speed or conditions at sea available for use within the analysis or as a proxy of effort.

Table 2.1: Origin of historical data for marine mammals in the Bay of Plenty, New Zealand.

Origin of the data	**Dates**	**Data originally provided**	**Data discarded (including strandings or carcasses at sea)**	**Data kept after standardisation**	**Purpose of collecting the data**
R. Tully, Department of Conservation liaison volunteer, Whakatane	1974-2013	3,344	2,217 (93)	1,127	Data were collected from various stakeholders (fishermen, tour operators, coastguards, etc) on behalf of the Department of Conservation (Whakatane), in order to dispose of a centralised database for marine mammals off Whakatane.
G. Butler, tour operator, Tauranga	1998-2010	2,219	1,415 (2)	804	Tour operator logbook
M. Fitzpatrick and C. Shweder Goad (BOP Polytechnic, Tauranga)	2001-2007	702	590 (0)	112	BOP Polytech student project with student operating on a tour vessel off Tauranga
P. Van Dusschoten, tour operator, Whakatane	2010-2012	100	94 (0)	6	Tour operator logbook
	Total	6,365	4,316 (95)	2,049	

2.2.2.2 Confidence in species identification

Successful species identification was ranked using confidence classification (Table 2.2). Confidence levels of “high”, “moderate” and “low” were assigned based on the likelihood the species could be successfully identified by each predefined observer group (*i.e.* experts, tour operators and mariners). Confidence criteria accounted for the (i) presence of key diagnostic features which may aid successful identification (*e.g.* sexually dimorphic dorsal fin in killer whales, unique tri-pigmentation pattern of common dolphins) and (ii) likelihood of morphologically similar species being present within the BOP region. For example, given the likelihood of confusion between pilot (*Globicephala* spp.) and false killer whales (*Pseudorca crassidens*, Table 2.2), both species were examined as a single group referred hereafter as “blackfish”. Similarly, the likelihood of misidentification between minke (*B. acutorostrata*), sei (*B. borealis*), Bryde’s (*B. brydei*), blue (*B. musculus*) and fin whales (*B. physalus*), resulted in those species being examined under the genus *Balaenopteridae* (Table 2.2). However, the elongated pectoral flippers of humpback whales (*Megaptera novaeangliae*, Table 2.2) were deemed distinguishable enough compared to other *Balaenopteridae* to examine the species independently. Moreover, this species is one of the most commonly targeted (O'Connor *et al.*, 2009) and consequently likely recognised species by tour operators in Australasia.

Table 2.2: Species (or group of species) identification, description and associated confidence rates of observers to accurately identify them in the Bay of Plenty, New Zealand.

		Confidence rate		
Species	**Ranking criteria**	**Experts**	**Tour operators**	**Mariners**
Common dolphins, *Delphinus* sp.	- Most abundant marine mammal species in the BOP (Gaborit-Haverkort and Stockin, 2011; Chapter 3). - Focus of the tourism industry in BOP waters. - No other tri-pigmented small delphinid in the region (Chapter 3).	High	High	High
Bottlenose dolphins, *Tursiops truncatus*	- Clear size and pigmentation differences between this and the most likely confused species occurring in the region, the common dolphin. - Focus of tourism industry in other regions of New Zealand, so easily identified. - Infrequently encountered in the BOP (Gaborit-Haverkort and Stockin, 2011; Meissner *et al.*, 2014; Chapter 3), so specifically noteworthy when encountered by tour operators (Meissner *et al.*, 2014).	High	High	High
Killer whales, *Orcinus orca*	- Unique pigmentation patterns and pronounced sexually dimorphic male dorsal fin (Baird and Stacey, 1988; Visser and Mäkeläinen, 2000; Ford, 2009). - Publically recognised due to outreach of Orca Research Trust and 0800 SEE ORCA	High	High	High
New Zealand fur seals, *Arctocephalus forsteri*	- Only pinniped species reliably encountered in the North Island, New Zealand (Gaborit-Haverkort and Stockin, 2011; Chapter 3) - Other pinnipeds (*i.e.* New Zealand sea lion, *Phocarctos hookeri*, leopard seal, *Hydrurga leptonyx*, Southern elephant seal, *Mirounga leonine*) generally restricted to offshore islands (Childerhouse and Gales, 1998; Harcourt, 2001).	High	High	High

Table 2.2 (*continued*): Species (or group of species) identification, description and associated confidence rates of observers to accurately identify them in the Bay of Plenty, New Zealand.

		Confidence rate		
Species	**Ranking criteria**	**Experts**	**Tour operators**	**Mariners**
Blackfish: Pilot, *Globicephala* spp., and false killer whales, *Pseudorca crassidens*	- Differences in head and dorsal fin shape and position enable accurate identification by expert observers (Jefferson *et al.*, 1993). - Both species confused by some experienced observers such as tour operators and often likely by most mariners (Frantzis *et al.*, 2003; Castro, 2004; Baird, 2010; Zaeschmar, 2014) and consequently often examined as a group (*i.e.* blackfish; Kasuya, 1971; Brabyn, 1991).	High	Moderate	Low
Balaenopteridae	- Apart from the size, pigmentation, fin position/shape and blow, *Balaenopteridae* species (*i.e.* northern minke, *B. acutorostrata*, sei, *B. borealis*, Bryde's, *B. brydei*, blue, *B. musculus*, and fin whales, *B. physalus*) are similar in external appearance, thus records may potentially be misidentified (Jefferson *et al.*, 1993; O'Callaghan and Baker, 2002; Jefferson and Hung, 2007; Smultea *et al.*, 2010). - All species of the genus *Balaenopteridae* have been confirmed in the BOP through stranding events (Gaborit-Haverkort and Stockin, 2011) and/or sightings collected during dedicated surveys (Chapter 3).	High	Moderate	Low
Sperm whales, *Physeter macrocephalus*	- The characteristic blow exhalation and body shape (similar to a log floating at the surface of the water) make the species recognisable from a closer distance, yet likely to be confused with humpback whales at greater distance (Jefferson *et al.*, 1993).	High	Moderate	Low

Table 2.2 (*continued*): Species (or group of species) identification, description and associated confidence rates of observers to accurately identify them in the Bay of Plenty, New Zealand.

		Confidence rate		
Species	**Ranking criteria**	**Experts**	**Tour operators**	**Mariners**
Beaked whales, *Ziphiidae*	- From a distance, beaked whales can be easily confused with minke whales (Jefferson *et al.*, 1993). - From a closer distance, the head and fin shape allow distinction between beaked whales and minke whales (Jefferson *et al.*, 1993). - Elusive, deep diving nature of all beaked whales hinders their successful identification to species level when at sea, even for experienced experts.	Moderate	Low	Low
Humpback whales, *Megaptera novaeangliae*	- From a distance, can be mistaken with other whales because of the shape of the blow and small dorsal fin (Jefferson *et al.*, 1993). - From a closer distance, easily distinguished by the head and body shape, as well as the size of the elongated pectoral fins (Jefferson *et al.*, 1993). - One of the most common species the whale-watching industry focuses on in Australasia (O'Connor *et al.*, 2009).	High	Moderate	Low
Southern right whales, *Eubalaena australis*	- The absence of dorsal fin, large head, arched mouthline, presence of callosities, combined to the V-shaped blow are distinct features making misidentification unlikely at close range (Jefferson *et al.*, 1993).	High	Moderate	Low

2.2.3 Data processing

Strandings can represent an important source of information for studying cetacean ecology, especially when identifying anthropogenic causes of mortality (e.g., Kemper *et al*., 2005; Stockin *et al.*, 2009b), determining species diet (Beatson *et al.*, 2007a; Santos *et al*., 2007; Kretzmann *et al*., 2010) or assessing individual health condition (Jepson *et al.*, 1999; Hall *et al.*, 2010). However, their statistical credibility is often disputed when examining occurrence and distribution of cetacean populations (Chit *et al.*, 2012; Jefferson *et al.*, 2014). Indeed, the area of death is considered to be a best indicator of the individual habitat use as opposed to the stranding location itself. Stranding location would require corrections using drift prediction models in order to determine the origin of the animals (Peltier *et al.*, 2012, 2013, 2014; Louis *et al.*, 2014). As this was beyond the scope of this study, strandings or carcasses observed at sea were discarded from the dataset (n=95, 1.49% of the original dataset). Sightings outside the limits of the study area (Section 2.2.1) and those not referenced spatially or temporally were also removed. When provided as latitude and longitude locations, the position of each observation was assumed to refer to the position of the initial sighting. When the sighting location was reported as distance and heading (*e.g.* N, E, S, W, NE etc…) to a point of interest on the coast, the position was calculated using ArcMap© 10.2 (ESRI, 2013, Redlands, California, USA). Fur seals were considered part of a haul out site if on shore or within 500m of the shore.

Data were also standardised temporally. Data missing any information about the day, month or year of the observation were discarded from the database. All records prior to 1 December 2000 and subsequent to 30 November 2010 were removed, as sightings outside this period were sparse. Sightings were classified according to austral seasons as per Torres *et al.* (2013). Austral seasons were defined as summer extending from December to February (with summer 2001 defined as December 2000 to February 2001), autumn extending from March to May, winter from June to August and spring from September to November. This facilitated comparisons between this and former comparative scientific studies (*e.g.* Stockin *et al.*, 2008b; Wiseman *et al.*, 2011; Dwyer, 2014; Zaeschmar *et al.*, 2014). Data were also pooled across the warm (*i.e.* summer and autumn) and cold (*i.e.* winter and spring) seasons (herein referred as bi-seasons), when required. To avoid pseudo-replication (*i.e.* records of a same group or individuals), only one observation per species/group species, day and sub-region was used in the analysis.

Information relative to behaviour and group dynamic were not considered in the analysis owing to numerous uncertainties and potential related biases. Firstly, the information was not reported systematically by observers. Secondly, it was uncertain if information reflected the behavioural state of the majority of the group (Lusseau, 2003a; Stockin *et al.*, 2009a; Meissner *et al.*, 2015; Chapter 4) or just conspicuous behaviours of some individuals. Finally, it also remains unclear whether data relative to behaviour, group size or composition were assessed at the onset of the encounter or during the overall encounter (Martinez and Stockin, 2011).

2.2.4 Data analysis

An overall confidence ranking for successful identification for each species/group of species was designated for the purpose of analysis. This was assigned by taking into consideration the rankings given for each observer group (*i.e.* experts, tour operators, mariners, Table 2.2) and the proportion of records originating from each observer type. For example, if a species/group of species scored “high”, “moderate” or “low” for all three observer groups, the overall pooled ranking of this species/group of species would be “high”, “moderate” or “low”, respectively. However, if the species/group of species ranked “high”, “moderate” and “low” for experts, tour operators and mariners, respectively, but more than 50.0% of records reported for that species/group of species originated from mariners, the overall ranking was considered “low”. Where more than 50.0% of records for a species/group of species originated from tour operators, the pooled ranking was “moderate”.

Species seasonality was examined based on the trip encounter rate (TER) during the austral season, calculated as the total number of sightings per number of trips for which encounters were reported. In the absence of encounters, trips were not reported. As such, the number of trips only represents a minimum total number of trips undertaken by stakeholders, and thus the TER is likely to be underestimated. Spatial patterns were investigated in terms of relationship between water depth and species occurrence and compared between seasons using analysis of variance.

Statistical analyses were performed using R 3.0.1 (R Core Team, 2013). Data were tested for normality and homogeneity of variances using the Shapiro-Wilk and Bartlett tests, respectively. Data normality and homogeneity of variances determined whether parametric or non-parametric techniques were applied. All tests were deemed significant when $p<0.05$.

2.2.5 Common dolphin habitat use

The overall "high" confidence ranking for common dolphins by all observer types (Table 2.2), in conjunction with the large dataset available for this species, allowed common dolphin habitat use to be further examined. Static and dynamic habitat variables known to influence common dolphin occurrence (*i.e.* depth, slope, aspect of the sea bed, Cañadas *et al.*, 2002; Kiszka *et al.*, 2007b; Dwyer, 2014; McClellan *et al.*, 2014; Chapter 3) were considered. Oceanic variables (SST, distance to the closest SST front and Chl-a) were used as alternative proxies for productivity (Reilly, 1990; Cañadas and Hammond, 2008; Jefferson *et al.*, 2009; Moura *et al.*, 2012; Correia *et al.*, 2015; Mannocci *et al.*, 2015). Indeed, using environmental variables instead of prey data as explanatory variables has provided better results when examining dolphin habitat in a heterogeneous habitat characterised by spatially dispersed prey patches (Torres *et al.*, 2008). Moreover, there was only limited data available on dolphin prey species for the region.

Data on those six eco-geographic variables (*i.e.* depth, slope, aspect of the sea bed, SST, distance to the closest SST front and Chl-a) were extracted using a Geographic Information System (GIS) created in Arcview© 10.2 (ESRI, 2013, Redlands, California, USA) using the Transverse Mercator projection (WGS84 Datum) for New Zealand at 60°S. Depth (m), slope (°) and aspect (°) of the sea bed were used to describe bathymetry. A depth raster layer was derived from the National Institute of Water and Atmospheric Research (NIWA) bathymetric datasets (CANZ, 2008) and transformed into slope and aspect rasters using the respective Spatial Analyst tools. Aspect of the sea floor was further transformed into a categorical variable and grouped in eight classes of

45° (N-NE, NE-E …) based on the NW-SE coastline orientation of the study area. Data on the SST and the Chl-a in the surface layer were obtained from the AquaModis sensor (http://oceancolor.gsfc.nasa.gov/). For both of these parameters, weekly (8-day) composite maps were used with a resolution of 4x4km. This facilitated the best use of the large sample size for common dolphins, dispersed across weeks and the three sub-regions, potentially allowing for spatial and temporal fine scale examination of habitat use. Same or similar resolution has been chosen in previous comparable studies (Dwyer, 2014; McClellan *et al.*, 2014; Correia *et al.*, 2015).

For SST, nocturnal values were used to avoid issues associated with solar heating of the surface layer during daylight hours. Front rasters for AquaModis SST images were created using the Cayula and Cornillon (1992) single image edge detection algorithm in the Marine Geospatial Ecology Tools (MGET, Roberts *et al.*, 2010). To match the resolution of SST and Chl-a satellite maps, weekly (8-day) composite maps of nocturnal values were also used with a resolution of 4x4km, and a front detection threshold of 1°C, above the minimum threshold advised for this tool (Roberts *et al.*, 2010). Time series data of SST, distance to the closest fronts and Chl-a values were automatically interpolated in ArcGIS for each sighting using the MGET (Roberts *et al.*, 2010).Data exploration was undertaken following Zuur *et al.* (2010). Specifically, pair plots of the explanatory variables were examined and variation inflation factors (VIF) were calculated to check for multivariate colinearity.

Common dolphin habitat use was tested by including the six eco-geographical variables in a Generalised Additive Model (GAM, Hastie and Tibshirani, 1990), where the response variable was common dolphin sightings. This analysis was appropriate for data with a combination of continuous (SST, Chl-a, depth, slope and distance to the closest SST front) and categorical (aspect of the sea floor) predictor variables. Depth, slope and distance to the front were log transformed, as values for these three variables ranged over several orders of magnitude (depth: 1-1,715m; slope: 0-16.5°; distance to the front: 0.05-350km). An interaction term between log(depth) and season was added to remove the potential effect of depth occurrence according to the season previously observed (Neumann, 2001c). GAMs were fitted using a backward selection procedure and the optimal model was identified by Akaike's Information Criteria (AIC). A binomial distribution with logit link was applied. A full model, which included all variables, was used initially and at each step, the least significant variable excluded (Goetz *et al*., 2015). The process continued until no further fall in the AIC value was obtained. The final model indicated no over dispersion in the residuals and relatively low leverage values (Zuur *et al*., 2007). An ANOVA on nested models was performed for each nominal variable in the final GAM to assess overall significance of the factor in the final model (Goetz *et al*., 2015).

2.3 Results

2.3.1 Effort

After data standardisation, 1,878 trips undertaken between December 2000 and November 2010 were considered for further analyses. The majority of these (61.3%, n=1,151) were undertaken by tour operators, followed by mariners (32.3%, n=606) and experts (6.4%, n=121, Table 2.3, Figure 2.1). Regardless of observer type, a large proportion of the trips were undertaken during summer (54.0%, n=1,014), followed by autumn (24.0%, n=451), winter (13.8%, n=260) and spring (8.1%, n=153).

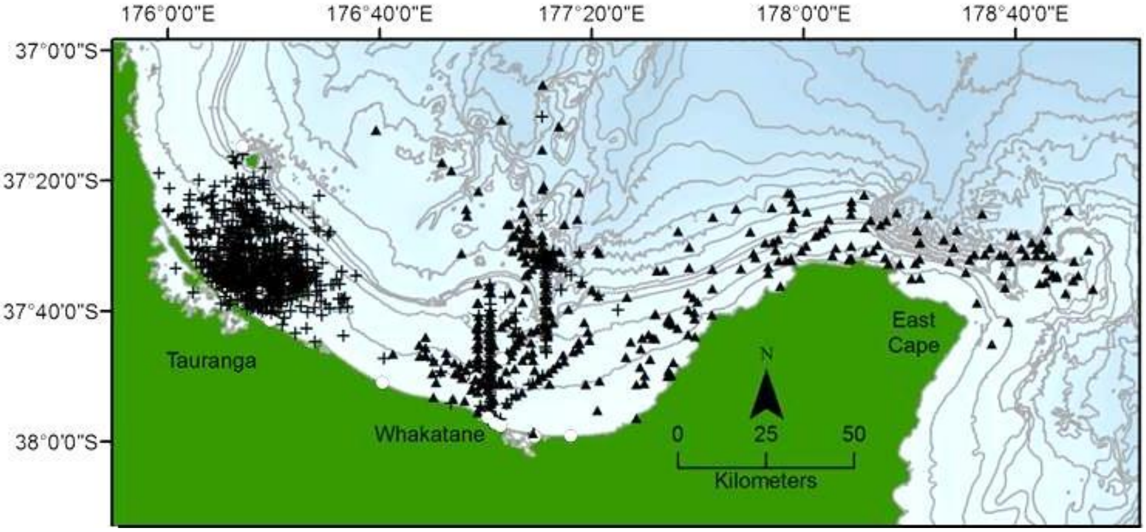

Figure 2.1: Distribution of marine mammals opportunistically reported between December 2000 and November 2010 in the Bay of Plenty, New Zealand, by mariners (▲), tour operators (+) and experts (**o**).

2.3.2 Marine mammal sightings, species identification and observer confidence

Out of 2,049 marine mammal independent encounters between December 2000 and November 2010, fourteen cetacean species were identified in the BOP waters, including seven odontocetes, seven mysticetes and one pinniped species (Table 2.4). Common dolphins were the most reported species in the region (75.7%, n=1,552, Table 2.4). Other *Delphinidae* included killer whales (5.1%, n=105) and bottlenose dolphins (4.0%, n=81). Blackfish (3.7%, n=76) included pilot (3.0%, n=61) and false killer whales (0.7%, n=15). Species from the family *Balaenopteridae* (5.6%, n=114), excluding humpback whales (0.7%, n=15), included minke (2.7%, n=55), Bryde’s (1.0%, n=20), fin (0.9%, n=18), sei (0.7%, n=14) and blue whales (0.3%, n=7). Other species, such as sperm (0.6%, n=12), beaked (0.1%, n=2) and southern right whales (0.1%, n=2) were uncommonly encountered in the BOP. New Zealand fur seals were the only pinniped species encountered in the area, totalling 4.4% (n=90) of marine mammal sightings.

Table 2.3: Effort (number of trips) by observer type and sub-region between December 2000 and November 2010 in the Bay of Plenty, New Zealand. Note: Mariners commenced their trips from Whakatane (Figure 2.1), however, details of the trips (*e.g.* direction) are unknown and were therefore pooled across the eastern and East Cape sub-regions.

Type of observer	**Region**	**Summer**	**Autumn**	**Winter**	**Spring**	**Total**
Experts	Western BOP	74	31	-	4	109
	Eastern BOP	3	2	5	2	12
	East Cape	-	-	-	-	-
	Total	**77**	**33**	**5**	**6**	**121**
Tour operators	Western BOP	394	207	44	109	754
	Eastern BOP	184	72	49	92	397
	East Cape	-	-	-	-	-
	Total	**578**	**279**	**93**	**201**	**1,151**
Mariners	Western BOP	-	-	-	-	-
	Eastern BOP + East Cape	359	139	55	53	606
	Total	**359**	**139**	**55**	**53**	**606**
	Total	**1,014**	**451**	**153**	**260**	**1,878**

Based on the confidence ranking for successful species identification for the three observer types (Table 2.2) and the proportion of sightings reported by different observer types (Table 2.4), an overall confidence ranking (OCR) was established for each species/group of species (Table 2.4). Blackfish were mainly reported by tour operators (63.2%, n=48, Table 2.4), whose confidence for identifying those species was considered “moderate” (Table 2.2). Therefore, the OCR for blackfish was “moderate” (Table 2.4). For *Balaenopteridae*, the large proportion of data collected by tour operators (77.2%, n=88, Table 2.4), combined to “moderate” confidence in identifying species for this observer type (Table 2.2) resulted in a “moderate” OCR (Table 2.4).

Table 2.4: Percentage (and number) of encounters per species opportunistically reported and type of observers between December 2000 and November 2010 in the Bay of Plenty, New Zealand. The overall confidence rate (OCR) is based on the confidence ranking for successful species identification for the three observer types (Table 2.2) and the proportion of sightings reported by different observer types.

Species	Experts	Tour operators	Mariners	Total	OCR
Common dolphins	1.6 (25)	66.0 (1,025)	32.3 (502)	100 (1,552)	High
Bottlenose dolphins	4.9 (4)	71.6 (58)	23.5 (19)	100 (81)	High
Killer whales	1.9 (2)	61.0 (64)	37.1 (39)	100 (105)	High
Fur seals	8.9 (8)	61.1 (55)	30.0 (27)	100 (90)	High
Pilot whales	-	60.7 (37)	39.3 (24)	100 (61)	Moderate
False killer whales	-	73.3 (11)	26.7 (4)	100 (15)	
Minke whales	1.8 (1)	92.7 (51)	5.5 (3)	100 (55)	Moderate
Bryde’s whales	-	70.0 (14)	30.0 (6)	100 (20)	
Fin whales	-	38.9 (7)	61.1 (11)	100 (18)	
Sei whales	-	64.3 (9)	35.7 (5)	100 (14)	
Blue whales	-	100 (7)	-	100 (7)	
Humpback whales	-	86.7 (13)	13.3 (2)	100 (15)	Moderate
Sperm whales	-	41.7 (5)	58.3 (7)	100 (12)	Low
Beaked whales	-	-	100 (2)	100 (2)	Low
Southern right whales	-	-	100 (2)	100 (2)	Low
Total	**2.0 (40)**	**66.2 (1356)**	**31.9 (653)**	**100 (2,049)**	

2.3.3 Common dolphins

Common dolphins were encountered by all three observer groups. Out of 1,552 encounters, the majority (66.0%, n=1,025) were collected by tour operators and a lower percentage by mariners (32.3%, n=502) and experts (1.6%, n=25, Table 2.4).

2.3.3.1 Seasonality

Common dolphins showed a strong seasonality with highest TER in summer (0.91 encounters/trip) and autumn (0.86 encounters/trip) compared to winter (0.65 encounters/trip) and spring (0.53 encounters/trip, Figure 2.2).

Common dolphins were encountered in median depth of 59.3m (IQR=73.6, n=1552) but exhibited a significant seasonal pattern in their spatial distribution (Kruskal-Wallis: H=13.799, df=3, p=0.003). Although they were recorded in a wide range of depths, common dolphins mainly occurred in shallower waters in summer (median=56.2, IQR=74.8, n=926) and autumn (median=56.2, IQR=66.7, n=387). Conversely, common dolphins used deeper waters in winter (median=81.7, IQR=102.3, n=139) and spring (median=63.8, IQR=80.3, n=100, Figure 2.3), although this may likely reflect effort bias which cannot be determined using this opportunistic dataset alone. Common dolphins were not reported off the East Cape sub-region during spring (Figure 2.3).

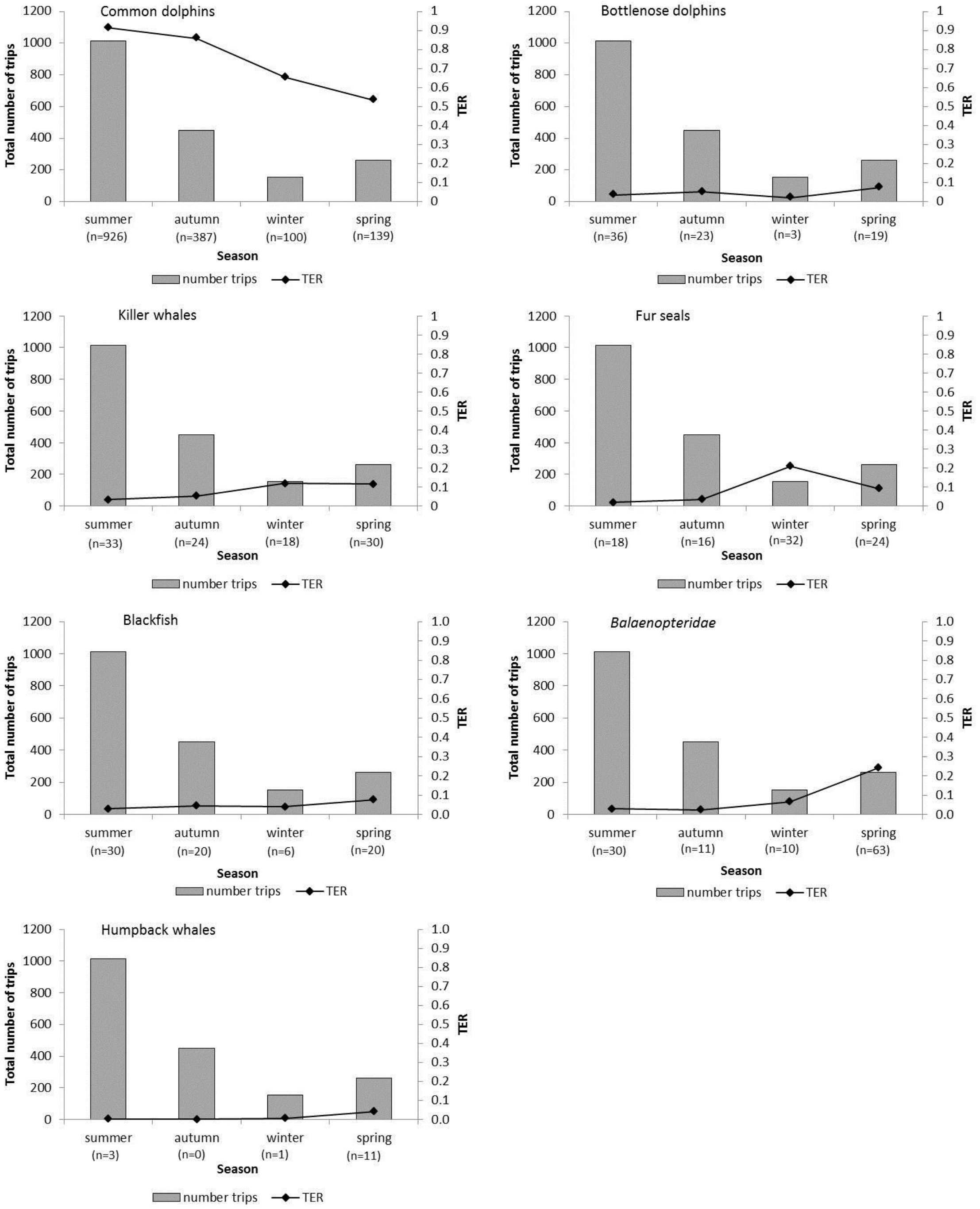

Figure 2.2: Seasonal trip encounter rate (TER) for marine mammals opportunistically reported between December 2000 and November 2010 in the Bay of Plenty, New Zealand.

2.3.3.2 Habitat use

The best fitted model to explain common dolphin occurrence accounted for 17.3% of the variability (Appendix 2). The variables selected in the model were SST (df=5.703, χ^2=19.280, p=0.007), log (distance to the front) (df=3.891, χ^2=19.770, p=0.001), log (slope) (df=7.718, χ^2=42.800, p=1.890^{e-06}) (Appendix 2). There was also a significant influence of the interaction between log (depth) and season (df=-6.367, deviance=-28.964, p=8.578^{e-05}) (Appendix 2). Common dolphin occurrence was higher in warmer waters (typically between 17 and 21°C, Figure 2.4). Beyond 10km from the SST front, the probability of encountering common dolphins decreased with increasing distance to the front (Figure 2.4). Results also showed a complex pattern associated with the slope (Figure 2.4). Regardless of the season, the probability of encountering common dolphins was higher over shallower depths (Figure 2.5). The observed pattern in common dolphin occurrence in relation to the depth was similar for summer and autumn. In the cold season, confidence intervals were larger compared to the warm season. In winter, the probability of encountering common dolphins was less influenced by the water depth, conversely to spring, where a sharp decrease in the probability was observed as water depth increased.

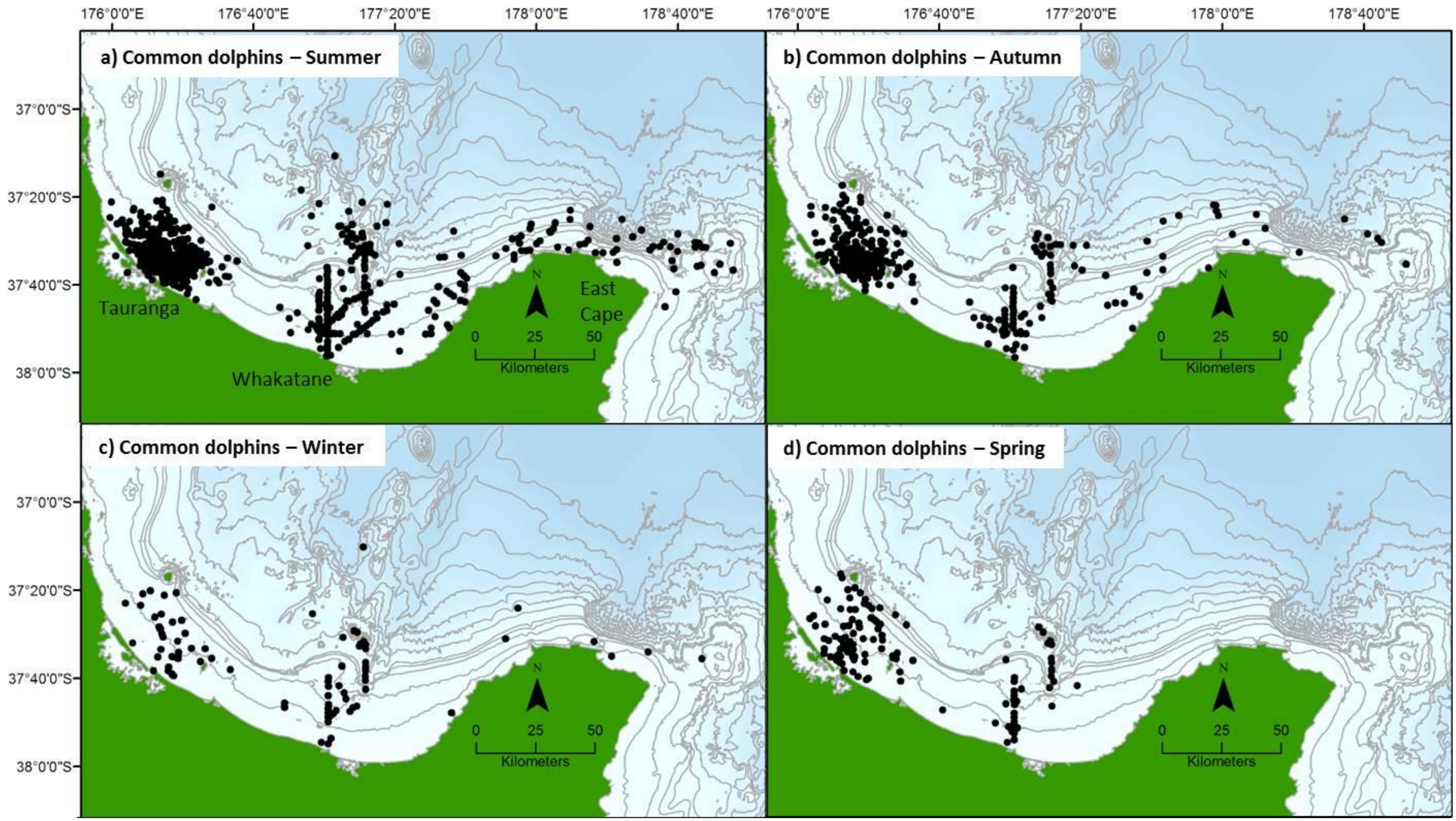

Figure 2.3: Seasonal distribution of marine mammals opportunistically reported between December 2000 and November 2010 in the Bay of Plenty, New Zealand.

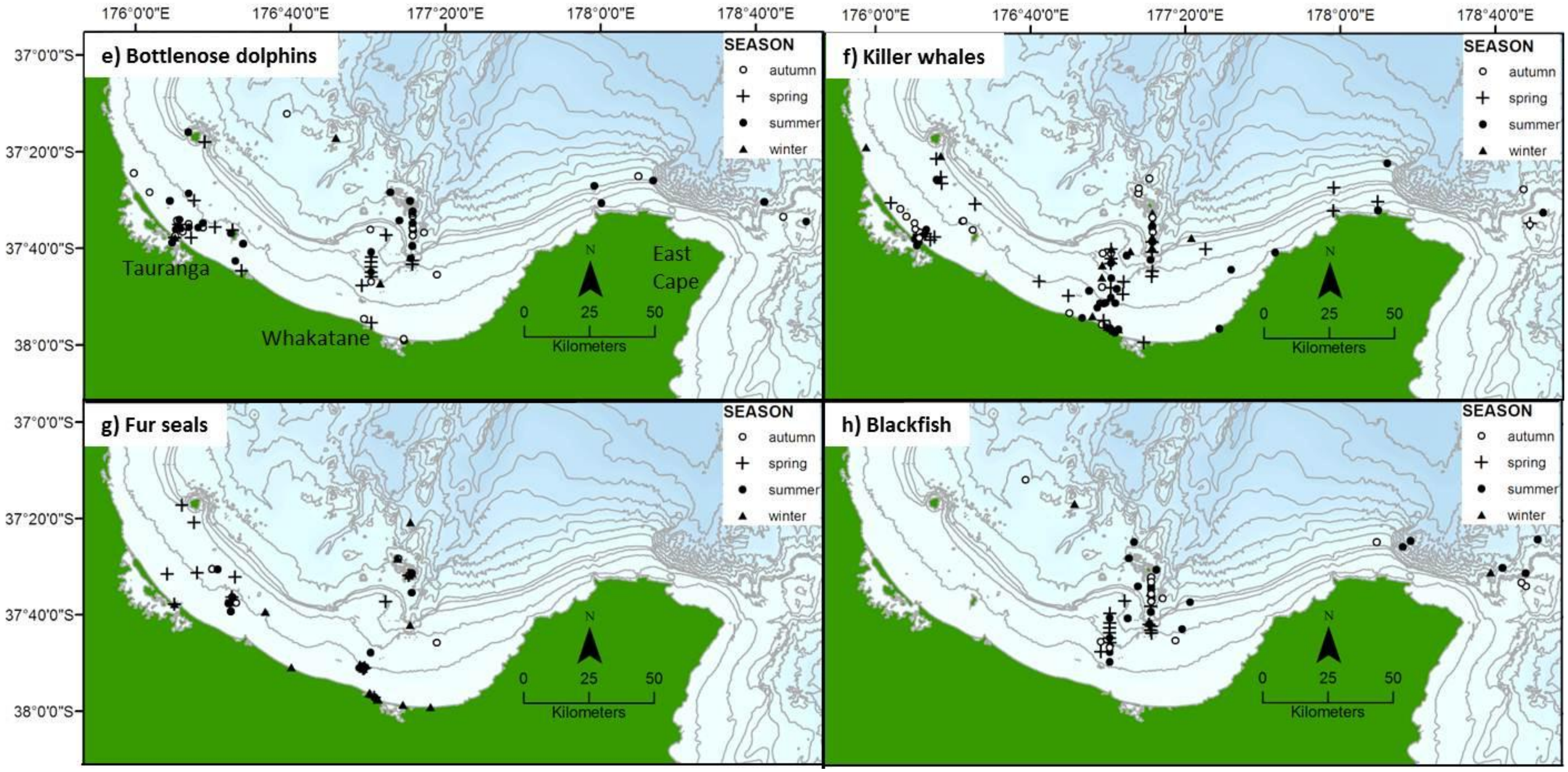

Figure 2.3 (*continued*): Seasonal distribution of marine mammals opportunistically reported between December 2000 and November 2010 in the Bay of Plenty, New Zealand.

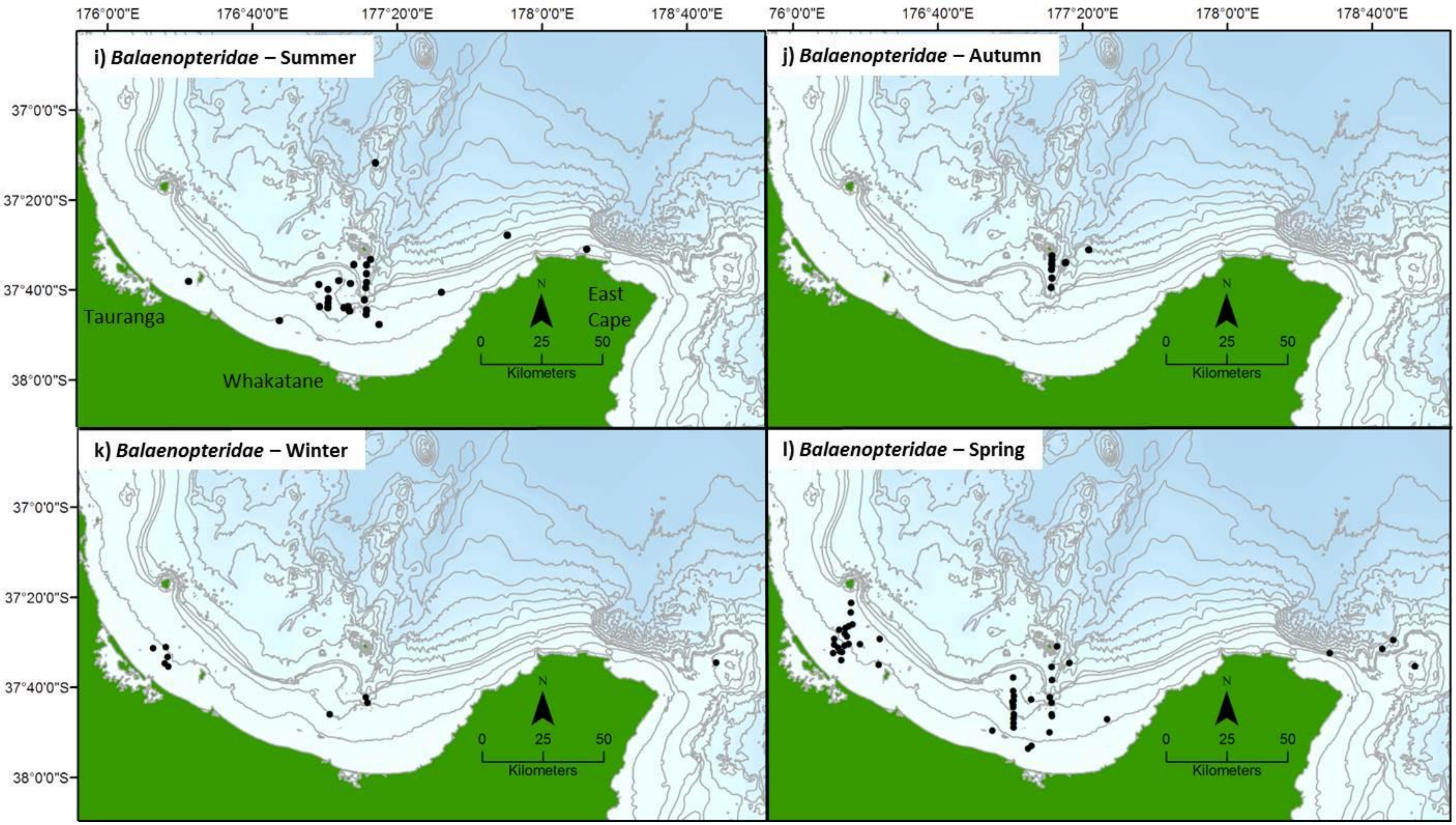

Figure 2.3 (*continued*): Seasonal distribution of marine mammals opportunistically reported between December 2000 and November 2010 in the Bay of Plenty, New Zealand.

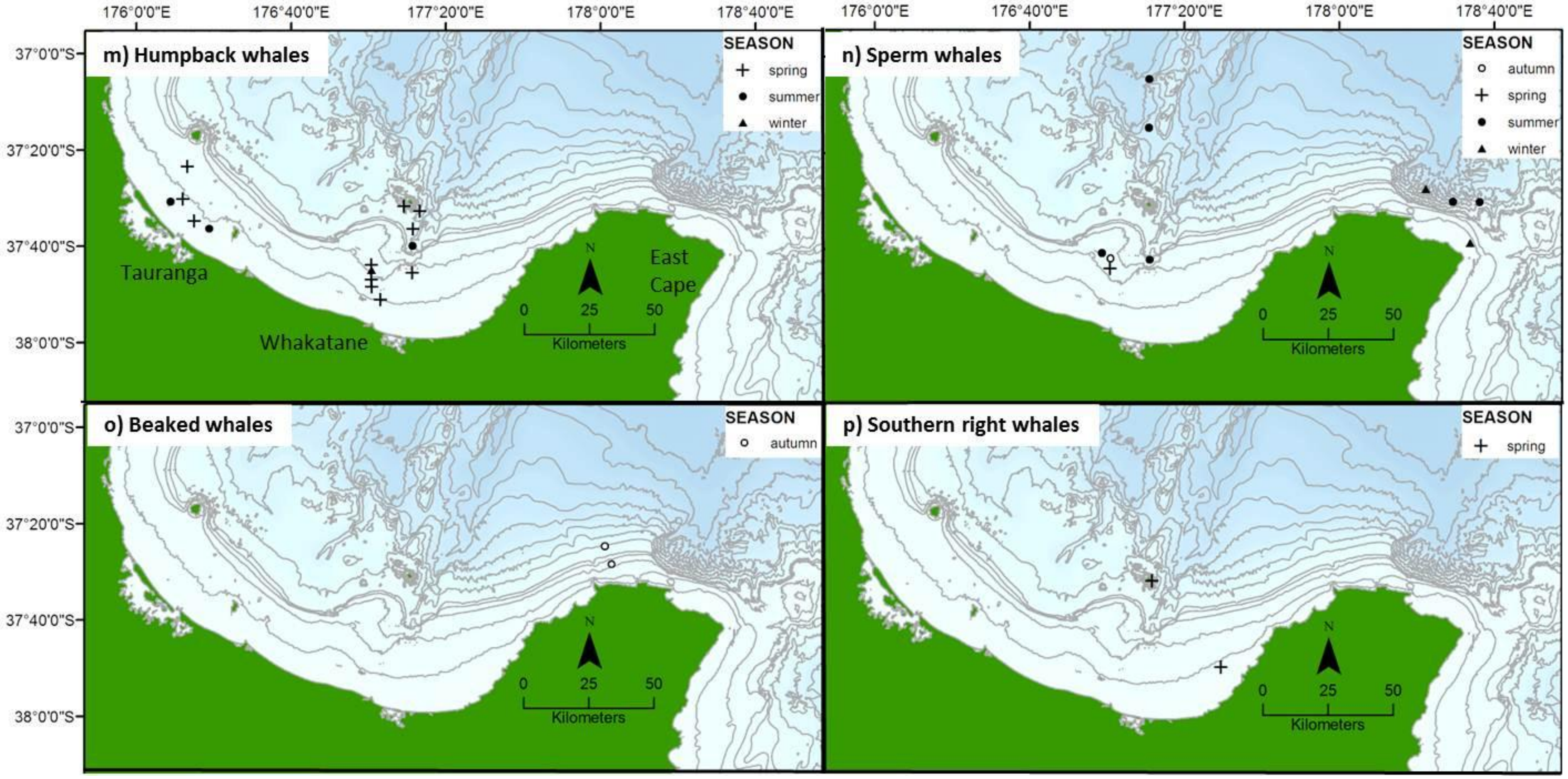

Figure 2.3 (*continued*): Seasonal distribution of marine mammals opportunistically reported between December 2000 and November 2010 in the Bay of Plenty, New Zealand.

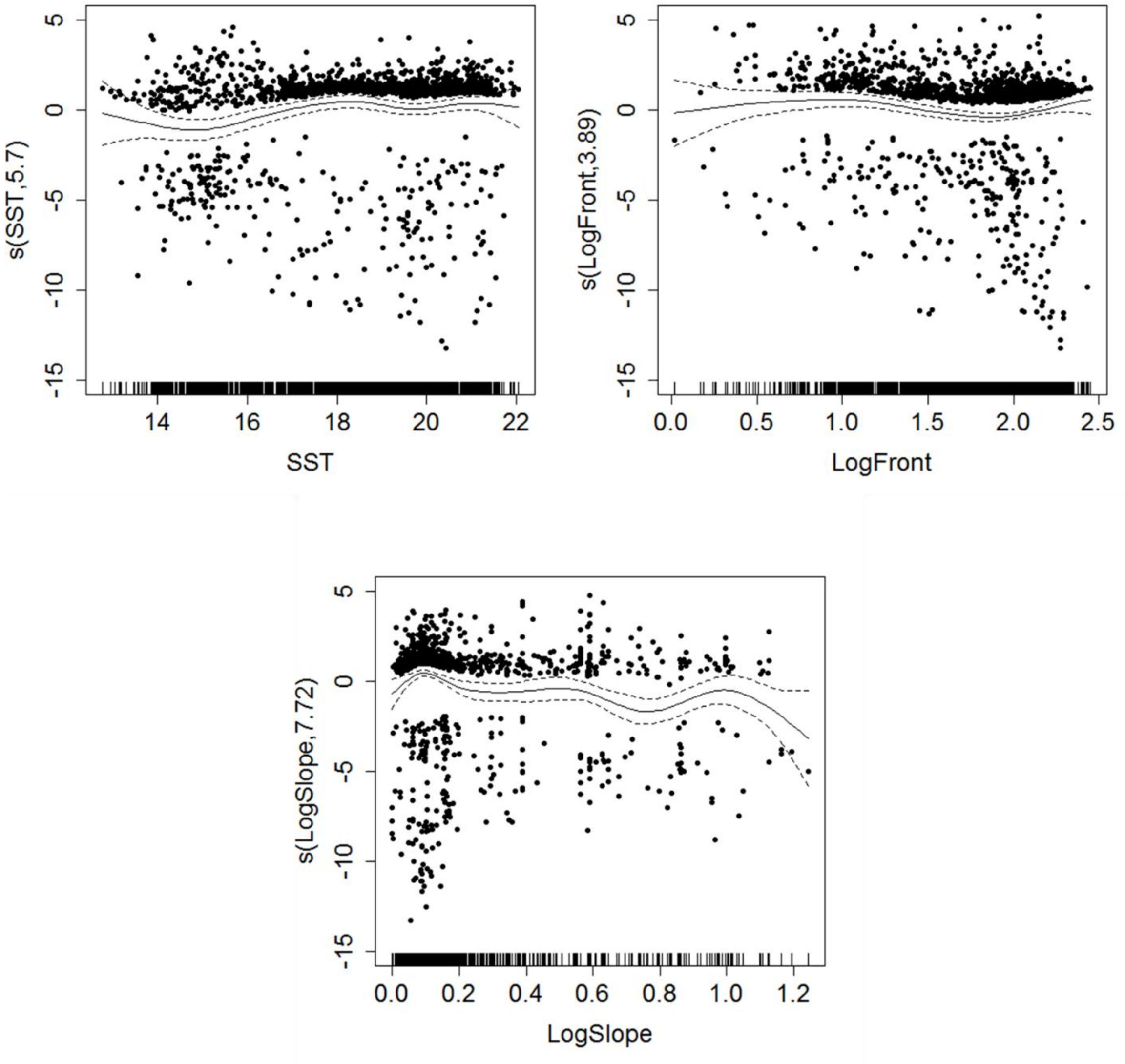

Figure 2.4: Effect of SST (°C), distance to the SST front (Logfront) and slope (LogSlope) on common dolphin occurrence (black dots) between December 2000 and November 2010 in the Bay of Plenty, New Zealand.

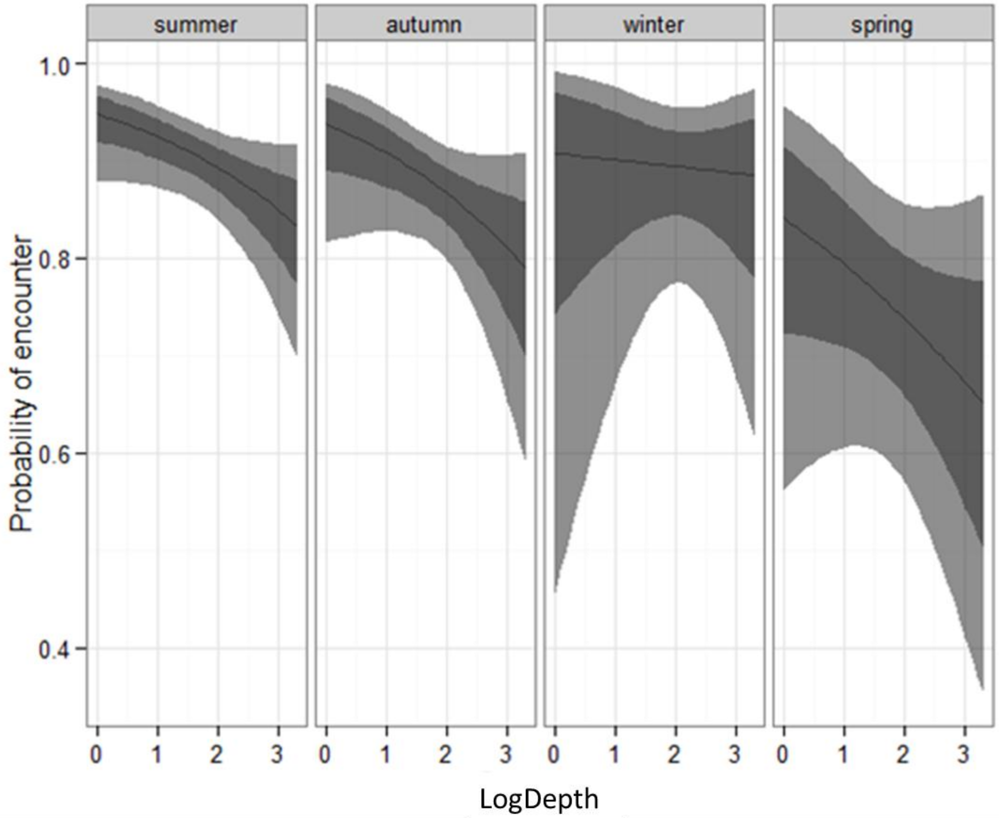

Figure 2.5: Effect of depth and season on common dolphin occurrence between December 2000 and November 2010 in the Bay of Plenty, New Zealand. The solid black line is the estimated smoother and the grey shading represents the error bars as +1 and +2 standard errors (dark and light grey, respectively).

2.3.4 Bottlenose dolphins

Bottlenose dolphin encounters were reported by all three observer types but primarily by tour operators (71.6%, n=58, Table 2.4). Encounters occurred year round with the highest TER in spring (0.07 encounters/trip) despite a low effort, conversely to summer for which effort was the highest but TER was lower (0.04 encounters/trip, Figure 2.2). Overall, bottlenose dolphins were encountered in median depth of 98.5m (IQR=217.8, n=81), without any evidence of seasonal variation (Kruskal-Wallis: H=1.936, df=3, p=0.586). Similarly to common dolphins, no sighting of bottlenose dolphins was reportedly encountered off the East Cape sub-region in spring and winter (Figure 2.3e).

2.3.5 Killer whales

Killer whales were encountered by all observer groups. Out of 105 encounters, a large proportion (61.0%, n=64) was collected by tour operators (Table 2.4). Seasonality was evident, with a high TER in winter and spring (both 0.12 encounters/trip) compared to summer and autumn (0.03 and 0.05 encounters/trip, respectively, Figure 2.2). Overall, the species was encountered in median depth of 69.8m (IQR=122.7, n=105), with no overall influence of seasonal variation detected (Kruskal-Wallis: H=6.627, df=3, p=0.085). No sighting of killer whales was reported off the East Cape sub-region in winter (Figure 2.3f).

2.3.6 New Zealand fur seals

New Zealand fur seals were encountered by all observer types. Out of 90 independent encounters, a large proportion (61.1%, n=55) was collected by tour operators (Table 2.4). Encounters occurred throughout the year but more frequently during winter (0.21 encounters/trips) and spring (0.09 encounters/trips) and less frequently in summer (0.02 encounters/trips) and autumn (0.04 encounters/trips, Figure 2.2). Overall, the species was encountered in median depth of 82.0m (IQR=87.7, n=13), with no overall influence of water depth detected (Kruskal-Wallis: H=4.785, df=3, p=0.188). No sightings of fur seals were reported off the East Cape sub-region (Figure 2.3g).

2.3.7 Blackfish: Pilot and false killer whales

The majority (63.2%, n=48) of blackfish sightings was collected by tour operators, while the remainder (36.8%, n=28) by mariners (Table 2.4).

Blackfish were reported throughout the year, although frequently encountered in spring (0.08 encounters/trip) compared with the other seasons (0.03 to 0.04 encounters/trip, Figure 2.2). Overall, blackfish were encountered in median depth of 201.0m (IQR=326.7, n=76), with evidence of seasonal variation in water depths (Kruskal-Wallis: H=15.630, df=3, p=0.001). Blackfish occurred in deeper waters in winter (median=431.3, IQR=18.5, n=6), summer (median=313.7, IQR=264.1, n=30) and autumn (median=271.4, IQR=343.9, n=20) compared with spring (median=121.2, IQR=36.1, n=20). Blackfish were mainly encountered in the eastern and off the East Cape sub-region (Figure 2.3h).

2.3.8 *Balaenopteridae* (excluding humpback whales)

While *Balaenopteridae* were encountered by all three observer groups (Table 2.4), the majority of encounters (77.2%, n=88) was collected by tour operators (Table 2.4). *Balaenopteridae* showed a strong seasonal pattern with the highest encounter rates in spring (0.24 encounters/trip) and the lowest TER in autumn and summer (0.02 and 0.03 encounters/trip, respectively, Figure 2.2). Whales were reported from each sub-region although in autumn encounters were only reported for the eastern sub-region (Figure 2.3i-l). Overall, *Balaenopteridae* were encountered in median depth of 115.8m (IQR=124.3, n=114), with seasonal variation in water depths evident (Kruskal-Wallis: H=28.773, df=3, $p=2.500^{e-06}$). Sightings occurred in deeper waters in autumn (median=446.6, IQR=111.1, n=11) compared with summer (median=132.0, IQR=198.1, n=30), spring (median=92.2, IQR=96.6, n=63) and winter (median=71.6, IQR=61.0, n=10).

2.3.9 Humpback whales

Out of 15 humpback whales encounters, 13 (86.7%) were reported by tour operators (Table 2.4). Similarly to *Balaenopteridae*, humpback whales exhibited a seasonal pattern with the highest encounter rates in spring (0.042 encounters/trip), lower TER in winter (0.007 encounters/trip) and the lowest TER in summer (0.03 encounters/trip). No sightings were reported in autumn (Figure 2.2). Whales were encountered in median water depth of 75.1m (IQR=137.6, n=15), with no evidence of seasonal variation (Kruskal-Wallis: H=1.130, df=2, p=0.568). However, the small sample size presented here warrants caution in interpretation. Whales were reported only in the eastern and western sub-regions (Figure 2.3m).

2.3.10 Sperm, beaked and southern right whales

Out of 12 sperm whale encounters, the large proportion (58.3%, n=7) were reported by mariners (Table 2.4). All sightings of beaked (100%, n=2) and southern right whales (100%, n=2) were reported by mariners (Table 2.4). Overall, sperm whales were observed in deep waters (median=160.3, IQR=828.2, n=12) in the eastern and East Cape sub-regions (Figure 2.3n). Beaked whales were only reported off East Cape in deep waters (166.0 and 491.0m, Figure 2.3o). Conversely, southern right whales were encountered in shallow waters of the eastern sub-region (29.7 and 37.1m, Figure 2.3p).

Low sample sizes prevented any examination of seasonal distribution for the three species/groups of species and warrant caution regarding present findings.

2.4 Discussion

Until now, limited information has been available on cetaceans and pinnipeds using the BOP waters. This is despite the rapid growth of marine mammal tourism over the last 25 years within the region (Chapter 1). Moreover, dedicated research that has so far been conducted in BOP region, has been restricted to the most common species targeted by tourism operations, *i.e.* common dolphins and New Zealand fur seals (Neumann and Orams, 2006; Cowling *et al.*, 2014; Meissner *et al.*, 2015; Chapter 3). While a provisional assessment of broader species occurrence within the region was recently attempted using strandings and tour operator interviews (Gaborit-Haverkort and Stockin, 2011), no attempt was made to assess all opportunistic datasets or deal with inherent biases that may occur as a consequence. Here, potential biases and limitations of such opportunistic data were identified *a priori* to provide a critical interpretation of species occurrence and distribution within the region.

Misidentification (*i.e.* false positives) is probably the most important parameter to account for when using opportunistic data (Evans and Hammond, 2004) and should never be excluded due to difficulties associated with marine mammal sightings at sea (*i.e.* inconspicuousness, glare and distance). However, confidence in species identification depends on diagnostic features of the species (Table 2.2) as well as observer experience (Section 2.2.2.1). Therefore, based on the proportion of sightings reported by different observer groups, it is possible to establish a confidence ranking

(Table 2.4), allowing cautious yet insightful interpretation of the data. Rankings established here allowed confidence in the interpretation of datasets relating to common and bottlenose dolphins, killer whales and fur seals. Limited confidence was achieved for blackfish, *Balaenopteridae* and humpback whales, while low confidence in sperm, beaked and southern right whale trends was achieved. Based on these confidence rankings, historical occurrence and distribution are discussed accordingly.

2.4.1 Common dolphins

Throughout its range, common dolphins are recognised as oceanic (*e.g.* Gaskin, 1992; Hooker *et al.*, 1999; Carretta *et al.*, 2000; Lopez *et al.*, 2004). However, regardless of the season, the probability of encountering common dolphins in the BOP decreased with increasing depth, suggesting common dolphin overall use shallower waters. While common dolphin occurrence in overall shallow waters has been observed in Gulf St Vincent, South Australia (Filby *et al.*, 2010) and the Hauraki Gulf (Stockin *et al.*, 2008b; Dwyer, 2014), this pattern is in contradiction to the western BOP, where common dolphin distribution was examined via effort related surveys (Chapter 3). This discrepancy could be explained by the larger area sampled in the present study compared to the limited geography of the western BOP (Chapter 3). Differences in the three sub-regions can potentially influence the model results and provide different patterns. However, given the absence of survey tracks, it remains unclear to what extent the three sub-regions were homogenously sampled during the collection of this opportunistic dataset. For example, it is possible that higher effort in coastal waters influenced the results obtained in the model. This hypothesis is plausible given the majority of the dataset for common dolphins was collected by tour operators, who conducted trips in coastal waters (Robbins and Mattila, 2000). Both considerations are not mutually exclusive and could have affected common dolphin occurrence demonstrated here.

Previous studies report common dolphins to associate with steep or complex bathymetry (Cañadas *et al.*, 2002; Kiszka *et al.*, 2007b; Oviedo *et al.*, 2010) due to hydrological processes concentrating prey (*e.g.* Huntley *et al.*, 2000; Cañadas *et al.*, 2002; Davis *et al.*, 2002). The absence of any obvious pattern reported for the BOP can again potentially be explained by the lack of homogeneous sampling throughout all the different bathymetric strata. This hypothesis is supported by the large proportion of dataset reported by tour operators, who typically survey the same areas. This is reflected by sightings being aligned between Whakatane and White Island (*e.g.* Figure 2.3, 2.13 and 2.15) and has also been observed in the western sub-region (*i.e.* surveys of reefs/hotspots by tour operators, Chapter 3). Alternatively, shifts in common dolphin habitat use over the last decade may also explain this discrepancy. This has recently been suggested for nursery groups of common dolphins in the Hauraki Gulf, where groups with neonates potentially shifted from shallow to deeper waters resulting in two different patterns (Stockin *et al.*, 2008b; Dwyer, 2014).

Despite a year round occurrence in the BOP, common dolphins showed evidence of seasonality, with frequent encounters in summer and autumn compared with winter and spring. While limited survey effort in winter and spring (22% of annual trips) likely affected the encounters during those two seasons, effort related surveys undertaken in the western sub-region (Chapter 3) reported a similar trend. This seasonality is presumably due to inshore-offshore movements, previously observed in the Mediterranean, Atlantic and Pacific (Lopez *et al.*, 2004; Cañadas and Hammond, 2008;

Cañadas *et al.*, 2009; Becker *et al.*, 2014), as well as off the east coast of the Coromandel Peninsula, New Zealand (Neumann, 2001c). Such seasonal shifts potentially relate to movements of dolphin prey (Selzer and Payne, 1988; Cañadas and Hammond, 2008; Jefferson *et al.*, 2009; Oviedo *et al.*, 2010). In New Zealand, it is suggested that the East Auckland Current, transporting relatively warm subtropical waters (Sharples, 1997; Stanton *et al.*, 1997; Tilburg *et al.*, 2001) and associated prey, influences the seasonality of common dolphins (Neumann, 2001c; Dwyer, 2014; Chapter 3). This likely also explains the higher probability of common dolphin encounters in warmer waters and closer to the SST front in the modeling analysis.

2.4.2 Bottlenose dolphins

Bottlenose dolphins exploit a wide variety of habitats, ranging from pelagic to coastal waters (*e.g.* Ingram, 2000; Cañadas *et al.*, 2002; Heithaus and Dill, 2002; Lusseau, 2003a; Azzellino *et al.*, 2008a). Similarly, bottlenose dolphins here were encountered in all three sub-regions of the BOP over various depths. Their distribution did not vary according to season in the region. This is contradictory to the northern regions (*i.e.* Hauraki Gulf and Bay of Islands), where bottlenose dolphins were reported in shallower waters in winter and deeper waters in summer (Constantine and Baker, 1997; Constantine, 2002; Dwyer, 2014; Hartel *et al.*, 2014). Seasonal movements of bottlenose dolphins are reportedly linked with SST and prey distribution (Würsig and Würsig, 1979; Shane, 1980; Irvine *et al.*, 1981; Elliott *et al.*, 2011). In New Zealand, influence of the East Auckland Current and associated prey has been suggested in the Bay of Islands and Hauraki Gulf (Constantine and Baker, 1997; Dwyer, 2014; Hartel *et al.*, 2014). It was therefore expected that movements of the East Auckland Current (Sharples, 1997;

Stanton *et al.*, 1997; Tilburg *et al.*, 2001), presumably explaining shifts in common dolphin distribution in the BOP (Neumann, 2001c; present study), also affect bottlenose dolphin distribution in the region. The small sample size and/or inappropriate survey coverage of bottlenose dolphin habitat is believed to have resulted in the absence of any clear relationship between depth and species distribution. Moreover, given that no further detailed information was available with the present sightings (*e.g*. group size, associated species), it is plausible that data for both coastal and offshore forms of bottlenose dolphins (Zaeschmar *et al.*, 2013, 2014; Meissner *et al.*, 2014) were collected in the present dataset. This might have further resulted in the absence of a clear pattern.

Bottlenose dolphins were encountered year round, but displayed seasonality in their occurrence, being more frequently sighted in spring compared to summer. The influence of the East Auckland Current in the BOP in spring is weaker compared to summer (Stanton *et al.*, 1997). If bottlenose dolphins are influenced by the East Auckland Current (Constantine and Baker, 1997; Dwyer, 2014; Hartel *et al.*, 2014), the species seasonality should show the opposite pattern. The occurrence of the species in shallow waters in spring in the Hauraki Gulf (Dwyer, 2014) combined to effort typically concentrated in the coastal waters of the BOP may explain biases in the present seasonality. Alternatively, these results may suggest that bottlenose dolphins shift their diet and feed opportunistically on different prey resources. Such diet plasticity has previously been observed for bottlenose dolphins (Leatherwood, 1975; Barros and Wells, 1998; Santos *et al.*, 2001; Gannon and Waples, 2004; Samuel and Worthy, 2004; Lopez, 2006) and is explained as a strategy increasing foraging opportunities and/or an adaptation to changing environmental conditions (Leatherwood, 1975; Allen *et al.*, 2001; Gannon and Waples, 2004; Lopez, 2006).

2.4.3 Killer whales

Killer whales have a wide, cosmopolitan distribution, ranging from Arctic to Antarctic (Reeves and Mitchell, 1988a; Kasamatsu and Joyce, 1995; Ferguson *et al.*, 2010; Lauriano *et al.*, 2011) and inhabit coastal and offshore waters (Reeves and Mitchell, 1988b; Ford *et al.*, 1998; Zerbini *et al.*, 2007; Williams *et al.*, 2009a; Nøttestad *et al.*, 2014). In New Zealand, the species frequently occurs along the coastline (Visser, 2007; Dwyer and Visser, 2011; Hupman *et al.*, 2014). Killer whales were sighted year round in the BOP, but displayed a strong seasonality, occurring more frequently in spring and winter compared to summer and autumn, similarly to that reported for the Hauraki Gulf and Northland (Visser, 2000, 2007; Hupman *et al.*, 2014), but the converse of that observed for the South Island (Visser, 2000). High sighting rates were also reported by Visser (2000) from October to December in the BOP.

These seasonal movements have been related to SST (Hupman *et al.*, 2014) and prey movements (Visser, 2000). Killer whales feed on a wide range of prey species in New Zealand waters (Visser, 2000), of which some display seasonal movements. In the North Island, killer whales have been observed predating on stingrays (*Dasyatis* spp., Visser, 1999a) including in the BOP (pers. obs.). Seasonal movements of stingrays (Le Port *et al.*, 2008, 2012) may at least in part, explain seasonal variations in killer whale distribution.

2.4.4 New Zealand fur seals

New Zealand fur seals have expanded their distribution along the North Island coastline (Crawley and Wilson, 1976; Lalas and Bradshaw, 2001), with recolonisation of the BOP likely still in its infancy (Chapter 3). The lack of records off East Cape could be explained by the absence of haul out sites in this sub-region and/or inherent observer biases. It is certainly unlikely the species is completely absent from this area, given the northward recolonisation from southern regions (Crawley and Wilson, 1976; Lalas and Bradshaw, 2001). Based on opportunistic data only, it is therefore difficult to establish whether this sub-region represents a suitable habitat for fur seals.

New Zealand fur seals alternate foraging trips at sea and breeding periods ashore (Miller, 1975; Crawley and Wilson, 1976; Goldsworthy and Shaughnessy, 1994). In New Zealand, adult males and females arrive at breeding colonies late October and late November, respectively, with pupping occurring between mid and late December (Miller, 1975; Lalas and Harcourt, 1995; Boren, 2005). The seasonality towards winter and spring observed in the BOP suggests that fur seals may preferentially exploit the region for foraging purposes. However, given that seals spend more time ashore during the breeding season, it is likely that encounter rate at sea decreases and breeding animals go unnoticed. Only regular and systematic monitoring of all potential haul out sites (*i.e.* islands and coastline) can clarify species seasonality and habitat use in the region.

2.4.5 Blackfish: Pilot and false killer whales

On a global scale, limited knowledge is available for blackfish, presumably because of infrequent encounters throughout their range (Acevedo-Gutiérrez *et al.*, 1997; Gannier, 2002; Kiszka *et al.*, 2007a, 2010; Baird *et al.*, 2008a; Boisseau *et al.*, 2010) and typical oceanic distribution (Podesta and Magnaghi, 1988; Notarbartolo Di Sciara *et al.*, 1993; Wade and Gerrodette, 1993; Gannier, 1998; Cañadas and Sagarminaga, 2000; Baird, 2008; Baird *et al.*, 2008a; Praca and Gannier, 2008; Boisseau *et al.*, 2010). In New Zealand, a similar distribution pattern is reported for false killer whales, with most encounters in oceanic waters and infrequent observations in coastal waters (Zaeschmar *et al.*, 2013, 2014). For pilot whales, the majority of current information originates from stranding events and is usually related to the species diet. Although, pilot whales are thought to be shallower water foragers (<150m) in the South Island (Beatson *et al.*, 2007a; Beatson and O'Shea, 2009), the presence of deep water squid and the absence of shallow water prey in the stomach content of stranded whales in the Northland (Beatson *et al.*, 2007b) and the overall absence in the Hauraki Gulf (*e.g.* Martinez *et al.*, 2010; Dwyer, 2014) suggests that pilot whales are a deep water (>500m) species.

In the present study, the majority of the data related to blackfish was collected by tour operators. Opportunistic surveys are typically unevenly distributed (Kiszka *et al.*, 2007b; Martinez *et al.*, 2010) and often concentrated within coastal areas (Robbins and Mattila, 2000). As such, the potential habitat of both species in the western sub-region is unlikely to have been sampled adequately, as deeper waters are distant from the coastline (Park, 1991). This presumably explains sightings off the East Cape and the eastern sub-regions, yet only two sightings in the western sub-region. Consequently, the occurrence of blackfish in the western sub-region remains unclear.

Blackfish showed a year round occurrence in the region, with a presumably higher encounter rate in spring. Seasonality has previously been observed for pilot whales in the Mediterranean and North Atlantic (Zachariassen, 1993; Gannier, 1998; Laran and Drouot-Dulau, 2007; Praca, 2008), but remains unclear for New Zealand waters (Beatson and O'Shea, 2009). Seasonal inshore-offshore movements, related to SST and prey distribution, have been observed for false killer whales, including in New Zealand waters (Leatherwood *et al.*, 1989; Acevedo-Gutiérrez *et al.*, 1997; Zaeschmar, 2014). In the northeastern coast of the North Island, false killer whale occurrence over the continental shelf during summer and autumn is suspected to be influenced by the East Auckland Current (Zaeschmar *et al.*, 2013). Therefore, the intrusion of the East Auckland Current closer to the continental slope of the BOP during summer and autumn (Zeldis *et al.*, 2004) may have resulted in higher TER during those two seasons. The pattern observed in the present study (higher TER in spring) remains unclear and might be due to observer biases, such as misidentification or false absence. Alternatively, if pilot and false killer whales exhibit different seasonality, it is likely that examining both species together, as presently, results in bias and limited interpretation. This hypothesis is further supported as 80.3% of the blackfish dataset relates to pilot whales, for which seasonality remains unknown in New Zealand waters (Beatson and O'Shea, 2009).

2.4.6 *Balaenopteridae* (excluding humpback whales)

The genus *Balaenopteridae* has been previously suggested to have an oceanic distribution (Kasamatsu *et al.*, 1995; Aguilar, 2009; Berkenbusch *et al.*, 2013). In New Zealand waters, it is supported by restricted number of encounters for some of those species (*e.g.* minke whales; Dawson and Slooten, 1990; Wiseman *et al.*, 2011) yet relatively high number of stranding records (Brabyn, 1991). Off the east coast of the North Island, visual observations, acoustic recordings and/or strandings of

Balaenopteridae are overall limited (Brabyn, 1991; McDonald, 2006; Wiseman *et al.*, 2011; Berkenbusch *et al.*, 2013) despite intensive spatial and temporal effort searching for marine mammals (*e.g.* McDonald, 2006, 2010; Wiseman *et al.*, 2011; Dwyer, 2014). Moreover, low encounter rates in the BOP can also potentially be explained by the present opportunistic data being geographically restricted.

The seasonality of *Balaenopteridae* in the BOP during austral spring suggests that sightings are those of whales migrating southwards from tropical breeding grounds to southern Arctic regions (Kasamatsu *et al.*, 1995; Aguilar, 2009; Horwood, 2009) along the east coast of New Zealand (McDonald, 2006; Constantine *et al.*, 2007, 2014b). Higher encounter rates in spring may be explained by the calving season (Baker and Madon, 2007) and are supported by the occurrence of cow-calf pairs in shallow waters in spring (Wiseman *et al.*, 2011) and higher records of immature strandings (Arnold *et al.*, 1987; Dawson and Slooten, 1990; Brabyn, 1991).

Lower encounter rates in autumn could be due to different migration routes, presumably linked to seasonal current shifts. This is supported by occurrence of blue whales in both the South Taranaki Bight, west coast of the North Island (Torres, 2013; Torres *et al.*, 2014) and BOP in spring. Additionally, biases related to temporal coverage have also been identified in opportunistic data (Robbins and Mattila, 2000; Kiszka *et al.*, 2007b; Martinez *et al.*, 2010). In the present study, the majority of the surveys (78.0%) were undertaken in summer and autumn. This can be explained as 61.3% of the data were collected by tour operators primarily operating in summer and autumn (Chapter 4). Finally, as previously suggested for blackfish, examining the overall seasonality of *Baleanopteridae* can potentially result in biases if each species exhibits different seasonality. This is supported by some species of the genus not migrating long-distances (blue whales, Reilly and Thayer, 1990; Bryde's whales, Kato and Perrin, 2009) and reported year round within New Zealand waters (*e.g.* Bryde's whales, Wiseman *et al.*, 2011). This consequently hinders any clear examination of seasonal habitat use or distribution of the genus *Balaenopteridae*.

2.4.7 Humpback whales

Humpback whales are widespread in all oceans and typically exhibit an oceanic distribution (McDonald, 2006; Hauser *et al.*, 2010). However, as for Bryde's whales (Wiseman *et al.*, 2011), it is suggested they spend more time within New Zealand coastal waters compared to other baleen whales such as fin or sei whales (Berkenbusch *et al.*, 2013), which could potentially explain humpback occurrence in coastal waters of the eastern and western sub-regions. The absence of encounters off East Cape remains unclear and is likely related to species misidentification and restricted geographical coverage. Other *Balaenopteridae* were reported in that sub-region (Section 2.3.8), while historical whaling of humpback whales in the BOP did also occur (Dawbin, 1956; Pricket, 2002).

Similarly to other *Balaenopteridae*, humpback whales in the Southern Hemisphere undertake migrations between austral summer feeding grounds in Antarctic and winter breeding grounds in tropical waters (Garrigue *et al.*, 2002; Constantine *et al.*, 2007; Hauser *et al.*, 2010). Off New Zealand coasts, the species travels southwards between May and October (Dawbin, 1997; McDonald, 2006), consistently with higher encounter rates reported in spring in the BOP and potentially explained by an input of immature individuals (Olson *et al.*, 2013). However, the absence of the species in autumn, during the northward migration, is unclear. Humpback whale migration routes remain poorly understood off New Zealand (Constantine *et al.*, 2007; Hauser *et al.*, 2010) and like other *Balaenopteridae,* different migration routes (Dawbin, 1956) can potentially explain low encounter rates. This is supported by encounters of the species in the Cook Strait in June-July (Gibbs and Childerhouse, 2000). Nevertheless, the total absence of sightings, conversely to reports of *Balaenopteridae,* including humpback whales (Gibbs and Childerhouse, 2000; Garrigue *et al.*, 2010) during autumn, could also be explained by misidentification, temporal and/or spatial coverage.

2.4.8 Sperm, beaked and southern right whales

Sperm, beaked and southern right whales were ranked “low” confidence given the potential misidentification with other species and large proportion of sightings collected by mariners. Interestingly, these are the three species with the overall lowest sighting proportions also (0.1 to 0.6%, Table 2.4): this can potentially be explained by species misidentification by non-expert observers and individuals being reported as *Balaenopteridae* or humpback whales. Alternatively, small sample size reported presently could be related to the non-detection of individuals (Gu and Swihart, 2004). False negatives can be related to animal behaviour, *e.g.* increasing for deep diving species which can go undetected (*e.g.* sperm and beaked whales). This is especially relevant when the platform of observation travels at increased speeds (Gerrodette and Forcada, 2002).

Sperm, beaked and southern right whales are generally encountered in areas of steep escarpments and deep waters (Whitehead *et al.*, 1992; Jaquet and Whitehead, 1996; Davis *et al.*, 1998, 2002; Cañadas *et al.*, 2002; MacLeod *et al.*, 2003; MacLeod and D'Amico, 2006; Gannier and Praca, 2007; Santos *et al.*, 2007; Praca and Gannier, 2008). In New Zealand, these species also exhibit an oceanic distribution (Gaskin, 1973; Fordyce *et al.*, 1979; Childerhouse *et al.*, 1995; Jaquet *et al.*, 2000; Torres *et al.*, 2013), with sightings off the East Cape and eastern sub-regions consistent with this pattern. Like for other species, the lack of sightings in the western sub-region is suggested to be due to surveys limited to coastal waters, although potential habitat in offshore waters of the western sub-region should not be excluded. This hypothesis is also supported by stranding reports along this sub-region (Gaborit-Haverkort and Stockin, 2011). However, caution should also apply to data inferred from recovered carcasses alone.

2.4.9 Recommendations

Despite discussed limitations, opportunistic data can still offer valuable first insights in the absence of systematic dedicated surveys if caution is applied to data interpretation. Given the importance of marine mammal tourism in New Zealand, tour vessels in particular, can offer a substantial contribution to traditional research methodologies (Clapham, 1988; Robbins, 2000). Access to commercial platforms by experienced observers (*i.e.* management authority representatives or researchers) could further minimise inherent biases, allowing accurate information to be standardised to improve quality. However, while this is a written condition of most commercial permits in New Zealand (Martinez and Stockin, 2011), the presence of management officers is usually related only to sporadic compliance checks or research projects of limited duration

(Clapham, 1988). While the data presented offer an important contribution to the overall knowledge of occurrence and distribution of marine mammals in the BOP, access to a larger dataset could have been possible if sightings had been reported and regularly submitted to management authorities by all operators in a systematic rather than *ad hoc* manner (Martinez and Stockin, 2011).

Finally, a number of species identified in the present study are classified as nationally endangered (*i.e.* southern right whales, Baker *et al.*, 2010) and/or have high stranding rate (*i.e.* pilot, false killer and minke whales, Brabyn, 1991). Due to limited knowledge on species ecology, the present study can represent a starting point for further investigations and assist with the assessment of human impacts (*e.g.* tourism, vessel strikes, fisheries interactions, deep sea oil exploration) on those populations.

2.5 Conclusion

The BOP is a region of great importance with growing marine-based activities including shipping, tourism, commercial and recreational fishing. To what extent, if any, these activities affect cetaceans and pinnipeds remain unclear. However, in the absence of dedicated surveys, the present study provides the first quality assured insights into the historical occurrence and distribution of marine mammal species in the BOP region. While inherent biases to opportunistic datasets used here are discussed and limitations presented, it is recommended that future dedicated research attempt to examine any changes in the marine mammal use of the BOP waters.

Chapter 3

Distribution, density and group dynamics of common dolphins (*Delphinus* sp.) and New Zealand fur seals (*Arctocephalus forsteri*) in the Bay of Plenty, New Zealand

New Zealand fur seal floating in the "jughandling" position, Bay of Plenty, New Zealand (Photograph: N. Shaw).

3.1 Introduction

Knowledge of species distribution is fundamental for effective conservation (Guisan and Thuiller, 2005). For example, the estimation of species densities allows the identification of areas of importance to marine mammals. In addition, changes in population densities can be used to detect and quantify the impacts that humans and human activities can have in those areas (Forney *et al*., 2015). Moreover, assessing the relationship between the distribution of a species and physiographic variables provide a strong basis to implement protective plans for endangered or vulnerable species and/or populations (Hooker *et al.*, 1999; Cañadas *et al*., 2002). Similarly, understanding how the species use physical and biological resources in a habitat and identifying their relationships, is not only of prime importance for theoretical studies on species ecological niches but also for practical purposes. For example, this may be to mitigate potential anthropogenic impacts or to evaluate effects of changing environmental conditions upon that species (Guisan *et al*., 2006; Lambert *et al.*, 2014).

The primary influence of the physical environment on cetacean distribution and density appears to be the distribution and availability of prey species (Irvine *et al*., 1981; Selzer and Payne, 1988; Ballance, 1992; Croll *et al*., 1998; Davis *et al.*, 1998, 2002; Cañadas *et al*., 2002). When physiographic characteristics of the environment are combined with winds and currents, they result in highly productive areas, locally concentrating prey while attracting predators (Huntley *et al.,* 2000). Therefore, in the absence of prey data, habitat use is often described through physical and/or biological components of the marine environment such as water depth, distance to the shore, slope gradient, sea surface temperature (SST) and/or chlorophyll-a concentration (Chl-a) (*e.g.* Notarbartolo

Di Sciara *et al.*, 1993; Davis *et al.*, 1998; Cañadas *et al.*, 2002; Lopez *et al.*, 2004; Laran and Drouot-Dulau, 2007; Azzellino *et al.*, 2008a; Macleod *et al.*, 2008).

In the dynamic marine environment, oceanographic components vary at a range of spatial and temporal scales, resulting in seasonal or inter-annual changes in the prey and predator species distribution (Fiedler and Reilly, 1994; Bosc *et al.*, 2004; Bearzi *et al.*, 2008; Douglas *et al.*, 2014). Influence of ecological factors on the species can be investigated by modeling techniques (Guisan and Thuiller, 2005; Guisan *et al.*, 2006; Redfern *et al.*, 2006), allowing not only the identification of habitat use but also providing the ability to understand and predict changes in the species distribution and density. Ecological variables of the marine environment can be obtained from a variety of sources including remotely sensed data. This provides the opportunity to examine, at appropriate spatio-temporal resolutions, the relationships between species and the environmental conditions.

The Bay of Plenty (BOP), North Island, New Zealand, is a region of high commercial and environmental interest. Indeed, the region supports a range of important commercial and recreational fisheries (*e.g.* purse seine trawling for skipjack tuna, *Katsuwonus pelamis*, set-netting for trevally, *Pseudocaranx dentex*, and snapper, *Chrysophrys auratus*, aquaculture, game fishing, Park, 1991). In recent years, an industry focused on marine mammal tourism has also undergone rapid expansion (Meissner *et al.*, 2015; Chapters 1 and 4). This activity is supported by a wide range of marine mammal species occurring in the region (Chapter 2), presumably linked to the unique marine environment. While the area is typically oceanic compared to neighbouring coastal regions (*e.g.* Hauraki Gulf, Bay of Islands), the width of the continental shelf, averaging

35km in the western bay but only 9km in the eastern bay (Chapter 1), likely explains the diversity of marine mammal species visiting the BOP (Chapter 2).

The marine mammal-based tourism industry in the BOP relies on common dolphins (*Delphinus* sp.) (Meissner *et al.*, 2015; Chapter 4) and more recently, New Zealand fur seals (*Arctocephalus forsteri*) (Cowling *et al.*, 2014) as the primary target species. Despite the year round occurrence of both species in the region (Chapter 2), tourism activities typically occur only during the warm season, *i.e.* austral autumn and summer (Meissner *et al.*, 2015; Chapter 4), when common dolphins occur closer to shore (Neumann, 2001c) and New Zealand fur seals come ashore to breed (Taylor *et al.*, 1995). Limited information is available on fur seal ecology in the BOP, most typically collected from sightings of colonies at haul out sites (Gaborit-Haverkort and Stockin, 2011; Cowling *et al.*, 2014). Despite their high commercial interest in the region, studies on common dolphin distribution have been restricted to the east coast of the Coromandel Peninsula, *ca.* 100km northwest of the BOP (Neumann, 2001c), where tourism activities are limited to one vessel (Neumann and Orams, 2006). This contrasts with the seven vessels operating in the western BOP (Meissner *et al.*, 2015; Chapter 4). Knowledge about parameters influencing dolphin and seal distribution is of primary importance in order to implement effective and sustainable management plans in areas where both populations are highly exposed to human activities.

In response to the lack of baseline data, the present study investigated the distribution and relative density of common dolphins and New Zealand fur seals in the western BOP, with respect to temporal (seasonal and annual effects) and spatial parameters (water depth, slope, aspect of the sea floor, SST and Chl-a). The influence of biological parameters (group size and/or group composition) on dolphin and fur seal distribution was additionally investigated. Specifically, the objectives of this chapter were to:

- Examine the temporal and spatial distribution of common dolphins and New Zealand fur seal at sea using dedicated surveys.
- Identify environmental parameters that influence the distribution at sea of both species.
- Investigate group dynamics with regards to common dolphin and fur seal habitat use.
- Provide first insights to fur seal haul out distribution within the study area using non-systematic data.

3.2 Methods

3.2.1 Study area

The BOP is a predominantly oceanic habitat, situated on the northeast coast of the North Island, New Zealand (Figure 3.1). Water depths generally reach 200m within 35km off the coastline (Park, 1991, Chapter 1, Section 1.5). The area is an open bay influenced by the East Auckland Current, the southeast current flowing along the northeast coast of New Zealand (Chapter 1, Section 1.5 for full information on the study area). The primary study site comprised the area off Tauranga (37.6878°S and 176.1651°E), between the islands of Karewa (37.3160°S and 176.0800°E) to the west, Mayor (37.1700°S and 176.15800°E) to the worth and Plate (37.3980°S and 176.3350°E) to the east (Figure 3.1). Few reefs and shoals occur between the southeast of Mayor Island and the northwest of Motiti Island (37.3700°S and 176.2500°E) (*i.e.* Tūhua Reef, Penguin Shoal, Pudney Rock, Astrolabe and Okaparu Reef, Figure 3.1). This region was particularly selected to include the area covered by seven commercial tour vessels, operating daily between November and April (Chapter 4).

3.2.2 Data collection

3.2.2.1 Platforms of observation

Non-systematic surveys were conducted between November 2010 and May 2013 from two types of platform. The primary platform, a dedicated research vessel, *Aronui Moana* (Figure 3.2A), was a 5.5m trailer-launched vessel powered by a 90hp four-stroke engine. Additionally, four commercial tour vessels (*i.e.* an 18m motorised dock-based sailing vessel – Figure 3.2B; a 15m motorised dock-based catamaran – Figure 3.2C; a 14.5m motorised dock-based launch – Figure 3.2D; and a 12m motorised dock-based launch – Figure 3.2E) were used as additional platforms of opportunity. In the framework of the contract with the Department of Conservation (Appendix 1) and when permissible, one or more tour vessel(s) were boarded concurrently in order to cover the widest spatial area possible, thus increasing the likelihood of encountering independent dolphin groups. Depending on the season, surveys aboard the tour vessels commenced between 0730 and 0900h and terminated approximately between 1200 to 1500h aboard three tour vessels, and between 1700 and 2000h aboard one of them.

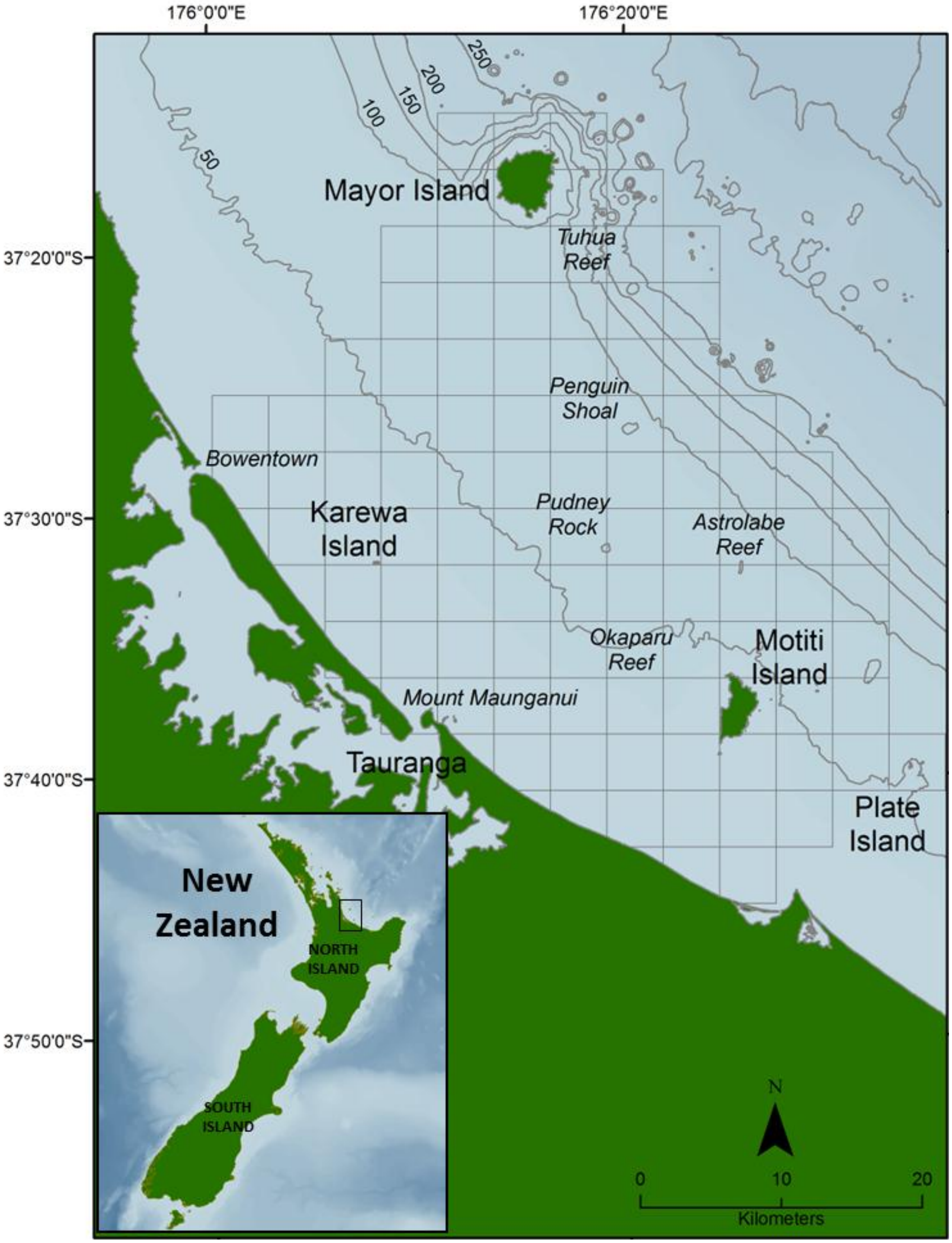

Figure 3.1: Location of the Bay of Plenty (BOP) and other places referred to in this chapter text in relation to the North and South Island of New Zealand. Bathymetry is depicted with darker shades of blue representing deeper waters and isobaths in 50m increment, bathymetry data courtesy of NIWA (CANZ, 2008). The study area is defined by 4x4km grid cells displayed in grey.

Figure 3.2: Observation platforms A) research vessel *Aronui Moana*, and B-E) tour vessels (Photographs: H. Cadwallader, N. Shaw, M. Vorenhout and A.M. Meissner).

3.2.2.2 Surveys

As platform height is known to affect the detectability of cetaceans at sea, survey conditions were assessed in relation to the observational platform used (Hammond *et al.*, 2002). Owing to the lower eye height of the research vessel, and consequent reduced detectability of dolphins, surveys were conducted in conditions of Beaufort Sea State 3 or less and in good visibility (≥1km). Surveys aboard the tour vessels were conducted in conditions of Beaufort Sea State 4 or less and in good visibility (≥1km). Observations ceased when any of the aforementioned weather conditions precluded the continuation of a survey.

When aboard the research vessel, a non-systematic survey design was employed in order to maximise time spent examining the behaviour of common dolphins interacting with the tour vessels (Chapter 4). Research vessel survey tracks were, therefore, often based on the tour vessel direction of travel. Search tracks of the tour vessels were primarily dependent on prevailing weather conditions (to ensure passenger comfort), although previous dolphin encounters were still considered on occasion. When the survey track was located within 500m of the coast (mainland or island), effort was made to survey along the shoreline in search of hauled out New Zealand fur seals. However, as the entire coastline of each island was not surveyed on a systematic basis, hauled out seals reported here represent opportunistic sightings only and thus are conservative in their representative of fur seal distribution on shore. Time spent travelling along survey tracks was classified as *on effort*, when vessel speed was maintained between 8 and 10kts and at least two experienced observers were actively searching for marine mammals by naked eyes and/or binoculars (Tasco Offshore OS36 7x50 magnification), using continuous scanning methodology (Mann, 1999).

Sighting cues used to detect dolphins included silhouettes of dolphins, sighting of dorsal fins, splashes, water disturbance due to surface activity of animals and/or the presence of feeding birds, especially Australasian gannets (*Morus serrator*), known to associate with common dolphins during foraging events (Stockin *et al.*, 2009a; Wiseman *et al.*, 2011). New Zealand fur seals out at sea were typically observed floating at the surface in the "jughandling" position, where both hind flippers and one fore-flipper were tucked and held above the water (photograph p.84, Liwanag, 2010).

A group of dolphins was defined as any number of animals observed in association, moving in a similar direction and usually engaged in a similar behavioural state (Shane, 1990). Members were assumed to be part of a group when within 100m of each other (Bearzi *et al.*, 1997). Beyond this distance, the structure was qualified as sub-groups. At the outset of each independent encounter, the following parameters were recorded: sighting cue, distance (estimated by eye) and bearing of the group, species, group composition and size, estimated as absolute minimum number, best estimate and maximum number of individuals likely to be in the group (Appendix 3).

When dolphins were sighted, the vessel would depart the survey track to approach the group in a slow and continuous manoeuvre (Chapter 4, Meissner *et al.*, 2015). Direction of travel would remain parallel to the course of moving dolphins (Stockin *et al.*, 2008a). The survey mode switched to *off effort* until returning back to the track to resume searching for another independent group of dolphins or until the vessel returned back to the harbour. Therefore, more than one independent focal group was occasionally encountered during a survey. Groups were considered independent if they were separated spatially (>5km) and temporally (>30min) to a degree that would prevent animals becoming resampled during the observation (Stockin *et al.*, 2009a). When possible, independence of the groups was further confirmed via photo-identification (Chapter 5).

Dolphin group composition was categorised by youngest component *i.e.* as adults only, adults and juveniles, and adults and immatures (*i.e.* neonates, calves and/or juveniles). Adults were defined as dolphins fully grown (*ca.* over 1.8m long) and independent. Juveniles were defined as individuals approximately two-thirds the size of an adult, frequently observed swimming in association with an adult animal, although not in the infant position, suggesting they were weaned (Mann *et al.*, 2000). Calves were defined as animals approximately half the size (or less) of an adult and observed swimming in association with an adult, presumed to be the mother (Fertl, 1994). Neonates were defined as small calves, which exhibited diagnostic features indicative of newborns (*e.g.* the presence of dorso-ventral foetal folds and/or a curved dorsal fin, Stockin *et al.*, 2008b).

Seals were considered part of a haul out site if on shore or within 500m of the shore. Due to the lack of literature for pinniped distances encountered at sea, individuals within 500m of each other were considered as part of a single group, otherwise they were deemed as independent encounters. This distance was determined after the observation of an adult-pup pair at sea, where each individual was separated by 470m, as calculated from GPS coordinates. Adult fur seals were defined as individuals over 1.2m long (Boren, 2005) and pups not exceeding 0.7m in length (Boren *et al.*, 2006b) and under a year old (Stirling, 1971; Bradshaw *et al.*, 1999a). Whether out at sea or on shore, the group size was estimated as minimum, best estimate and maximum number of fur seals within the group/colony.

3.2.3 Data analysis

3.2.3.1 General methods

Seasonal analyses were based on austral seasons (Chapter 2, Section 2.2.3). This facilitated comparisons between this and former studies on common dolphins in New Zealand (*e.g.* Stockin *et al.*, 2008b; Dwyer, 2014). However, due to the seasonality of the tourism industry in the BOP and thus, a low sample size in spring and winter, data were pooled across the warm (*i.e.* summer and autumn) and cold (*i.e.* winter and spring) season, further referred as bi-seasons (Meissner *et al*., 2014).

Statistical analyses were performed using R 3.0.1 (R Core Team, 2013). Data were tested for normality and homogeneity of variances using the Shapiro-Wilk and Bartlett tests, respectively. Data normality and homogeneity of variances determined whether parametric or non-parametric techniques were applied.

Only *on effort* sighting data were included in analyses and best estimate group sizes used. Duplicate sightings where two or more vessels collected data on the same group of dolphins were excluded from the dataset. Their associated tracks were also removed to prevent the resampling of similar areas. Vessel tracks and observation locations were processed in ArcGIS version 10.2 (ESRI, 2013, Redlands, California, USA) using the Transverse Mercator projection (WGS84 Datum) for New Zealand at 60°S.

3.2.3.2 Effort

Grids of 4x4km, determined by the size of the study area and the coverage of the overall survey effort, were created using cartography tools in ArcMap (Figure 3.1). The total and seasonal search effort was quantified by calculating the number of kilometres (km) of tracks *on effort* and in good visibility per grid cell using Hawth's tool version 3.27 (Beyer, 2004). Grid cells selected for further analysis contained over 10km of tracks *on effort* and were sampled by both types of platform. Tracks and sightings associated with removed grid cells were reclassified as *off effort*. Consequently, the study area summed 102 grid cells covering 1,586km^2 once the regions of land within the cells were erased. Total and seasonal survey effort was tested for homogeneity across the grid cells (Shapiro-Wilk test).

3.2.3.3 Sightings, group size and composition

Previous studies have demonstrated dolphin attraction (Martinez, 2010), avoidance (Neumann and Orams, 2006) and/or changes in group cohesion (Bejder *et al.*, 1999; Steckenreuter *et al.*, 2012) as response to vessel interaction. Consequently, to prevent any bias in distribution and group dynamics, dolphin groups interacting with another vessel within 30min prior to approach of the observing vessel were removed from further analysis. A period of 30min was chosen as common dolphins in the BOP return to their initial behavioural states within 31.5min after a vessel interaction (Meissner *et al.*, 2015; Chapter 4). Due to non-normality (Shapiro: W=0.5085, p<2.2e-16), common dolphin group size was log transformed and further compared across platforms (*i.e.* research vessel *versus* tour vessels). Group composition was examined in relation to group size, which was classified as 1-10, 11-20, 21-30, 31-50, 51-100 and 100+ individuals as per Stockin *et al.* (2008b). New Zealand fur seal group size (based on the number of individuals) was examined in relation to their location (*i.e.* at sea *versus* on shore) and platforms of observation. The presence/absence of pups was further recorded.

3.2.3.4 Temporal relative density

Sighting rate (SR) and encounter rate (ER) indices of common dolphins or New Zealand fur seals were calculated as the number of groups or individuals encountered while on effort, per kilometre travelled *on effort*, respectively (Bearzi *et al.*, 2005; Cañadas *et al.*, 2005; Filby *et al.*, 2010; Dwyer, 2014). Seasonal SR and ER were calculated by combining the total number of groups/individuals and the total number of kilometres covered for each season and year. These were then weighted proportionally to the bi-seasonal effort to examine inter- and intra-annual variations. Average SR and ER, based on seasonal SR and ER, were calculated to enable comparisons with Dwyer (2014).

3.2.3.5 Spatial relative density

Home ranges of common dolphins and New Zealand fur seals were examined using kernel density estimates (KDE, Silverman, 1986; Powell, 2000). To account for the heterogeneity in survey effort throughout the study area, KDE were based on ER instead of by number of individuals as it is typically done. Each sighting was weighted proportionally to the total number of sightings per grid cell, as n_i / Σn_i, where n_i is the number of individuals encountered per sighting per grid cell, and Σn_i is the total number of individuals encountered per grid cell. As no significant variation in seasonal ER across years was detected (common dolphins: Kruskal-Wallis: H=8.426, df=5, p=0.134, New Zealand fur seals: Kruskal-Wallis: H=6.818, df=5, p=0.235), KDE were examined for the warm and cold seasons. KDE were created in ArcGIS using the *Kernel Interpolation with Barriers Tool* to take into account the mainland and the islands as physical barriers to animal movements. Cell size was set to 1x1km, found to best reflect the resolution of the habitat variables and the fine scale analysis of the present study. Moreover, the selected value of 1x1km allowed direct comparison with habitat densities examined in the Hauraki Gulf (Dwyer, 2014). The search radius was set at 6km to restrict calculations to adjacent 4x4km grid cells.

3.2.3.6 Eco-geographical data

Several variables were examined to test their influence on common dolphin and New Zealand fur seal distribution. Depth, slope and aspect of the sea floor, SST, Chl-a, year and platform of observation were examined for both species. The variable bi-season was added for the New Zealand fur seal model, but not for the common dolphin model given that only data for the warm season were examined (owing to the very low sample size in the cold season, *i.e.* three encounters).

Data on five eco-geographic variables were extracted and processed using a Geographic Information System (GIS) created in Arcview© 10.2 (ESRI, 2013, Redlands, California, USA using Tranverse Mercator projection (WGS84 Datum) for New Zealand at 60°S. Depth (m), slope (°) and aspect (°) of the sea floor, used for describing the bathymetry, were derived from the National Institute of Water and Atmospheric Research (NIWA) bathymetric datasets (CANZ, 2008) and transformed as explained in Chapter 2, Section 2.2.5. Raster layers were further used to obtain the mean water depth, slope and aspect for each grid cell using the Z*onal* Spatial Analyst tool.

Data on the SST (°C) and the Chl-a (mg.m^{-3}) in the surface layer were obtained from the AquaModis sensor (http://oceancolor.gsfc.nasa.gov/). For both of these parameters, seasonal (*i.e.* three months) composite maps were used with a resolution of 4x4km. This seasonal resolution was chosen as the data were previously processed in order to provide the number of individuals and groups per grid cell per season to calculate the temporal relative density (Section 3.2.3.4). For SST, nocturnal values were used to avoid issues associated with solar heating of the surface layer during daylight hours. SST and Chl-a values were extracted and converted into rasters using the Marine Geospatial Ecology Tools (Roberts *et al.*, 2010). Rasters were then transformed into points with the ArcGis conversion tool and converted into a 4x4km grid, which directly overlaid the bathymetric grids using the Inverse Distance Weighted (IDW) technique available in Spatial Analyst tool. Data from each variable (*i.e.* depth, slope, aspect of the sea floor, seasonal SST, seasonal Chl-a) were then computed for each grid cell, respectively, to the season, year and platform of observation. Data exploration was undertaken following Zuur *et al.* (2010). Specifically, pair plots of the explanatory variables were examined and variation inflation factors (VIF) were calculated to check for multivariate colinearity.

3.2.3.7 Habitat use

Habitat use was tested by including the eco-geographical variables in a Generalised Additive Model (GAM, Hastie and Tibshirani, 1990), where the response variable was the presence of a sighting in a grid cell. This analysis was appropriate for data with a combination of continuous (SST, Chl-a, depth and slope) and categorical (aspect of the sea floor) predictor variables. Temporal covariates (bi-season and year) were included to examine whether the habitat use varied temporally. Bi-season and year were fitted as nominal variables. The platform was included as a nominal covariate, as the different survey coverage could potentially influence any inferred habitat use. Models accounted for effort. GAMs were fitted using a backward selection procedure and the optimal model was identified by Akaike's Information Criteria (AIC). A binomial distribution with logit link was applied. A full model, which included all variables, was used initially and at each step, the least significant variable excluded (Goetz *et al.*, 2015). The process continued until no further fall in the AIC values was obtained. The final model indicated no over dispersion in the residuals and relatively low leverage values (Zuur *et al.*, 2007). An ANOVA on nested models was performed for each nominal variable in the final GAM to assess overall significance of the factor in the final model (Goetz *et al.*, 2015).

3.3 Results

3.3.1 Effort

Between November 2010 and May 2013, a total of 272 survey days were undertaken in the study area (Table 3.1). A total of 294 boat-based surveys were conducted, of which 45.9% (n=135) were based from the independent research vessel and the remaining 54.1% (n=159) from the four different tour vessels (Table 3.1). Surveys aboard the research vessel began in November 2010, while data collection aboard tour vessels commenced in January 2011. A total of 18,041.7km were spent *on effort* (Figure 3.3, Table 3.1), including 6,152.9 and 11,888.8km from the research vessel and tour vessels, respectively. Additionally, 7,347.2km were spent *off effort*, while conducting behavioural focal follows (Chapter 4), undertaking photo-identification (Chapter 5) and travelling to and/or from port. Effort was overall greater in summer and autumn compared to winter and spring (Table 3.1), due to better weather conditions and seasonality of the surveys undertaken from aboard the tour vessels.

Table 3.1: Survey effort (km) between November 2010 and May 2013 in the western Bay of Plenty, New Zealand. Note: Some days were concurrent to the research vessel (RV) and the tour vessels (TV). Consequently, the total days *on effort* does not equal the sum of the days *on effort* aboard the research vessel and the tour vessels.

Years	Vessel	Summer	Autumn	Winter	Spring	Total
Survey days *on effort*	RV	52	32	24	27	135
	TV	98	50	1	10	159
	Total	**130**	**82**	**25**	**35**	**272**
2010	RV	-	-	-	63.1	63.1
	TV	-	-	-	-	-
	Total	**-**	**-**	**-**	**63.1**	**63.1**
2011	RV	185.9	659.1	492.6	584.8	1,922.4
	TV	1,562.9	2,294.3		240.7	4,097.9
	Total	**1,748.8**	**2,953.4**	**492.6**	**825.5**	**6,020.3**
2012	RV	1,255.9	648.8	885.6	773.9	3,564.2
	TV	2,522.4	429.5	72.2	298.2	3,322.3
	Total	**3,778.3**	**1,078.3**	**957.8**	**1,072.1**	**6,886.5**
2013	RV	389.6	213.6	-	-	603.2
	TV	3,314.6	1,154.0	-	-	4,468.6
	Total	**3,704.2**	**1,367.6**	**-**	**-**	**5,071.8**
Total effort	RV	1,831.4	1,521.5	1,378.2	1,421.8	6,152.9
	TV	7,399.9	3,877.8	72.2	538.9	11,888.8
	Total	**9,231.3**	**5,399.3**	**1,450.4**	**1,960.7**	**18,041.7**

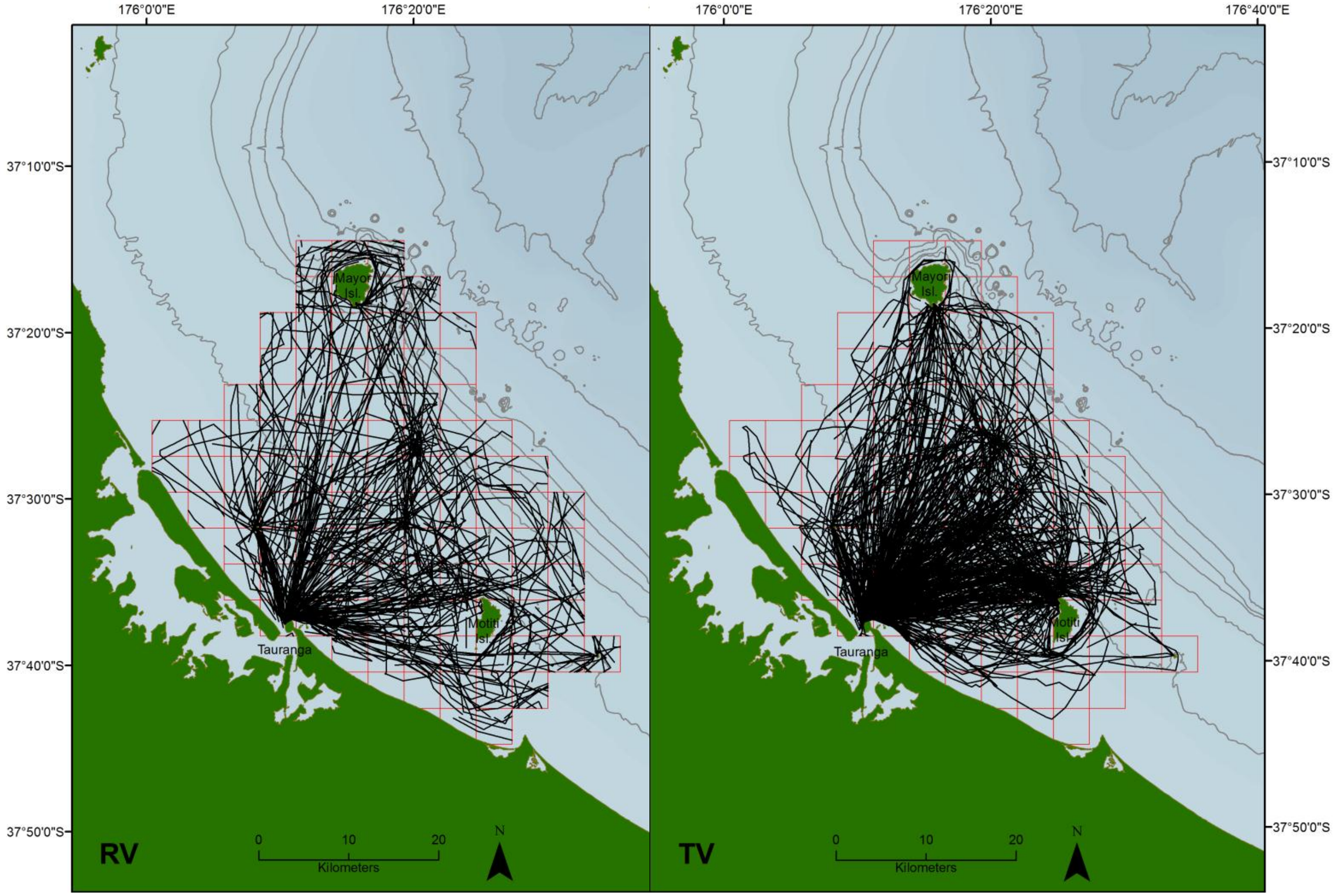

Figure 3.3: Search effort from aboard the research vessel (RV) and the tour vessels (TV) between November 2010 and May 2013 in the western Bay of Plenty, New Zealand. The black lines represent on effort boat survey tracks and 4x4km grid cells are shown in red. Isobaths are depicted in 50m increment, bathymetry data courtesy of NIWA (CANZ, 2008).

When considering the total survey effort per grid cell, the distribution was not uniform (Shapiro: W=0.758, $p<1.13^{e-11}$). Total effort per grid cell ranged from 14.0 to 1,054.9km (median=110.3, IQR=186.6, n=102, Figure 3.4). Grid cells located closer to the home port (Tauranga harbour) received the highest amount of effort. Grid cells located between Karewa, Mayor and Motiti islands received a significant amount of effort, conversely to the grid cells on the periphery of the study area.

Survey effort in all grid cells was not uniformly distributed across seasons (Shapiro: W=0.559, $p<2.20^{e-16}$, Figure 3.5). Total effort per grid cell per season ranged from 0 to 638.3km according to the season (median=19.7, IQR=33.2, n=408). For example, during summer, total effort per grid cell was four times higher (median=44.3, IQR=118.5, n=102) compared to winter (median=11.8, IQR=12.6, n=102).

3.3.2 Sightings

3.3.2.1 Marine mammals

Overall, a total of 464 independent marine mammal observations were made in the western BOP, of which 63.6% (n=295) *on effort* and 36.4% (n=169) *off effort*, and included eight cetacean and one pinniped species (Table 3.2). As expected, common dolphins and New Zealand fur seals were the most encountered species (59.7%, n=176 and 33.2%, n=8, of *on effort* encounters, respectively, Table 3.2) and were observed year round. As these species are the focus of the tourism industry within BOP, only these were further considered in this chapter. Other species infrequently encountered (<3% of *on effort* encounters, Table 3.2) are summarised here only for context and for comparison with opportunistic data presented in Chapter 2.

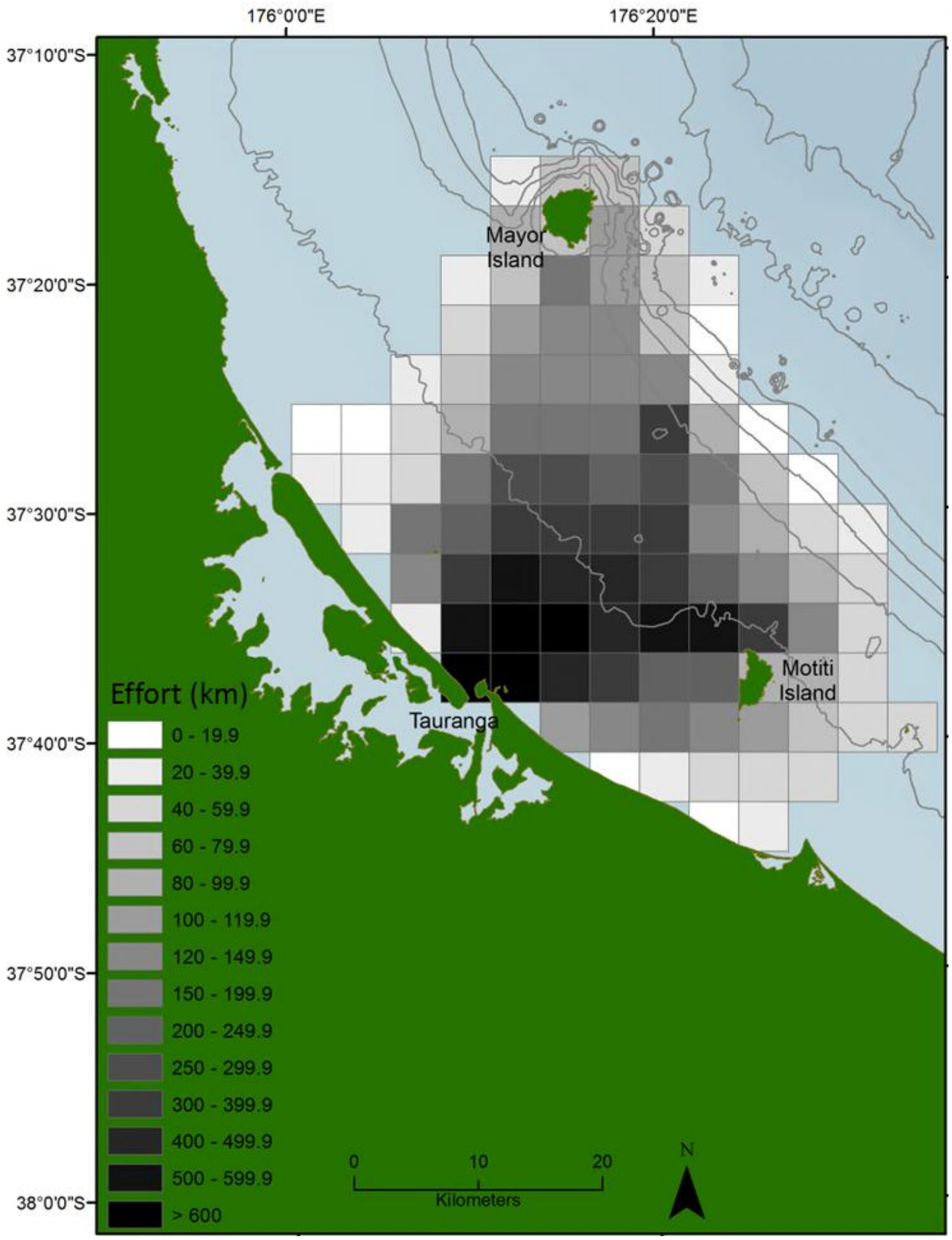

Figure 3.4: Distribution of survey effort (km) for the research and tour vessels between November 2010 and May 2013 in the western Bay of Plenty, New Zealand, 4x4km grid cells are shown in shades of grey (from white to black). Isobaths are depicted in 50m increment, bathymetry data courtesy of NIWA (CANZ, 2008).

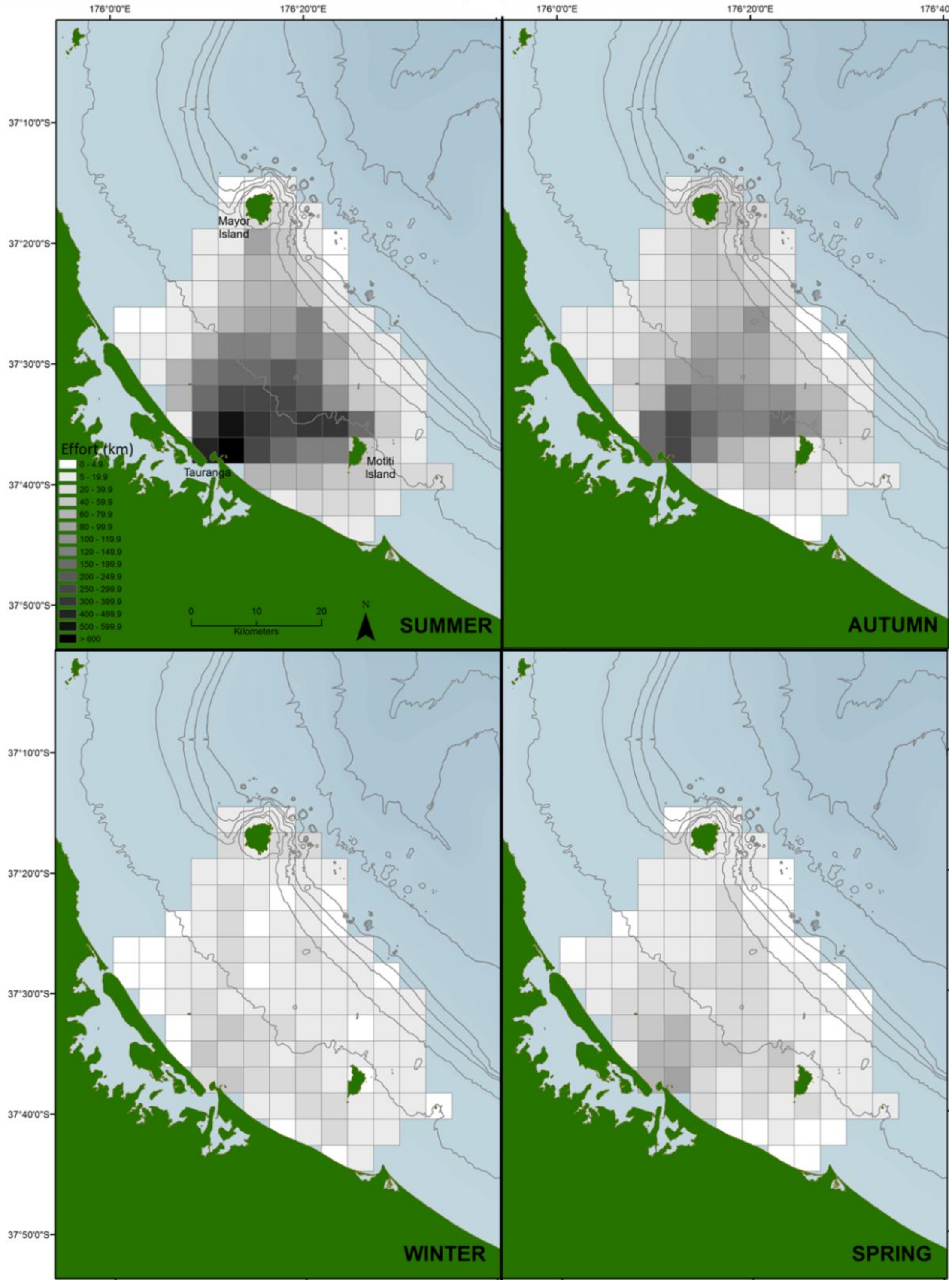

Figure 3.5: Distribution of seasonal survey effort (km) for the research and tour vessels between November 2010 and May 2013 in the western Bay of Plenty, New Zealand. 4x4km grid cells are shown in shades of grey (from white to black). Isobaths are depicted in 50m increment, bathymetry data courtesy of NIWA (CANZ, 2008).

Table 3.2: Seasonal marine mammal encounters *on effort* (and *off effort*) between November 2010 and May 2013 in the western Bay of Plenty, New Zealand.

Species	**Summer**	**Autum**	**Winter**	**Spring**	**Total**
Common dolphins *Delphinus* sp.	115 (74)	58 (32)	1 (5)	2 (1)	**176 (112)**
Bottlenose dolphins *Tursiops truncatus*	7 (1)	-	1	-	**8 (1)**
Killer whales *Orcinus orca*	2 (2)	1	-	1 (5)	**4 (7)**
False killer whales *Pseudorca crassidens*	2 (2)	-	-	-	**2 (2)**
Pilot whales *Globicephala* spp.	0 (1)	-	-	-	**0 (1)**
Blue whales *Balaenoptera musculus*	3	-	-	1 (1)	**4 (1)**
Minke whales *B. acutorostrata*	1	-	-	1 (1)	**2 (1)**
Bryde's whales *B. brydei*	-	-	-	1	**1**
Fur seals *Arctocephalus forsteri*	7 (10)	33 (15)	19 (9)	39 (10)	**98 (44)**
Total	**137 (90)**	**92 (47)**	**21 (14)**	**45 (18)**	**295 (169)**

3.3.2.2 Common dolphins

Overall, a total of 176 groups of common dolphins were encountered *on effort* in the study area, 11.9% (n=21) and 88.1% (n=155) from aboard the research vessel and the tour vessels, respectively. Common dolphins were primarily encountered in the warm season (98.3%, n=173, SR=0.014gp/km, ER=0.577 ind/km, Section 3.3.3).

Group size was similar across the platforms (ANOVA: F=3.694, df=1, p=0.056) and cold and warm seasons (ANOVA: F=2.451, df=1, p=0.119). Common dolphin group size ranged between 1 and 550 individuals (mean=38.3, SD=62.07, n=176). A majority (82.1%, n=145) of groups were smaller than 50 individuals (Pearson's χ^2: χ^2=68.977, df=5, p=1.673^{e-13}), with a large proportion smaller than 10 individuals (38.1%, n=67). Common dolphins were encountered over various depths, with the smaller groups occurring significantly more often in shallower waters (Kruskal-Wallis: H=18.288, df=5, p=0.003).

Common dolphin group composition was assessed at initial onset of the encounter for 81.3% groups (n=143). Groups were composed of adults (36.4%, n=52), adults and juveniles (33.6%, n=48) and adults, juveniles and calves (30.1%, n=43) in similar proportions. Composition did not vary significantly according to platform type (Pearson's χ^2: χ^2=0.592, df=2, p=0.744) or season (Pearson's χ^2: χ^2=1.929, df=2, p=0.381), but did vary with group size (Pearson's χ^2: χ^2=32.274, df=10, p=3.604^{e-04}). The proportion of adult only groups decreased by half between groups smaller (53.6% of adult only groups, n=37) and larger than 20 individuals (20.3% of adult only groups, n=15, Figure 3.6). Conversely, groups with immatures showed the opposite trend. Less than 12% (n=8) of the groups smaller than 20 individuals contained calves, while this proportion reached 47.3% (n=35) for groups larger than 20 individuals. Groups containing juveniles were overall similarly distributed across all group sizes (23.5 to 42.9%). Common dolphins were encountered in similar depths (median=60.5, IQR=40.9, n=143) regardless of their group composition (Kruskal-Wallis: H=0.975, df=2, p=0.614).

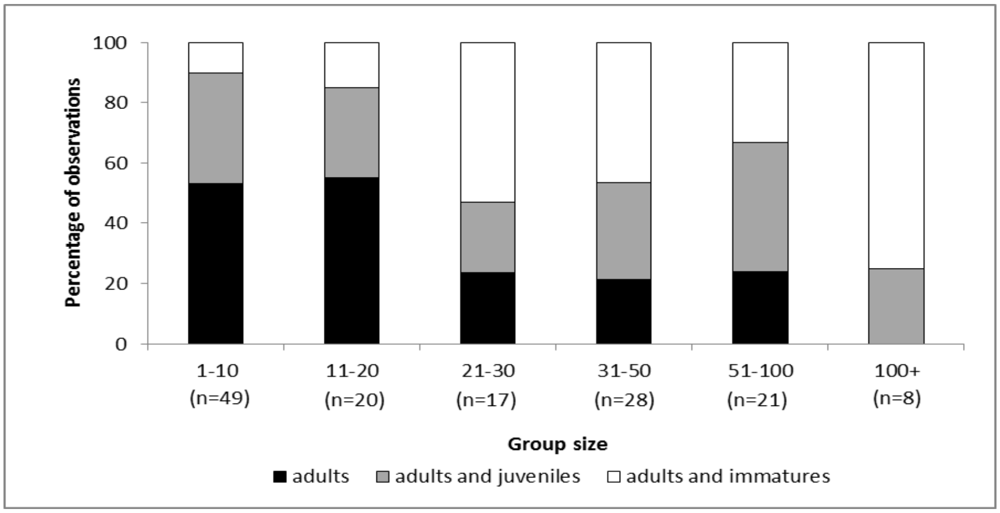

Figure 3.6: Composition of common dolphin groups according to group size between November 2010 and May 2013 in the western Bay of Plenty, New Zealand.

3.3.2.3 New Zealand fur seals

Overall, a total of 98 groups of New Zealand fur seals were encountered *on effort*, including 53.1% (n=52) from the research vessel and 46.9% (n=46) from the tour vessels. New Zealand fur seals were primarily detected out at sea (62.2%, n=61). When on shore (37.8%, n=37), seals were observed on the islands of Karewa, Mayor, Motiti and Plate (Figure 3.1 for their location).

When at sea, New Zealand fur seal group size ranged from one to four individuals (median=1.0, IQR=0, n=61). The large majority of seals encountered were typically singletons (80.3%, n=49), while pairs represented a further 14.5% (n=10). On land, groups ranged between one and 49 individuals (median=6.0, IQR=14.0, n=37). Group size did not vary annually (Kruskal-Wallis: H=0.176, df=3, p=0.916) but according to the platform of observation (Kruskal-Wallis: H=4.136, df=1, p=0.042) and to the haul out site (Kruskal-Wallis: H=10.925, df=3, p=0.012, Table 3.3). Groups were also significantly larger during the cold (median=13.5, IQR=19.0, n=22) compared to warm season (median=4.0, IQR=5.0, n=15, Kruskal-Wallis: H=8.072, df=1, p=0.005, Table 3.3). Pups were only encountered occasionally when in the colonies (n=3, July 2011 on Plate Island; September 2001 on Karewa Island; May 2012 on Mayor Island) and only once at sea (September 2011).

Table 3.3: Group size of New Zealand fur seals encountered at haul out sites between November 2010 and May 2013 in the western Bay of Plenty, New Zealand.

Island	**Season**	**Median**	**IQR**	**Range**	**n**
Karewa	Warm	1	0	1	1
	Cold	13.5	21	1 - 30	10
Mayor	Warm	6	8	4 - 16	6
	Cold	15	7	5 - 24	5
Motiti	Warm	1	0.8	1 - 4	6
	Cold	4	2	2 - 6	2
Plate	Warm	8	6	2 - 14	2
	Cold	13	30	4- 49	5

3.3.3 Temporal relative density

3.3.3.1 Common dolphins

The temporal relative density for common dolphins was higher in the warm (SR=0.014gp/km, ER=0.577 ind/km) compared with the cold season (SR=0.001gp/km, ER=0.009 ind/km, Figure 3.7). However, due to a low sample size, results presented for the cold season are severely constrained. Between 2011 and 2013, SR and ER showed an opposite trend, with a gradual increase in number of sighted groups and a decrease in the number of individuals encountered (Figure 3.7), although these variations were not significant (SR: Kruskal-Wallis: H=0.286, df=2, p=0.867; ER: Kruskal-Wallis: H=2, df=2, p=0.368). The overall SR and ER were 0.008gp/km and 0.319ind/km, respectively.

3.3.3.2 New Zealand fur seals

New Zealand fur seals exhibited the opposite trend to common dolphins, with significantly higher temporal densities in the cold (SR=0.011gp/km, ER=0.014 ind/km) compared with the warm season (SR=0.002gp/km, Kruskal-Wallis: H=5.659, df=1, p=0.017; ER=0.003ind/km, Kruskal-Wallis: H=5.633, df=1, p=0.018, Figure 3.7). There was an overall decrease in fur seal SR and ER (Figure 3.7), although this was not significant (SR: Kruskal-Wallis: H=0.084, df=1, p=0.772; ER: Kruskal-Wallis: H=0.083, df=1, p=0.773). Overall, the mean SR and ER were 0.007gp/km and 0.008ind/km, respectively.

3.3.4 Spatial relative density

3.3.4.1 Common dolphins

Spatial relative density for common dolphins was investigated only for the warm season, due to the restricted sample size in the cold season. In the warm season (*i.e.* December to April), higher densities of common dolphins were typically recorded in deeper waters, particularly between the 100 and 200m depth contours (Figure 3.8). Hot spots were identified east to north of Motiti Island and north to northeast of Astrolabe Reef, centred along the 150m isobath. Common dolphins were observed close to Astrolabe Reef in summer and autumn 2011, and located further from the reef in the following seasons. Densities were also higher in the area situated between Mayor Island and Penguin Shoal. Two very intense zones were identified east and south west of Mayor Island (Figure 3.8). However, these should be considered with caution given the relatively limited effort in the surveyed grid cells (*i.e.* 12.8 and 40.4km *on effort* per 4x4km cell) and the encounter of two large groups (*i.e.* 120 and 400 individuals, respectively).

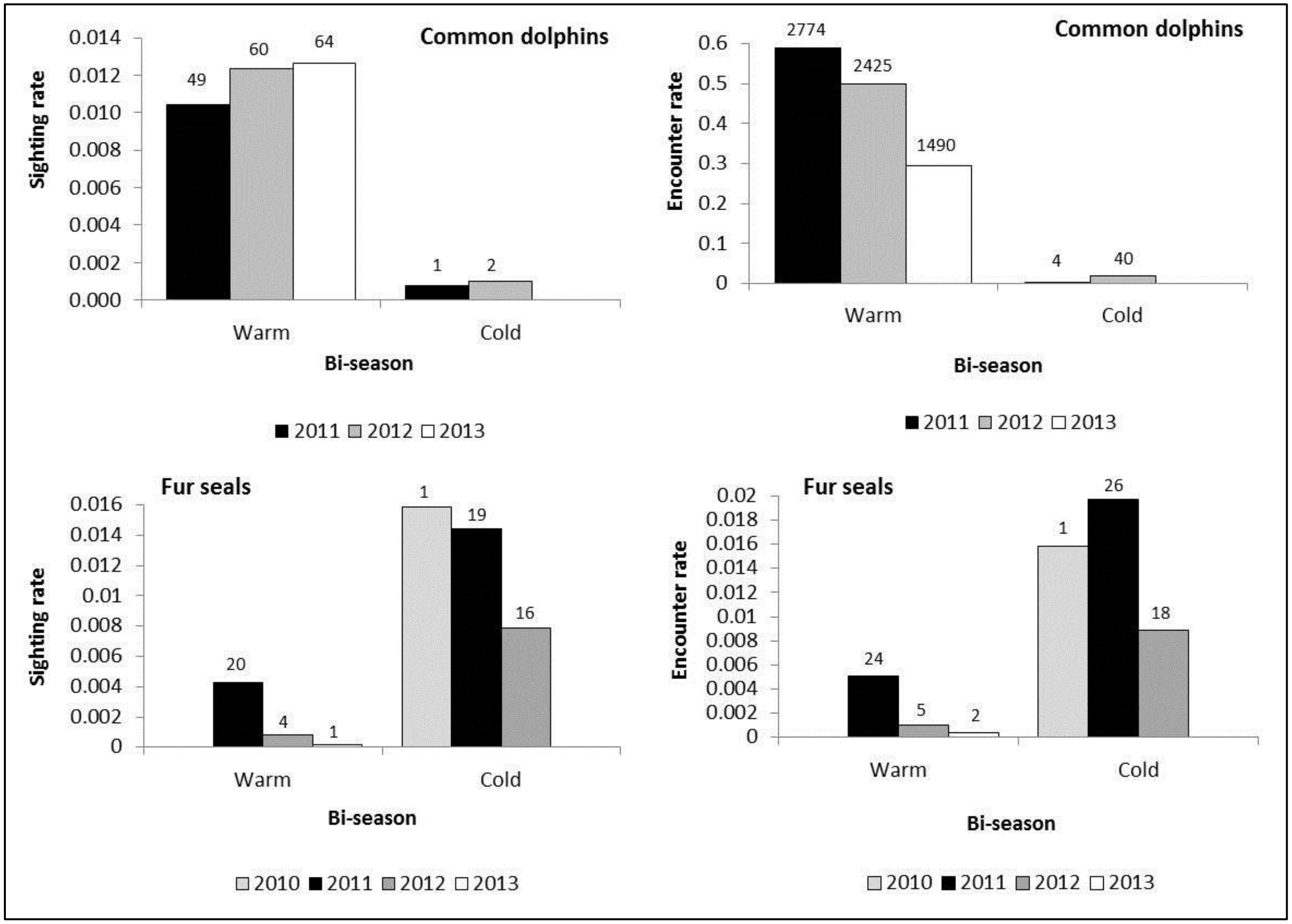

Figure 3.7: Sighting rates (SR) and encounter rates (ER) for common dolphins and New Zealand fur seals between November 2010 and May 2013 in the western Bay of Plenty, New Zealand. Number of groups and individuals are shown for each histogram, relative to sighting and encounter rate, respectively.

3.3.4.2 New Zealand fur seals

Spatial relative density of New Zealand fur seals varied across the bi-seasons (Figure 3.9). During the cold season (*i.e.* winter and spring), seal distribution was widespread throughout the study area, with encounters recorded from shallow (<50m) to deep waters (>250m). However, higher densities were typically reported in deeper waters (>50m). The highest densities were associated with two specific encounters centred north of Penguin Shoal: the largest group encountered in the cold season (*i.e.* four individuals) and a singleton associated with a small survey effort (6km *on effort*).

During the warm season, fur seals were restricted to a smaller area and infrequently encountered in waters shallower than 50m. Higher densities were located around Mayor Island, between Penguin Shoal, Pudney Rock and east of Motiti Island. The highest densities were identified north of Astrolabe Reef, in an area situated between *ca.* 80 and 250m depth. These hotspots were identified as two specific encounters: the largest group encountered in the warm season (*i.e.* four individuals) and a singleton associated with the smallest survey effort (12.3km *on effort*), respectively.

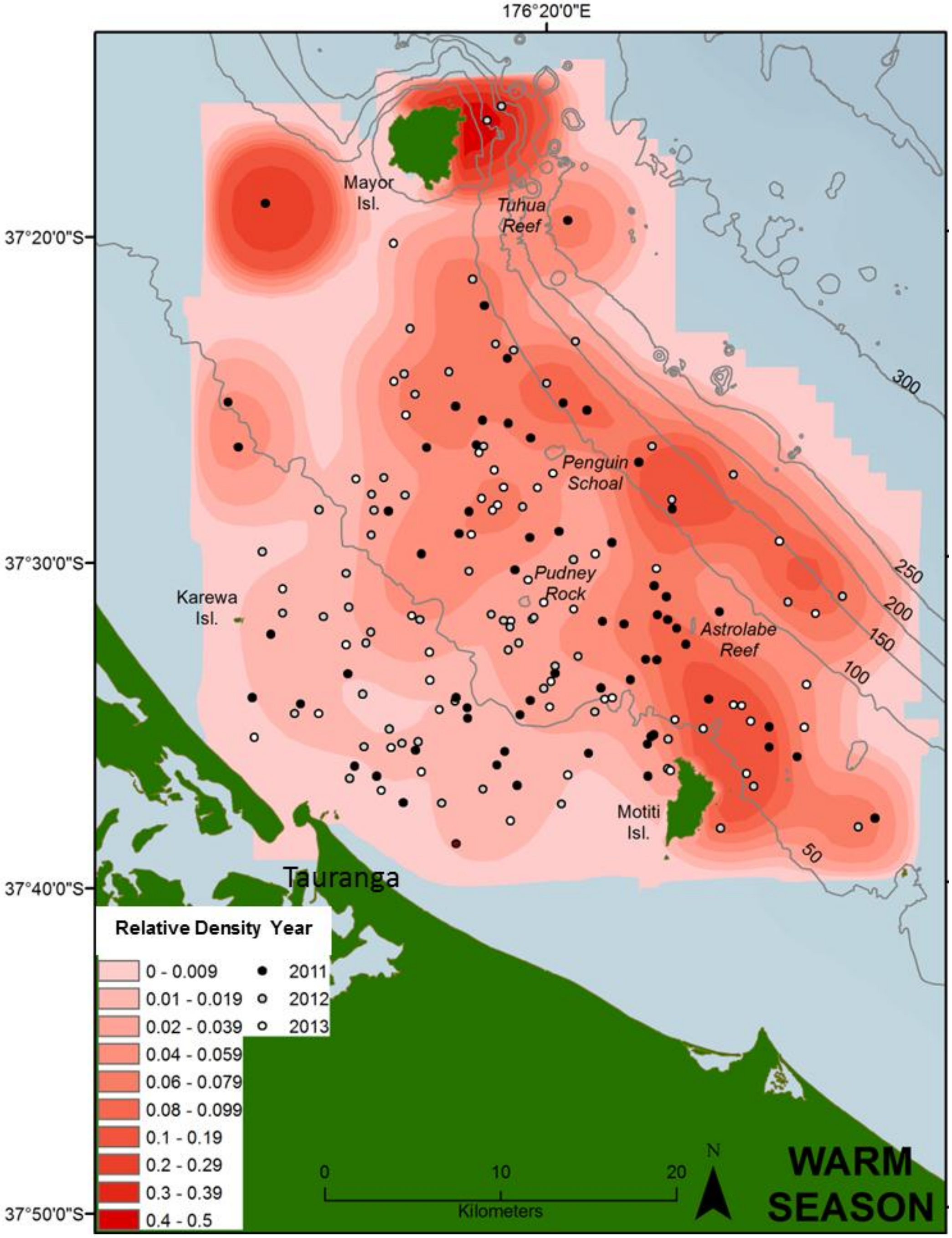

Figure 3.8: Relative density of common dolphins in the warm season (December to April) between November 2010 and May 2013 in the western Bay of Plenty, New Zealand. Areas in red represent higher dolphin density. The sighting position of common dolphin groups is indicated by black (season 2011), grey (season 2012) or white (season 2013) dots. Isobaths are depicted in 50m increment, bathymetry data courtesy of NIWA (CANZ, 2008).

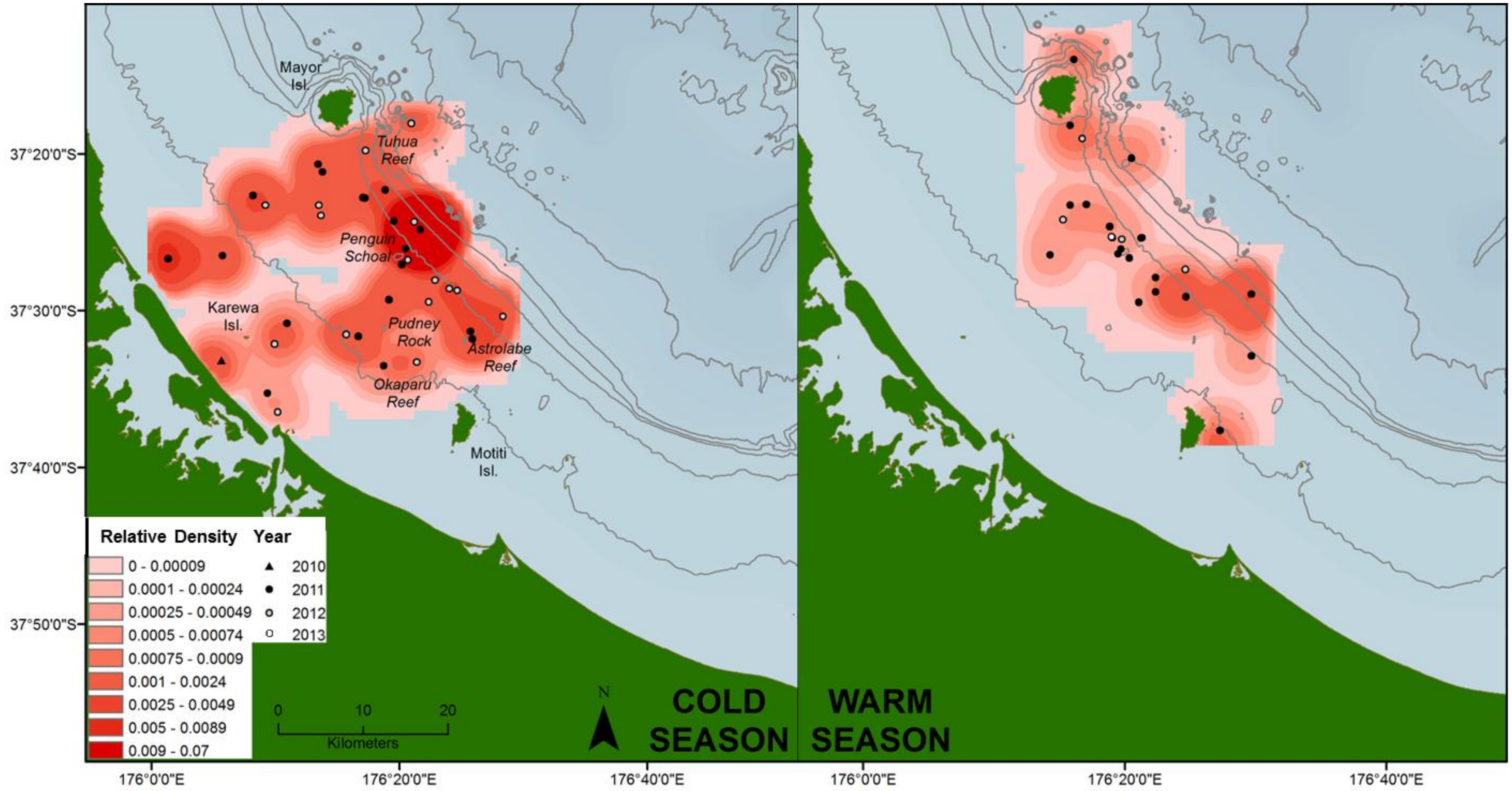

Figure 3.9: Relative density of New Zealand fur seals in the cold (May to November) and warm (December to April) season between November 2010 and May 2013 in the western Bay of Plenty, New Zealand. Areas in red represent higher seal density. The sighting position of fur seals is indicated by coloured dots according to the season and year. Isobaths are depicted in 50m increment, bathymetry data courtesy of NIWA (CANZ, 2008).

3.3.5 Modeling results

3.3.5.1 Common dolphins

The final model to explain common dolphin distribution retained the variables effort (df=2.803, χ^2=62.384, p=2.130^{e-13}), platform of observation (df=-0.91, χ^2=-13.371, p=2.143^{e-04}), depth (df=1.767, χ^2=22.061, p=2.240^{e-05}), slope (df=1.833, χ^2=5.438, p=0.067), SST (df=1, χ^2=4.514, p=0.034) and Chl-a (df=2.71, χ^2=8.601, p=0.034, Appendix 4). The final model explained 30.8% of the variability. In summary, the chances of encountering common dolphins increased with survey effort, although the relationship was non-linear and the probability of encounters reached a plateau for any effort greater than 50km per grid cell (Figure 3.10). Dolphin occurrence was higher over deeper waters and typically decreased with slopes steeper than 1° (Figure 3.10). There was a very slight relationship between dolphin occurrence, increasing SST and Chl-a averaging 0.2 mg.m^{-3}.

3.3.5.2 New Zealand fur seals

The final model to explain fur seal occurrence retained the variables effort (df=1.927, χ^2=20.890, p=3.080^{e-05}), depth (df=2.298, χ^2=30.030, p=1.470^{e-06}), aspect of the sea floor (df=-4.0283, χ^2=-16.120, p=2.935^{e-03}), SST (df=1.595, χ^2=16.150, p=3.140^{e-04}) and year (df=-2.7363, χ^2=-22.312, p=4.027^{e-05}, Appendix 5), explaining 25.9% of the variability. Similarly to common dolphins, chances of encountering fur seals increased with survey effort in a non-linear relationship (Figure 3.11). Seal occurrence was typically higher over deeper waters (Figure 3.11). The relationship between SST indicates two distinct patterns related to the cold (SST<16°C) and warm (>17°C) bi-seasonal dataset, with the overall fur seal occurrence marginally decreasing with increasing SST (Figure 3.11). The spatial aspect of the sea floor revealed that fur seal occurrence was higher from northwest to south. Finally, the probability of encountering fur seals in 2011 was significantly higher compared to 2012 (df=1.1, z-value=-3.432, p=5.990^{e-04}, Appendix 5) and not significantly different in other years.

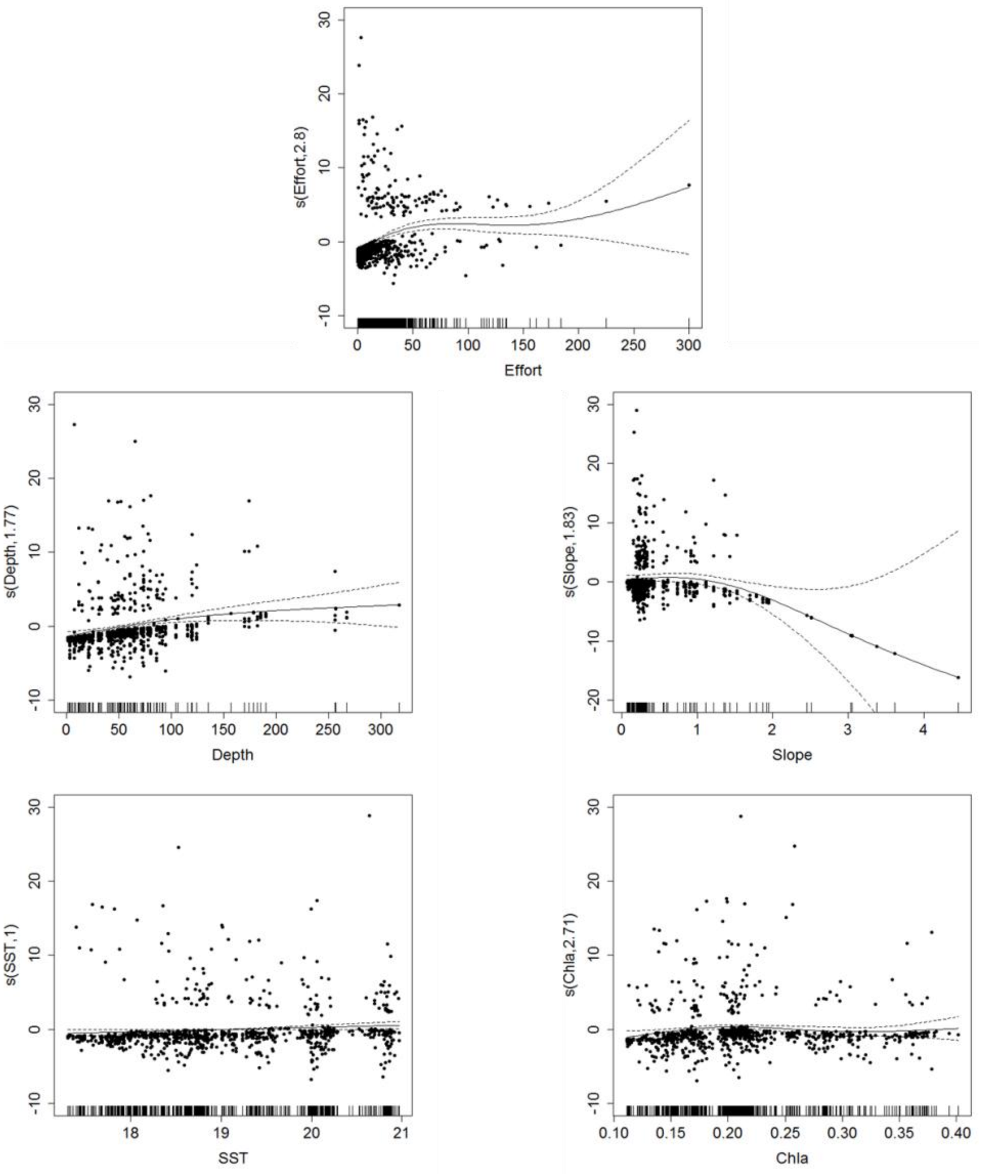

Figure 3.10: Effect of effort (km), depth (m), slope (°), SST (°C) and Chl-a (mg.m^{-3}) on common dolphin occurrence between November 2010 and May 2013 in the western Bay of Plenty, New Zealand. The solid line is the estimated smoother and the dashed line is the 95% confidence interval.

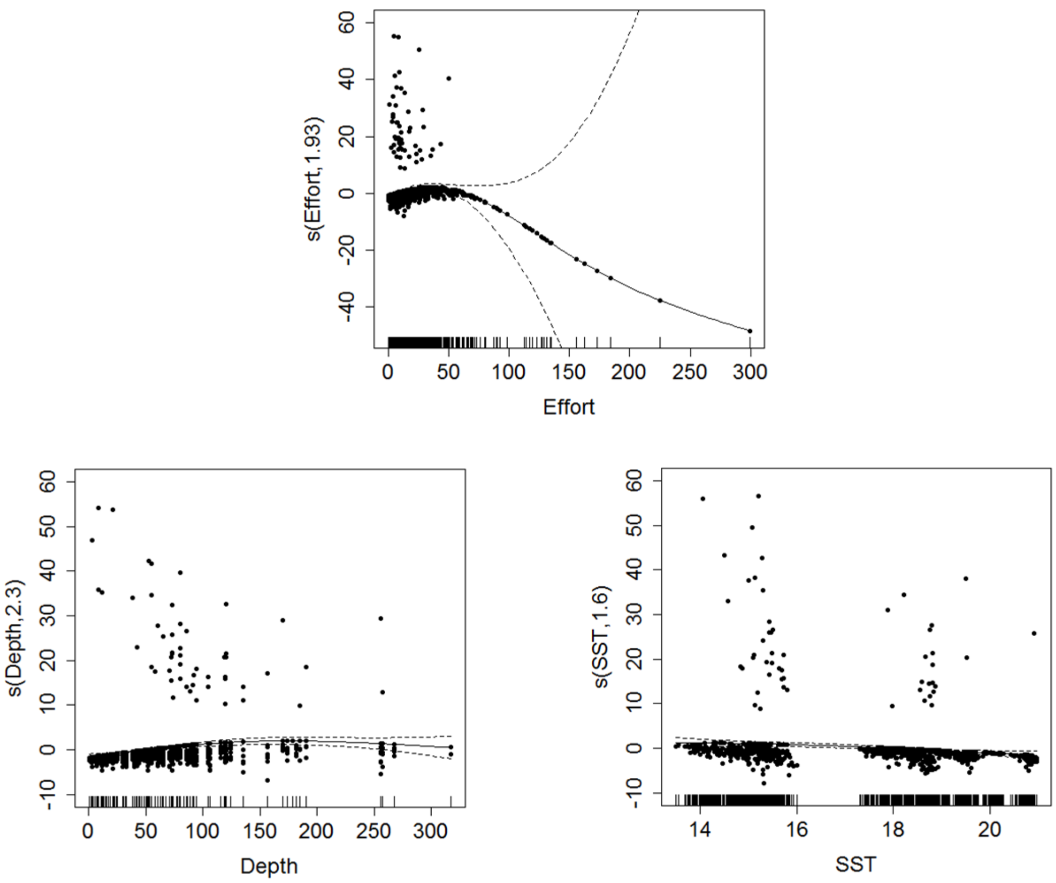

Figure 3.11: Effect of effort (km), depth (m), slope (°), SST (°C) on New Zealand fur seal occurrence between November 2010 and December 2013 in the western Bay of Plenty, New Zealand. The solid line is the estimated smoother and the dashed line is the 95% confidence interval.

3.4 Discussion

3.4.1 Common dolphins

Common dolphins were sighted year round in the BOP, although the species showed a strong warm seasonality. The limited survey effort in the cold season (one *versus* five vessels operating) explains scarce encounters during this time. However, the non-linear relationship with effort reveals that common dolphins are typically less common in the BOP in the cold season, presumably due to inshore-offshore movements, as previously described off the east coast of the Coromandel Peninsula (*ca.* 100km northwest of the study area, Neumann, 2001c). Similar seasonal changes in common dolphin distribution have previously been reported in various regions of the Mediterranean, Atlantic and Pacific (Lopez *et al.*, 2004; Cañadas and Hammond, 2008; Cañadas *et al.*, 2009; Becker *et al.*, 2014). In the Hauraki Gulf, common dolphins are also found in shallower waters during the summer months (Stockin *et al.*, 2008b; Dwyer, 2014). Indeed, the role of the East Auckland Current, transporting relatively warm subtropical water (Sharples, 1997; Stanton *et al.*, 1997; Tilburg *et al.*, 2001), likely influences the seasonality of some of the species along the northeast coast of New Zealand, including marine mammals in the BOP (Chapter 2).

Common dolphins showed an increasing use of deeper waters and increasing slope (up to 1°). Hot spots were specifically identified over the shelf break (100-200m depth), around islands and reefs (*e.g.* east of Mayor Island, Penguin Shoal, Pudney Rock, northeast of Motiti Island). Lower densities reported around Astrolabe Reef can be explained by insufficient survey coverage. This is likely due to the restriction area, closed to any unauthorised vessel, instigated after the grounding of the container ship *MV Rena* in October 2011, on Astrolabe Reef. Previous studies report common dolphins to associate with steep bathymetry (Cañadas *et al.*, 2002; Kiszka *et al.*, 2007b; Oviedo *et al.*, 2010), presumably due to the combination of physiographic features (*i.e.* escarpments, slopes, canyons) in conjunction with winds and currents, and resulting in complex hydrological dynamics (*i.e.* upwellings) concentrating prey species.

The BOP is characterised by distinct zones in terms of waters masses, of which the outer shelf zone mainly dominated by the East Auckland Current (Park, 1991). The convergence of oceanic boundary currents combined with the steep bathymetry over the shelf break often results in eddy formations, which can concentrate zooplankton and associated prey species (*e.g.* Huntley *et al.*, 2000; Cañadas *et al.*, 2002; Davis *et al.*, 2002). Similarly, local upwellings are potentially concentrating prey species over steep slopes around islands and reefs, providing higher foraging opportunities for the dolphins.

The decreasing occurrence observed in the models for slope steeper than 1° is in contradiction with the general pattern. However, this is possibly explained by limited survey effort beyond the shelf break (*i.e.* over slope steeper than 1°, Figures 3.4 and 1.3). Indeed, surveys were limited to 12nm off the coastline (*i.e.* 22km) and typically covered the continental shelf margin, which off Tauranga, extends up to 35km (Park, 1991). It is therefore recommended to examine dolphin occurrence in deeper waters and over steeper slopes (*i.e.* beyond the continental shelf) in order to fully understand common dolphin distribution in terms of oceanographic features.

In the BOP, SST increases in an offshore direction (Ridgway and Greig, 1986; Park, 1991). Therefore, the higher occurrence of common dolphins in deeper waters indicates that they may associate with warmer currents, as previously suggested by Neumann (2001c) for neighbouring Coromandel waters. However, the relationship between dolphin distribution and SST was slight and did not show any obvious pattern, potentially due to the restricted temporal scale of the dataset limited to the warm season. Moreover, it is also likely that the satellite seasonal composite maps used in the present study may not have been the most appropriate in terms of temporal resolution, masking any potential changes in oceanographic processes and consequently preventing the detection of any clear pattern for SST. However, owing to the tolerance of common dolphins to a wide range of SST (12 – 24.2°C, Carretta *et al.*, 2000), it is suggested that individuals are instead attracted by the front separating coastal waters from those dominated by warm waters of the East Auckland Current. Indeed, such oceanographic fronts often correspond to areas of enhanced productivity and zooplankton concentrations (Lalli and Parsons, 1997).

Similarly to SST, the relationship between dolphin distribution and Chl-a did not show any obvious pattern, conversely to other studies where Chl-a successfully explained distribution of *Delphinidae*, including common dolphins (Cañadas and Hammond, 2008; Moura *et al.*, 2012; McClellan *et al.*, 2014; Mannocci *et al.*, 2015). It is recognised that satellite data inaccurately estimate chlorophyll concentrations in coastal turbid waters (Antoine *et al.*, 1996), limiting the use or significance of this variable in cetacean distribution analysis in coastal areas (Praca and Gannier, 2008; Dwyer, 2014). It is possible that the input of the Tauranga harbour and Whakatane River into the bay prevent satellite sensors to provide accurate measurements of the chlorophyll. Alternatively, owing that Chl-a concentration was correlated with common dolphin distribution in other coastal areas (Cañadas and Hammond, 2008; Moura *et al.*, 2012; McClellan *et al.*, 2014), the lack of significance found in the present study may be explained by the data being limited to the warm season and satellite map resolution masking any spatial and temporal fluctuations.

Overall, common dolphin group size averaged 40 individuals (mean=38.3, SD=62.07). This is within the range reported for the Hauraki Gulf (mean=48.1, SD=64.9, Stockin *et al.*, 2008b; mean=22.2, SD=43.9, Dwyer, 2014), Great Barrier Island (mean=28.3, SD=41.7, Dwyer, 2014) and the east coast of the Coromandel Peninsula (mean=57.3, SD=50.78, Neumann, 2001b). Smaller groups of common dolphins were predominantly observed in shallower waters, while larger groups were most frequently recorded in deeper waters, as previously reported in the Hauraki Gulf (Stockin *et al.*, 2008b). Concurrently, immatures seemed to be more frequently observed in larger groups. In the Hauraki Gulf and off the east coast of the Coromandel Peninsula, common dolphins were found to display the opposite pattern as neonates were typically found in waters shallower than 20m (Stockin *et al.*, 2008b) and in smaller groups (Neumann, 2001b). In the Mediterranean, higher density of groups containing calves was also found in shallower waters (Cañadas and Hammond, 2008). This habitat segregation according to age classes is suggested to be driven by foraging strategies of lactating females, feeding on highly nutritive prey in shallow waters (Cañadas and Hammond, 2008). Recent studies in the Hauraki Gulf reported nursery groups in relatively deeper waters (*ca.* 40m, Dwyer, 2014), explicable potentially by a change in habitat (Dwyer, 2014), possibly related to prey availability (Stockin *et al.*, 2008b). Likewise, in the BOP, the presence of nursery groups in deeper waters may be explicable by increased foraging opportunities associated with steep bathymetry.

In the present study, group composition was similar across the cold and warm seasons, conversely to that reported for the east coast of the Coromandel Peninsula (Neumann, 2001a) and the Hauraki Gulf (Stockin *et al.*, 2008b; Dwyer, 2014), where groups with immatures were more prevalent in the warm season. However, due to a low sample size, results presented here for the cold season are severely constrained, offering little real insight. Neonates were observed between mid-January and mid-February in the study area, consistent with the Hauraki Gulf (Stockin *et al.*, 2008b), and is consistent with the hypothesis that seasonality for the New Zealand population may be related to prey resources for the lactating females and suitable water temperatures for the calves (Stockin *et al.*, 2008b). The occurrence of neonates also suggests that females calve within BOP waters, as previously suggested (Gaborit-Haverkort and Stockin, 2011).

Density rates found in the BOP are comparable to those reported for some regions in the Atlantic and Mediterranean. For instance, values reported for the warm season (0.014gp/km) are similar to those in the western English Channel (0.013gp/km, Kiszka *et al.*, 2007b), the northern Bay of Biscay (0.011gp/km, Kiszka *et al.*, 2007b) and the Gulf of Vera (0.016gp/km, Cañadas *et al.*, 2002). Low densities observed in the cold season (0.001gp/km) are similar to those found in the southern Bay of Biscay (0.005gp/km, Kiszka *et al.*, 2007b), off Portuguese coasts (0.002gp/km, Correia *et al.*, 2015) and in the eastern Ionian Sea (0.004gp/km, Bearzi *et al.*, 2005).

Sighting frequencies in the BOP are lower than those reported for the Gulf St Vincent, Australia (SR=0.03gp/km, Filby *et al.*, 2010). However, the encounter rates for the warm season (ER=0.58ind/km) are higher (0.16ind/km, Filby *et al.*, 2010) and explained by larger groups found in the BOP. The open oceanic waters of the BOP potentially favour larger and less dispersed groups, presumably because of the presence of predators. Shark species, such as short-fin mako (*Isurus oxyrinchus*), blue (*Prionace glauca*) and smooth hammerhead (*Sphyrna zygaena*) sharks, as well as killer whales (*Orcinus orc*a) have regularly been observed in the BOP waters and are potential threats to common dolphins (Stockin *et al.*, 2008b; Visser *et al.*, 2010). Alternatively, the dispersion of the prey resource in the BOP may also explain that larger groups are more successful at localising and gathering prey. Both hypotheses are non-exclusive and have been previously suggested for delphinids (Scott and Cattanach, 1998; Neumann, 2001b; Acevedo-Gutiérrez, 2002).

Sighting frequencies reported in the present study during the warm season (SF=0.014gp/km and ER=0.58ind/km) are similar to those reported for the same period in the Hauraki Gulf (0.014gp/km and 0.346ind/km, Dwyer, 2014). Higher densities and sighting rates were recorded in the Hauraki Gulf in winter (Stockin *et al.*, 2008b; Dwyer, 2014) concurrently with higher levels of foraging behaviour (Stockin *et al.*, 2009a). The lower densities found in the BOP (SF=0.001gp/km and ER=0.009ind/km) might be related to less feeding opportunities, as previously suspected in the Ionian Sea (Bearzi *et al.*, 2003). However, caution is urged when reviewing results for the cold season in the BOP due to restricted sample size. The decrease in common dolphin occurrence in the BOP notably matches the increase reported in the Hauraki Gulf, suggesting common dolphins may potentially shift between both areas. This hypothesis is supported by Neumann *et al.* (2002) using photo-identification to confirm movements between the BOP and the Hauraki Gulf waters (>200km northwest).

3.4.2 New Zealand fur seals

Fur seals alternate between foraging trips at sea and visits ashore to establish colonies and nurse pups (*e.g.* Goldsworthy and Shaughnessy, 1994). The average number of fur seals encountered on shore (mean=11.2 individuals) is within the range of what was reported in the eastern BOP (mean=22.2 individuals for Whale Island and 9.5 individuals at McEwan's Bay, Cowling *et al.*, 2014), although seasonal comparison is limited to the warm season for the eastern sub-region. The average number of fur seals occurring in the BOP is low overall compared with other regions in New Zealand. Indeed, colonies of 40 to 134 individuals have been reported in the Waikato region, west coast of the North Island (Bouma *et al.*, 2008), while typically exceeding a few hundred in the South Island (Taylor *et al.*, 1995; Bradshaw *et al.*, 1999a; Boren *et al.*, 2006b). While New Zealand fur seals are increasing in numbers (*e.g.* Lalas and Harcourt, 1995; Taylor *et al.*, 1995; Boren *et al.*, 2006b) and expanding northward (Taylor *et al.*, 1995), results presented here suggest that the recolonisation of the North Island by the New Zealand fur seals, remains in its early stages. However, island coastlines were surveyed in an opportunistic manner which restricted the ability to fully identify the overall extent and usage of haul out sites in the region.

Fur seal group size varied according to the haul out site and can be explained by the degree of human inhabitance on each island. Out of the four haul out sites observed, groups on Motiti Island, the only inhabited island in the BOP, were the smallest with less than five individuals recorded regardless of season. On the other islands, where landing is restricted and only allowed by permit, groups were significantly larger. For example, on Mayor and Plate Islands, groups averaged eight animals and were larger than 15 individuals in the warm and cold season, respectively. This pattern can be explained by the degree of human disturbance, observed in other areas (*i.e.* Boren *et al.*, 2002; Cowling *et al*., 2014), although dedicated surveys of the coastline should be undertaken to confirm this hypothesis. New Zealand fur seals have only recently began to reestablish breeding colonies in the BOP and therefore, are more vulnerable to human or ecological disturbance compared with well-established colonies (Stevens and Boness, 2003).

In New Zealand, adult males and females arrive at breeding colonies late October and late November, respectively, with pupping occurring between mid and late December (Miller, 1975; Lalas and Harcourt, 1995; Boren, 2005). The decline in fur seal relative abundance in the warm season, as evidenced in SR, ER and group size ashore, coincides with the breeding season and suggests that the western BOP might not support a breeding colony. This is further confirmed by the low encounter of pups (only three pups encountered in the western BOP between November 2010 and May 2013), compared with the eastern sub-region, where a minimum of eight births were reported between November 2011 and March 2012 (Cowling *et al.*, 2014). Instead, it is suggested that the western BOP supports a non-breeding colony (*i.e.* colony were less than 10 pups are born each year, Bradshaw *et al.*, 1999a) and that fur seal visit outside the breeding period (Stirling, 1970; Crawley and Wilson, 1976; Bouma *et al.*, 2008).

The availability of coastal food resources is suggested as the most important factor influencing fur seals recolonisation (Bradshaw *et al.*, 2002). For instance, proximity of foraging areas and abundance of prey resource determine the duration of female trips at sea, consequently influencing pup condition (Boyd, 1998; Bradshaw *et al.*, 2000a; Bradshaw *et al.*, 2002). Composition of the prey resource also plays an important role in fulfilling the high energetic requirements of females and may indirectly influence the success of pup rearing (Boyd, 1998; Page *et al.*, 2005). It is possible that differences in the marine environment between the western and eastern BOP explains the establishment of a breeding colony off Whakatane and a non-breeding colony off Tauranga. Alternatively, given that New Zealand fur seals have demonstrated site fidelity to both marine foraging and terrestrial breeding sites (Stirling, 1971; Bradshaw *et al.*, 2000b; Baylis *et al.*, 2012), immigration from established colonies to new ones can presumably be a long and complex process. Again, only dedicated long-term monitoring of the BOP islands will clarify the use of terrestrial sites as breeding or non-breeding areas.

In terms of bathymetric and oceanographic features, fur seal distribution in the warm season resembles that of common dolphins, with higher densities found in deep waters along the 100-200m isobaths and few reefs (*e.g.* Tūhua Reef and Penguin Shoal). During the cold season, high densities were also observed in shallower waters, located off Bowentown and Mount Maunganui entrances (Healy and de Lange, 2014). This distribution can potentially be explained by the presence of prey species, concentrated by local upwellings (Baylis *et al.*, 2008) and tidal currents (Davies-Colley, 1976; Davies-Colley and Healy, 1978). Fur seals have been shown to forage on benthic prey in winter (Harcourt *et al.*, 2002), explaining that aspect of the sea floor can represent an important bathymetric feature increasing foraging efficiency (Cook *et al.*, 2006).

Fur seals are known to respond to inter-annual changes of their environment conditions. For instance, decrease in pup production and their condition were observed during years where abnormal warm conditions were found in the tropical eastern Pacific waters (*i.e.* El Niño years) (Bradshaw *et al.*, 2000a; Boren *et al.*, 2006b). This is presumably explained by a reduction in prey resource availability to lactating females who extend their foraging trip at sea and shorten nursing time ashore (Ono *et al.*, 1987; Trillmich *et al.*, 1991; Burkanov *et al.*, 2011). Changes in fur seal occurrence observed between 2011 and 2012 (corresponding to abnormal cold conditions (*i.e.* La Niña – as opposed to

El Niño, and to normal conditions, respectively) is evident in the ER, SR and habitat models and can potentially be attributed to similar environmental changes.

3.4.3 Study limitations and recommendations for further research

The occurrence of common dolphins and New Zealand fur seals in the BOP is relatively well explained by the selected eco-geographical variables, owing the high deviance observed in both models. This is particularly true for common dolphins when comparing modeling results with those found in the Hauraki Gulf, using similar variables and methodology (Dwyer, 2014). However, the relationship between dolphin distribution in the BOP and SST and Chl-a did not show any obvious pattern, although it was found significant, and warrant therefore further investigation. For the fur seal model, Chl-a concentration did not significantly influence on the species occurrence.

In other studies, Chl-a was found to successfully explain distribution of some baleen whale species (*e.g.* Moore *et al.*, 2002; Penry *et al.*, 2011; Torres *et al.*, 2013; Correia *et al.*, 2015). However, it is suggested that mysticetes respond more quickly to nutrient-enriching events than odontocetes or pinnipeds because they feed on prey that is lower in the food chain (Kemper *et al.*, 2013). Furthermore, influence of Chl-a on marine apex predators can be less obvious presumably because phytoplankton can be quickly grazed down after the bloom (Lalli and Parsons, 1997). Additionally, the use of satellite maps in distribution models often shows bias for coastal areas (Antoine *et al.*, 1996), limiting the use or significance of these variables in cetacean distribution analysis (Praca and Gannier, 2008; Dwyer, 2014).

Finally, fluctuations in water temperature and productivity may have been masked by the temporal resolution of the satellite maps (*i.e.* three-month composite) and can presumably explain the weak patterns. Monthly or weekly composite maps are often used in distribution studies (Moura *et al.*, 2012; Dwyer, 2014; McClellan *et al.*, 2014; Correia *et al.*, 2015; Mannocci *et al.*, 2015) and could be used to investigate whether it would result in a clear pattern. However, monthly or weekly resolutions do not always result in better prediction or model performance including models on common dolphins in New Zealand (Dwyer, 2014; Correia *et al.*, 2015; Chapter 2). It is therefore possible that Chl-a is not a variable that can potentially explain common dolphin or fur seal distribution in New Zealand waters.

Nevertheless, the present study is the first to successfully identify environmental parameters (*i.e.* depth, aspect of the sea floor and SST) influencing the distribution at sea of fur seals. Similarly to observations in the South Island (Bradshaw *et al*., 2000a; Boren *et al*., 2006b), ENSO conditions are suspected to influence fur seal density in the BOP and therefore warrant further research to be conducted. This study also provided initial insights to fur seal haul out distribution. While the average number of fur seals at haul out sites is comparable between the eastern and western BOP (Cowling *et al.*, 2014), higher densities are reported in other regions of New Zealand (Taylor *et al.*, 1995; Bradshaw *et al.*, 1999a; Boren *et al.*, 2006b; Bouma *et al.*, 2008). Fur seals are only starting to recolonise the North Island (Taylor *et al.*, 1995) which may, therefore, explain lower densities found in the region. Establishment of new colonies is also presumably a long and complex process, involving site fidelity to foraging areas (Baylis *et al.*, 2012). Alternatively, given that the coastline of each island was not surveyed systematically (due to other primary objectives, Chapter 4), hauled out seals reported here represent opportunistic sightings only and thus, should be considered as conservative minimum estimates.

3.5 Conclusion

Common dolphins and New Zealand fur seals exhibited a strong yet contradictory seasonality in the BOP. The seasonal decrease in common dolphin occurrence in the western BOP is further opposite to the seasonal increase reported in the Hauraki Gulf. It is suggested that common dolphins change habitats according to the season and related foraging opportunities. During the warm season, common dolphins were influenced by the bathymetric and oceanographic features, presumably concentrating prey resource over the shelf break, around reefs and islands.

The presence of fur seals in the winter and spring, during the non-breeding season, suggests that the western BOP is used by the species for foraging purposes. This is supported by the identification of hotspots over the shelf break and around reefs, where prey resource is potentially enriched by the local currents and upwellings and concentrated by the steep bathymetry. Alternatively, due to the presence of few pups during the study period and the proximity of a breeding colony in the eastern BOP, the western BOP may potentially be just at an early stage of recolonisation. While the present study provides baseline information for management authorities, further monitoring of the population, and more specifically dedicated surveys of individuals at haul out sites, is recommended in order to better understand the expansion and ecology of New Zealand fur seals in the region.

Chapter 4

Behavioural effects of tourism on oceanic common dolphins (*Delphinus* sp.) in New Zealand: The effects of Markov analysis variations and current tour operator compliance with regulations

Commercial tour vessel interacting with common dolphins in the Bay of Plenty.

4.1 Introduction

Over the past two decades, an abundance of literature referring to boat-based marine mammal tourism has clearly shown that cetacean-watching is seldom benign and that careful management is required to minimise potential negative effects on targeted populations (Lusseau, 2004; Orams, 2004; Bejder *et al.*, 2006b; Williams *et al.*, 2009b; Parsons, 2012; Scarpaci and Parsons, 2013). Vessel presence has, for example, been shown to increase dolphin travelling behaviour at the expenses of foraging (Neumann and Orams, 2006; Stockin *et al.*, 2008a), resting (Lusseau, 2003a; Stockin *et al.*, 2008a) or socialising (Stensland and Berggren, 2007; Christiansen *et al.*, 2010). Authors have also reported some species avoid approaching vessels (Neumann and Orams, 2006; Stamation *et al.*, 2010; Steckenreuter *et al.*, 2012). Although the risk of ship strike has long been a concern for larger whales (Laist *et al.*, 2001), collisions between small delphinids and tour vessels (International Whaling Commission, 2014) or recreational craft (Dwyer *et al.*, 2014a) have also been reported.

Tourism may also expose cetaceans to noise pollution which can lead to chronic auditory damage (Martinez and Orams, 2011; Martinez *et al.*, 2012) or to exhaust emissions that are likely to cause serious health effects (Lachmuth *et al.*, 2011). Close encounters with wild cetaceans at sea have also become more intrusive, including swimming (Constantine, 2001; Martinez *et al.*, 2011; Filby *et al.*, 2014) or provisioning dolphins with food, whether monitored or illegal (Rafic, 1999; Samuels and Bejder, 2004), leading to possibly dangerous situations for both dolphins and humans (Orams *et al.*, 1996; Mann *et al.*, 2000; Orams, 2002; Samuels and Bejder, 2004; Smith *et al.*, 2008; Donaldson *et al.*, 2010; Foroughirad and Mann, 2013). Although viewing and swimming activities are regarded as relatively safe from an infectious standpoint (Waltzek *et al.*, 2012), serious concerns have been raised as increased opportunities for disease transmissions exist and dolphins could potentially be infected by humans (International Whaling Commission, 2001).

Recent tourism impact studies have argued that short-term behavioural changes can have long-term implications for targeted populations by disrupting energy budgets, reducing energy uptake and/or increasing physical demands (Boggs, 1992; Williams *et al.*, 2006b; Lusseau *et al.*, 2009; Christiansen *et al.*, 2013a, 2014). As such, there is increasing evidence that individual behavioural changes can potentially lead to population-level effects (Bejder *et al.*, 2006b). However, despite numerous concerns raised by the scientific community, the cetacean-watching industry is still experiencing a fast world-wide expansion, as the economic benefits of marine mammal-based activities represent a significant part of the ecotourism industry (Hoyt, 2001; O'Connor *et al.*, 2009). The dolphin-watching industry in Oceania has followed this global trend and is now widespread in 17 countries within this region. In New Zealand alone, approximately 550,000 international and domestic cetacean-watching tourists generated over US$80 million in 2008 (O'Connor *et al.*, 2009). Permits to watch and/or swim-with-dolphins in New Zealand increased from 90 in 2005 (International Fund for Animal Welfare, 2005) to 112 in 2011 (Young, Department of Conservation, pers.com.).

Most marine mammals in New Zealand are the focus of tourism operations, including rare endemic species such as the Hector’s dolphin (*Cephalorhynchus hectori hectori*) (Martinez *et al.*, 2011) and the New Zealand sea lion (*Phocarctos hookeri*) (Hollingworth, 2001). Nationally endangered, the bottlenose dolphin (*Tursiops* *truncatus*) is also targeted by tourism activities (Lusseau, 2003a; Constantine *et al.*, 2004; Guerra *et al.*, 2014). While the vast majority of scientific studies have evaluated the effects of tourism activities on the behaviour of coastal species (Lusseau, 2003a; Stensland and Berggren, 2007; Arcangeli and Crosti, 2009; Christiansen *et al.*, 2010; Martinez, 2010; Steckenreuter *et al.*, 2012), considerable less is known about the effects of tourism activities on pelagic oceanic populations of delphinids (Neumann and Orams, 2006; Courbis and Timmel, 2009; Lundquist *et al.*, 2012). This is because oceanic species are believed to be less subject to and impacted by human activities.

Short- and long-beaked common dolphins (*Delphinus delphis* and *D. capensis*) are listed by the International Union for Conservation of Nature (IUCN) as “least concern” and “data deficient”, respectively (Hammond *et al.*, 2008a,b). Under the New Zealand Threat Classification System (Townsend *et al.*, 2008), common dolphins (*Delphinus* sp.) are currently classified as “not threatened” (Baker *et al.*, 2010), despite the absence of any population estimates (Stockin and Orams, 2009). Moreover, they remain the only resident cetacean species within New Zealand to lack a species-specific Marine Mammal Action Plan (Suisted and Neale, 2004).

Although generally considered to be a pelagic species associated with deep waters (Gaskin, 1992), common dolphins in many parts of New Zealand use near-shore waters and may therefore be vulnerable to coastal anthropogenic activities such as pollution, fisheries by-catch and vessel collision (Stockin *et al.*, 2007, 2009b; Martinez and Stockin, 2013; Thompson *et al.*, 2013). The effects of tourism activities on common dolphins have previously been examined in northern coastal regions of New Zealand, including the Bay of Islands, the Hauraki Gulf and the east coast of the Coromandel

Peninsula (Constantine and Baker, 1997; Neumann and Orams, 2006; Stockin *et al.*, 2008a). However, with a typical oceanic distribution off the Bay of Plenty (BOP, Figure 4.1), common dolphins have been considered as less vulnerable to tourism effects given their offshore movements (Neumann, 2001c).Common dolphins are the focus of marine mammal tourism operations in the BOP, especially in austral summer when the peak of tourism activities coincides with the species breeding season (Neumann, 2001a; Stockin *et al.*, 2011). Since 1995, eight permits (all commercial marine mammal tour operators require a permit in New Zealand) have been issued by the Department of Conservation.

In the current study, effects of vessel interactions on the behaviour of common dolphins using open oceanic waters off the BOP were investigated. This allowed for a comparison with the effects previously demonstrated for this species using inshore coastal waters in neighbouring areas of the North Island of New Zealand (Stockin *et al.*, 2008a). Compliance of dolphin-viewing and swimming operations were assessed with regards to their adherence to permit conditions and to the Marine Mammal Protection Regulations (MMPR, 1992). More specifically, the objectives of this chapter were to:

- Examine the level of vessel traffic and interactions with common dolphins within the BOP region.
- Investigate variations in dolphin responses to vessel interaction by applying two approaches of Markov chain analysis to compare animal behaviour.
- Assess compliance of dolphin-based activities in the region to regulations and permit conditions.

4.2 Methods

4.2.1 Study area

The BOP, situated in the North Island, New Zealand (Figure 1.2), is an important habitat for common dolphins (Gaborit-Haverkort and Stockin, 2011). The area is an open bay influenced by the East Auckland Current and where water depths reach 250m within 30km off the coastline (Chapter 1, Section 1.5). Common dolphins frequent the area throughout the year, but especially during the austral summer (Gaborit-Haverkort and Stockin, 2011; Meissner *et al.*, 2014; Chapters 2 and 3).

Marine traffic in the BOP consists of a wide variety of vessels. As one of New Zealand's fastest growing cities and being the largest port in the country in terms of total cargo volume (Port of Tauranga, 2014), Tauranga (37.6878°S and 176.1651°E) accommodates large commercial ships, fishing boats, ferries, cruise liners, recreational power boats, yachts and other non-motorised craft. Tauranga is also the departure port for seven commercial dolphin tour vessels from November to April, while the coastal township of Whakatane (37.5700°S 177.0050°E, 90km to the south east) is the base for three further commercial vessels, two of which undertake opportunistic dolphin-viewing year round during sight-seeing trips to the active volcano White Island (37.3100°S and 177.1150°E, Figure 1.3).

4.2.2 Data collection

4.2.2.1 Platforms of observation

Non-systematic surveys were conducted between November 2010 and May 2013 from two types of platforms. A dedicated research vessel was used departing from Tauranga harbour (Chapter 3, Section 3.2.2.1 for full information on the research vessel). Four tour vessels (Chapter 3, Section 3.2.2.1 for full information on these vessels) were utilised as platforms of opportunity in the western part of the region, departing from Tauranga harbour (Figure 4.1). Three additional tour vessels (*i.e.* a 10.5m motorised trailer-launched vessel, an 18.3 and 22.3m motorised dock-launches, respectively) were boarded in the eastern part of the region, departing from Whakatane (Figure 4.1), between November 2011 and February 2012, once permission had been granted by local tour operators. Access to the tour vessels was granted on a daily basis by the tour operators to the observers (Anna Meissner or the research assistants) and was dependent on the space aboard the tour vessels.

4.2.2.2 Surveys

As platform height is known to affect the detectability of cetaceans at sea, survey conditions were assessed in relation to the observational platform used (Hammond *et al.*, 2002, Chapter 3, Section 3.2.2.2 for full information on weather conditions during surveys).

When aboard the research vessel, a non-systematic survey design was employed in order to maximize time spent examining the behaviour of common dolphins interacting with the tour vessels. The research vessel survey tracks were therefore often based on the tour vessel direction of travel, primarily dependent on prevailing weather conditions and previous dolphin encounters. Vessel speed was maintained between 8 and 10kts when searching for dolphins, with at least two experienced observers actively searching the horizon by naked eyes and/or binoculars (Tasco Offshore OS36 7x50 magnification), using continuous scanning methodology (Mann, 1999). Time spent travelling along survey tracks was classified as *on effort* (Chapter 3, Methods, Section 3.2.2.2). Once the research or tour vessels departed the survey track to approach a group of dolphins, the survey mode switched to *off effort* until returning back to the track to resume searching for another group of dolphins or until the vessel returned back to the harbour. Therefore, more than one independent focal group was occasionally encountered during a survey. Groups were considered independent if they were separated spatially (> 5km) and temporally (> 30min) to a degree that would prevent animals becoming resampled during the second focal follow (Stockin et al., 2009a).

4.2.2.3 Focal group follows

The effects of vessel interactions on dolphin behaviour were only examined from aboard the research vessel, using focal group scan sampling (Altmann, 1974; Mann, 1999). Focal individual follows (Mann, 1999) were neither feasible nor appropriate for this study owing to the difficulties of identifying individual common dolphins in the field, and to the increased probability of disturbing the group when attempting to track individuals (Neumann, 2001a; Stockin *et al.*, 2009a). Instead, focal group scan sampling followed established protocols for collecting behavioural data on this species, with scans undertaken with naked eyes from the left to the right in order to include all individuals within the group (Stockin *et al.*, 2009a) and to avoid attention being drawn only to conspicuous individuals and/or behaviours (Mann, 1999). If fission of the focal group occurred, the largest subgroup became the focal group.

A group of dolphins was defined as any number of dolphins observed in association, moving in a similar direction and usually engaged in a similar behaviour (Shane, 1990). Members were assumed to be part of a group when they remained within 100m of each other (Bearzi *et al.*, 1997). Group size was recorded in the field as a minimum number, best estimate and maximum number of individuals likely to be in the group. Group composition was categorised as adults and immatures (*i.e.* neonates, calves and/or juveniles), following Stockin *et al.* (2008b).

Once a focal group follow started, the behavioural state of the dolphin group was assessed every 3min using categories modeled on Neumann (2001a) and Stockin *et al.* (2008a) (Table 4.1, Appendix 6). The predominant behaviour was determined as the behavioural state in which more than 50.0% of the dolphins within the group were involved at the time of sampling (Lusseau, 2003a; Stockin *et al.*, 2008a). Where groups exhibited an equal percentage of individuals engaged in different behaviours, all represented behavioural states were recorded. Only behaviours that could be reliably identified were collected (Mann, 1999) and those were always determined by the same observer (Anna Meissner) to allow consistency throughout the study.

A focal group follow was composed of one or several sequences, *i.e.* succession of behavioural states. Those sequences were considered as control sequences in the presence of the research vessel only (Lusseau, 2003a; Stockin *et al.*, 2008a). The use of a research vessel has the potential for disturbing dolphin behaviour. However, observing dolphin behaviour from land-based theodolite viewing stations (e.g. Martinez, 2010, Lundquist *et al.*, 2012) was constrained by the flat topography of the coastline. In compliance with the Department of Conservation guidelines, the MMPR (1992) and to minimise effects on dolphin behaviour, consistent and careful handling of the research vessel (no sudden change of speed or course, course kept parallel to the dolphin group) was operated when approaching and following dolphin groups. This resulted in constant effects of the research vessel on dolphin behaviour (Lusseau, 2003a; Stockin *et al.*, 2008a). Interaction sequences were considered when the research vessel and other vessel(s) was (were) present within 300m of the focal group of dolphins (Lusseau, 2003a; Stockin *et al.*, 2008a), this distance being consistent with the MMPR (1992). Interactions sequences qualified whether passangers of the other vessel(s) where viewing and/or swimming with the dolphins.. Any changes in dolphin behaviour, when comparing control and interaction sequences, were therefore attributed to the presence of other vessel(s) than the research vessel.

The time of vessels interacting with the dolphins was recorded and vessels were categorised as: a) commercial tour vessels; b) non-motorised craft – kayaks, stand up paddleboards, rowing craft, *etc*; c) motorised recreational launches – inboard vessels; d) motorised recreational trailer-launched vessels – outboard vessels less than 8m; e) motorised personal water craft – jet skis; f) motorised commercial vessels – container ships, commercial fishing vessels, *etc*. Approximate speed of interacting vessels was estimated in relation to the speed of the research vessel.

All focal follows terminated when fuel reserves became low, weather or daylight deteriorated, or when visual contact with the dolphins was lost. The end of an encounter was therefore not dependent on the behaviour of the focal group (Stockin *et al.*, 2008a). This protocol was maintained during vessel interactions and thus, the state of the observing research vessel remained consistent throughout all control and interaction scenarios. Consequently, differences observed in the behaviour of the dolphins were assumed to be related only to the presence of the other interacting vessel(s).

Table 4.1: Definitions of mutually exclusive behavioural states of common dolphin groups in the Bay of Plenty, New Zealand modeled on Neumann (2001a) and Stockin *et al.* (2008a).

Behavioural state	**Definition**
Foraging	Dolphins involved in any effort to pursue, capture and/or consume prey, as defined by observations of fish chasing (herding), coordinated deep and/or long diving and rapid circle swimming. Prey can often be observed at the surface during foraging. High number of non-coordinated re-entry leaps, rapid changes in direction and long dives are observed.
Milling	Dolphins exhibit non-directional mouvements, 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.
Resting	Dolphins observed in a tight group (less than one body length apart), engaged in slow manoeuvres (slower than the idle speed of the observing boat) with little evidence of forward propulsion. Surfacings appear slow and are generally more predictable (often synchronous) than those observed in other behavioural states.
Socialising	Dolphins observed in diverse interactive events among members of the group such as social rub, aggressiveness, chasing, mating and/or engaging in any other physical contact with other dolphins (excluding mother-calf pairs). Aerial behavioural events such as breaching are frequently observed.
Travelling	Dolphins engaged in persistent, directional movement making noticeable headway along a specific compass bearing at a constant speed (usually faster than the idle speed of the observing boat). Group spacing varies and individuals swim with short, relatively constant dive intervals.

4.2.2.4 Swimming with the dolphins

In accordance with their permits, commercial tour operators performed swim encounters with the dolphins, which consisted of one or several swim attempts. Swim-with-dolphins activities in the BOP are active and boat-based (International Whaling Commission, 2001; Parsons *et al.*, 2006). Tour vessels typically approach parallel or behind the group of dolphins, while assessing for the presence of calves, dolphin behaviour and weather conditions for swimmer safety. Once a decision is made by the skipper to proceed to a swim, swimmers are actively placed in the water, generally holding onto ropes or bars at the stern of the vessel and only occasionally free swimming/snorkelling (Meissner *et al.*, 2014). Swim activities were monitored from the boat in respect to dolphin behaviour only. The time and duration of the swim attempt, recorded from the research vessel and from aboard the tour vessels, commenced when the first swimmer entered the water and ended when the last swimmer got back aboard the boat (Appendix 7). Dolphin responses to swimmers were recorded from aboard the tour vessels and adapted from Constantine (2001) and Martinez *et al*. (2011) as follows: a) neutral presence – no apparent change in dolphin behaviour. At least one dolphin remained within 5m of the swimmers for at least 5sec. Interaction time was recorded when at least one dolphin was within 5m of the swimmers; b) neutral absence – no apparent change in dolphin behaviour. Dolphins were initially more than 5m distant from the swimmers and did not approach within 5m; c) avoidance – change in dolphin behaviour. Dolphins were within 5m of the boat and departed as swimmers entered the water; d) interaction – change in dolphin behaviour. Dolphins were greater than 5m distant from the swimmers and at least one dolphin approached the swimmers at least once and for at least 5sec.

The different reasons for ending a swim encounter were recorded from aboard the tour vessels and categorised as follows: a) unsuccessful swim due to dolphin behaviour – fast travelling dolphins could not be pursued; b) loss of sight of dolphins – the dolphin group could not be viewed from the surface; c) skipper decision – due to time restrictions, *i.e.* the maximum time allowed for dolphin encounters was reached; d) presence of calf(ves) detected during the swim attempt.

4.2.3 Regulations applying to commercial tour vessels in the BOP

In accordance with their permit conditions, commercial operators in the BOP are restricted to operate outside Tauranga harbour and interact with dolphins for a maximum of 90min per trip, of which 60min can be used to swim with the dolphins (assuming no calves are present in the group). In addition, under the MMPR (1992), all commercial and recreational vessels are limited to a "non-wake" speed (approximately 5kts) while within 300m of the dolphins and cannot approach the group if three vessels (commercial and/or recreational) are already engaged with the group (*i.e.* viewing and/or swimming within 300m of the dolphins).

4.2.4 Statistical analysis

4.2.4.3.1 Effect of boat interactions

Markov chain analyses have been widely applied as a technique to explore the potential effects of tourism activities on marine mammals (*e.g.* Lusseau, 2003a; Williams *et al.*, 2006b; Christiansen *et al.*, 2010, 2013b; Martinez, 2010; Dans *et al.*, 2012). In New Zealand, this technique has previously been selected to examine tourism effects on common dolphin behaviour occurring in coastal waters of the Hauraki Gulf (Stockin *et* *al.*, 2008a). In an attempt to compare tourism effects between coastal and oceanic populations, the same methodology was applied presently.

Markov chain analyses compare the behaviour of the dolphins both when in the presence and absence of tour vessels, while simultaneously taking into account the temporal dependence between behavioural states. This is achieved by calculating probabilities of transitions from preceding to succeeding behavioural states (Lusseau, 2003a). However, as the effect of the approach and departure of vessels on dolphin behaviour remains unclear, authors have considered those specific transitions (going from no boats present to boats present and *vice versa*) differently across the various published studies. A conservative approach eliminates any transition in which the animal state might potentially be uncertain as to whether it is a control or interaction situation (behavioural states following or affected by the approach/departure of a vessel are discarded from the analysis, Table 4.2) and focuses on examining the transitions in the presence and absence of interacting vessels, respectively (Stockin *et al.*, 2008a; Martinez, 2010; Lundquist *et al.*, 2012). Conversely, other authors consider also the transition in behavioural state at the onset of an interaction (going from no boats present to boats present) as affected (Lusseau, 2003a; Christiansen *et al.*, 2010, Table 4.2). In the present study, we examined the effects of vessel interactions using both approaches to examine the level of difference in dolphin responses. As Markov chain analysis does not account for multiple behavioural states when collected simultaneously (*i.e.* when the group was split equally between two behavioural states), double states were excluded from the analyses. The program UNCERT (http://www.animalbehavior.org/Resources/CSASAB/) was used to develop two-way contingency tables (preceding *versus* succeeding behavioural states) and to calculate the number of transitions between the behavioural states in both control and interaction conditions. Foraging, milling and travelling behaviours are likely to be affected by the previous interaction up to 15min following the departure of the vessel (Stockin *et al.*, 2008a). Based on this assumption, post-interaction sequences of 15min immediately following the departure of interacting vessel(s) were added to the interaction sequences for further analyses.

Following the Perron-Frobenius theorem (Caswell, 2001), the behavioural budget (*i.e.* the proportion of time dolphins engaged in each behavioural state, Lusseau, 2003a; Stockin *et al.*, 2008b; Martinez, 2010) under control and interaction conditions was approximated by the left eigenvector of the dominant eigenvalue of the transition matrices using the Excel add-in PopTools (Version 3.0.3, CSIRO: www.cse.csiro.au/poptools/). Differences between control and interaction behavioural budgets were tested with a binomial Z-test for proportions (Fleiss *et al.*, 2003) and 95% confidence intervals (CI) were calculated.

To assess changes in behavioural states due to vessel presence, transition probabilities, from the immediately preceding to the succeeding behavioural state, were calculated for the control and interaction chains separately by (Lusseau, 2003a):

$$p_{ij} = a_{ij} / \sum_{j=1}^{n} a_{ij}, \sum_{j=1}^{n} p_{ij} = 1$$

where *i* is the preceding behavioural state, *j* is the succeeding behavioural state, a_{ij} is the number of transitions observed from behavioural state *i* to *j*, p_{ij} is the transition probability from *i* to *j* in the Markov chain and *n* is the total number of behavioural states. Control and interaction transition probabilities were compared using a binomial Z-test for proportions (Fleiss *et al*., 2003) and 95% CI were calculated.

Table 4.2: Different approaches of Markov chain analysis. The leftward and rightward arrows indicate the vessel arrival and departure, respectively. Conservative approach – *Scenario 1*: Vessel arrives/departs between samples S3 and S4, and S7 and S8, respectively. Samples S4 and S8 following the vessel arrival/departure are discarded. *Scenario 2*: Vessel arrives/departs during samples S4 and S7, respectively. S4 and S7 are discarded. Less conservative approach – *Scenario 3*: Vessel arrives and departs between S3 and S4, and S7 and S8, respectively. S3 is considered affected by the vessel arrival. Sample S8 following the vessel departure is discarded. *Scenario 4*: Vessel arrives/departs during S4 and S7, respectively. Sample S3 preceding the vessel arrival is considered affected. Sample S8 following the vessel departure is discarded.

Type of approach	**Conservative**				**Less conservative**			
Scenario	**1**		**2**		**3**		**4**	
3min samples	S_1		S_1		S_1		S_1	
	S_2		S_2		S_2		S_2	
	S_3		S_3		S_3		S_3	
		←				←		
	S_4		S_4	←	S_4		S_4	←
	S_5		S_5		S_5		S_5	
	S_6		S_6		S_6		S_6	
	S_7		S_7	→	S_7		S_7	→
		→				→		
	S_8		S_8		S_8		S_8	
	S_9		S_9		S_9		S_9	
	S_{10}		S_{10}		S_{10}		S_{10}	
Discarded samples	S_4, S_8		S_4, S_7		S_8		S_8	
Control chains	$S_1S_2S_3$–S_9S_{10}		$S_1S_2S_3$–$S_8S_9S_{10}$		S_1S_2–S_9S_{10}		S_1S_2–S_9S_{10}	
Interaction chains	$S_5S_6S_7$		S_5S_6		$S_3S_4S_5S_6S_7$		$S_3S_4S_5S_6S_7$	

To assess the recovery period after disturbance for different behavioural states, the average time (min) it took dolphins to return to each initial behavioural state was calculated and compared between control and interaction conditions, following Stockin *et al.* (2008a):

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

where (T_j) denotes the time (*i.e.* number of transitions multiplied by the length of each transition unit, *i.e.* 3min) it takes to return to state *j* given that the dolphins are currently in state *j* and π is the steady-state probability of each behaviour in the chain.

Behavioural bout lengths (*i.e.* episodes, periods) $\overline{t_{ii}}$ were also estimated from the Markov chains, as detailed in Lusseau (2003a), and compared between control and interaction situations using the Student's t-test. Pearson's χ^2 tests were used to examine any difference in the identified effects while using both sensitivities for the Markov chain analyses. Statistical analyses were performed using R 3.0.1 (2013).

4.2.4.3.2 Levels of vessel traffic

During a focal follow, each vessel interacting with dolphins was considered an independent sampling unit. On a broad scale, commercial tour vessels were compared to non-tour vessels (hereafter non-tour vessels, categories b-f, as described in Section 4.2.2.2). Vessel traffic analyses examined the number and type of vessels interacting, independently or simultaneously, with the focal group of dolphins. The duration (min) of the encounters was examined with regard to the maximum time of 90min allowed per vessel, as defined in the commercial tour permits. The number of approaches per vessel was also reported. For each focal group, the overall time dolphins spent in the presence of vessels was estimated and compared according to the type of vessel. When a vessel interacted with a focal group more than once, successive encounters were cumulated, interaction time was summed and compared between vessel types using non-parametric Kruskal-Wallis tests. The speed (in kts) of each vessel was recorded every 3min while within 300m of the focal group and compared according to the different types of vessels (Kruskal-Wallis tests). If a vessel encountered a focal dolphin group and attempted to approach and interact more than once with that same group, the second attempt was excluded from the speed analysis to ensure independence across encounters (Martinez, 2010).

4.2.4.3.3 Cumulative behavioural budget

The interaction behavioural budget describes the behaviour of the dolphins during interactions with vessels. Thus, it is an instantaneous measure, which does not take into account the amount of time that dolphins are exposed to interacting vessels throughout the year. To incorporate boat exposure into the behavioural effect on dolphins, the dolphin cumulative behavioural budget (seasonal behavioural budget) was estimated following Lusseau (2003a) and Christiansen *et al.* (2010):

$$\text{Cumulative budget} = (a \times \text{impact budget}) + (b \times \text{control budget})$$

where a is the proportion of time (relative number of daylight hours per day) that common dolphins spend with interacting vessels (thus following a behavioural budget similar to interaction) and $b = 1 - a$ is the proportion of time dolphins spend without interacting vessels (thus following a behavioural budget similar to control). If dolphins had no exposure to interacting vessels, a would equal 0 and the cumulative behavioural budget of the dolphins would be the same as the control budget. Conversely, if the dolphins were interacting with vessels throughout all the daylight hours, a would equal 1 and the cumulative behavioural budget would be the same as the interaction budget. To test if the dolphin cumulative behavioural budget was significantly different from their control budget, a 2-tailed Z-test for proportions for each behavioural state was used. The effects of vessel traffic intensity on the dolphin cumulative behavioural budget was also investigated by artificially changing a from 0 to 100% and testing if the resulting cumulative behavioural budget differed significantly from the control budget (Christiansen *et al.*, 2010).

4.2.4.3.4 Effect of swimmers

The size and composition of the group of dolphins interacting with the vessel while swim activities occurred were monitored from both the tour vessels and the research vessel, in order to compare the level of compliance of commercial tour operations. The duration (min) of the swim attempts, dolphin behavioural state (Table 4.1) and dolphin responses to swimmers, as well as the different reasons for ending a swim encounter were determined.

4.3 Results

4.3.1 Effort

Between November 2010 and May 2013, a total of 55 focal follows were undertaken during 7,634min (*i.e.* 127.2h) and 828.5km of survey effort across 50 days aboard the research vessel. Control and interaction sequences of more than 15min (*i.e.* composed of a minimum of five transitions) were considered for Markov chain analyses (as per Stockin *et al.*, 2008a). Regardless of whether in control or interaction conditions, and using the more or less conservative Markov chain approach, only a low number of transitions between resting and socialising and the other behavioural states were observed. Moreover, the low proportion of time spent resting and socialising (less than 13.5%) in the overall behavioural budget of the dolphins precluded the use of those two behavioural states in further analyses. Any transitions containing resting and/or socialising states were therefore omitted and Markov chain analyses were examined taking into account only the three remaining behavioural states, *i.e.* foraging, milling and travelling (Table 4.3).

Table 4.3: Percentage and duration (mean and range in min) of sequences and percentage of behavioural transitions during control scenarios (presence of the research vessel only) and during interaction scenarios (when in the presence of other vessels). Calculated and presented considering three behavioural states (foraging, milling and travelling) and using the conservative and less conservative approaches, respectively.

	Type of approach	**Conservative**	**Less conservative**
Control	Number of sequences	38.6% (n=34)	39.8% (n=33)
	Duration of sequences	49.8 (15.0-279.0)	50.8 (15.0-279.0)
	Number of transitions	60.2% (n=564)	60.1% (n=559)
Interaction	Number of sequences	61.4% (n=54)	60.2% (n=50)
	Duration of sequences	20.7 (15.0-81.0)	22.3 (15.0-87.0)
	Number of transitions	39.8% (n=373)	39.9% (n=371)

4.3.2 Effect of boat interactions

Following the conservative approach and under control conditions, common dolphins spent the majority (58.9%, n=352) of their time travelling. Foraging represented an important proportion of their behaviour (26.8%, n=160), while milling accounted for only half of that time (14.4%, n=86). There was no significant difference to this pattern while following the less conservative approach (Pearson's χ^2: χ^2=0.12, df=2, p=0.944). The behaviour of common dolphins differed in the presence of vessels (Figure 4.2). Travelling increased by 10.1% (95% CI: 3.7–16.4%, z=-3.12, p=0.002) or by 11.7% (95% CI: 5.3–18.0%, z=-3.60, p=0.0003), while foraging decreased by 12.4% (95% CI: 7.1–17.8%, z=4.56, p<0.001) or by 16.7% (95% CI: 11.5–21.9%, z=6.30, p<0.001), according to the conservative and less conservative approach, respectively.

The temporal dependence between behavioural states was also affected by vessel presence. The transition from travelling to foraging significantly decreased by 67.9% (Z-test: z=2.47, p=0.014) when using the conservative approach (Figure 4.3). Based on the less conservative approach, the same transition decreased more (74.7%, Z-test: z=2.78, p=0.009) and transition from milling to foraging significantly decreased by 67.5% (Z-test: z=2.41, p=0.010). Moreover, once disrupted, foraging dolphins took longer to return to this state, with an increase of 91.4% or 175.2%, from 11.5min to 22.1min or to 31.5min, for the conservative or less conservative approach, respectively (Table 4.4). Time taken to return to milling and travelling decreased by 13.3% from 19.6min to 17.0min and by 14.6% from 5.1min to 4.4min, respectively, in the presence of interacting vessels when using the conservative approach (Table 4.4). Using the less conservative approach, time to return to milling and travelling was shortened (time decreased by 23.6% from 18.5min to 14.1min and by 16.8% from 5.2min to 4.3min, respectively, Table 4.4). The average length of behavioural bouts significantly varied when vessels were present (Table 4.5). Bout length increased by 12.2% for foraging dolphins (95% CI: 0.36–0.64; t=-7.20, df=202, p<0.001) when using the conservative approach, while the less conservative approach found no difference. For travelling dolphins, bout length increased by 55.9% (95% CI: 4.34–4.44; t=-168.33, df=573, p<0.001) or by 54.2% (95% CI: 4.04–4.14; t=-157.31, df=561, p<0.001), for the conservative and less conservative approach, respectively. Similarly, during interactions, the duration of milling bouts increased by 11.9% (95% CI: 0.16–0.46; t=-4.05, df=156, p<0.001) or by 26.0% (95% CI: 0.54–0.82; t=-9.43, df=166, p<0.001), for the conservative and less conservative approach, respectively.

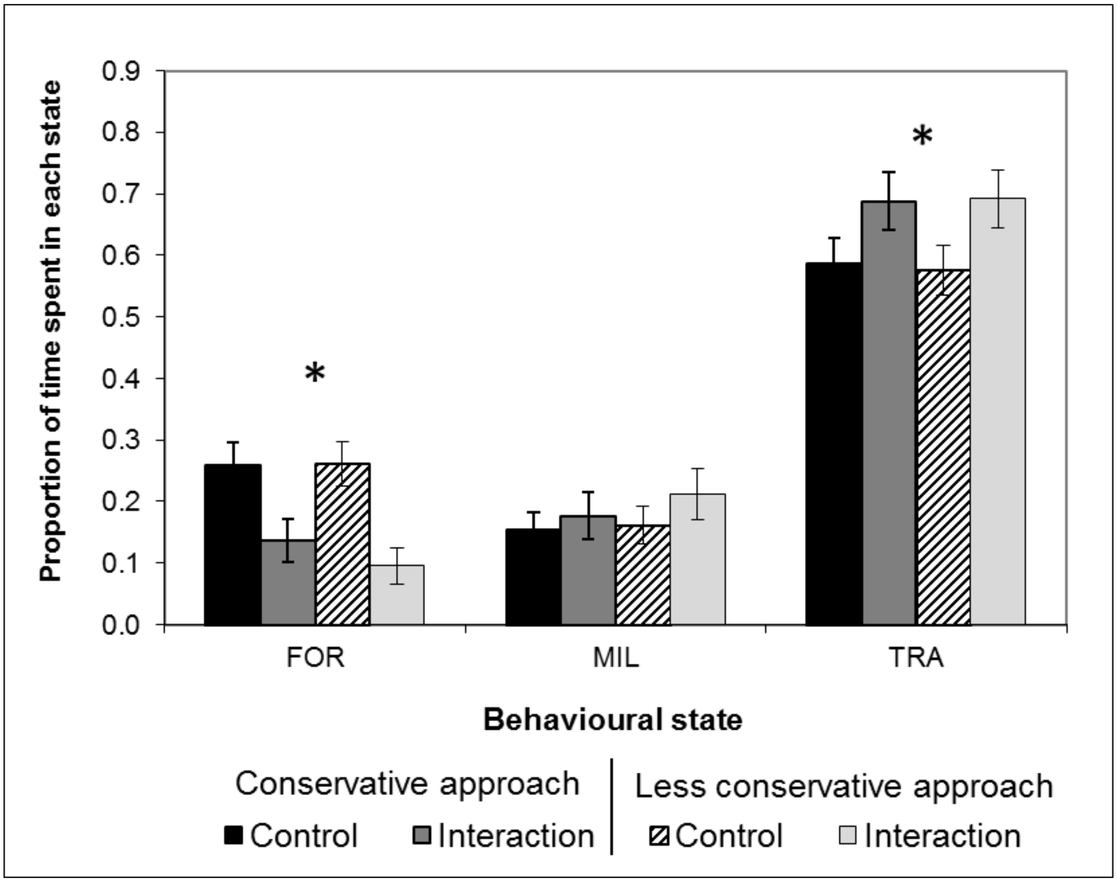

Figure 4.1: Effect of vessel interactions on the behavioural budget of common dolphins between November 2010 and May 2013 in the Bay of Plenty, New Zealand. Proportion of time spent in each behavioural state in the presence and absence of interacting vessels. Error bars represent 95% confidence intervals. Significant differences (p<0.05) between control (solid or striped black bars) and interaction scenarios (light and dark grey bars) are denoted by an (*). Results are shown following the conservative and less conservative approaches. Note: FOR=foraging, MIL=milling, TRA=travelling.

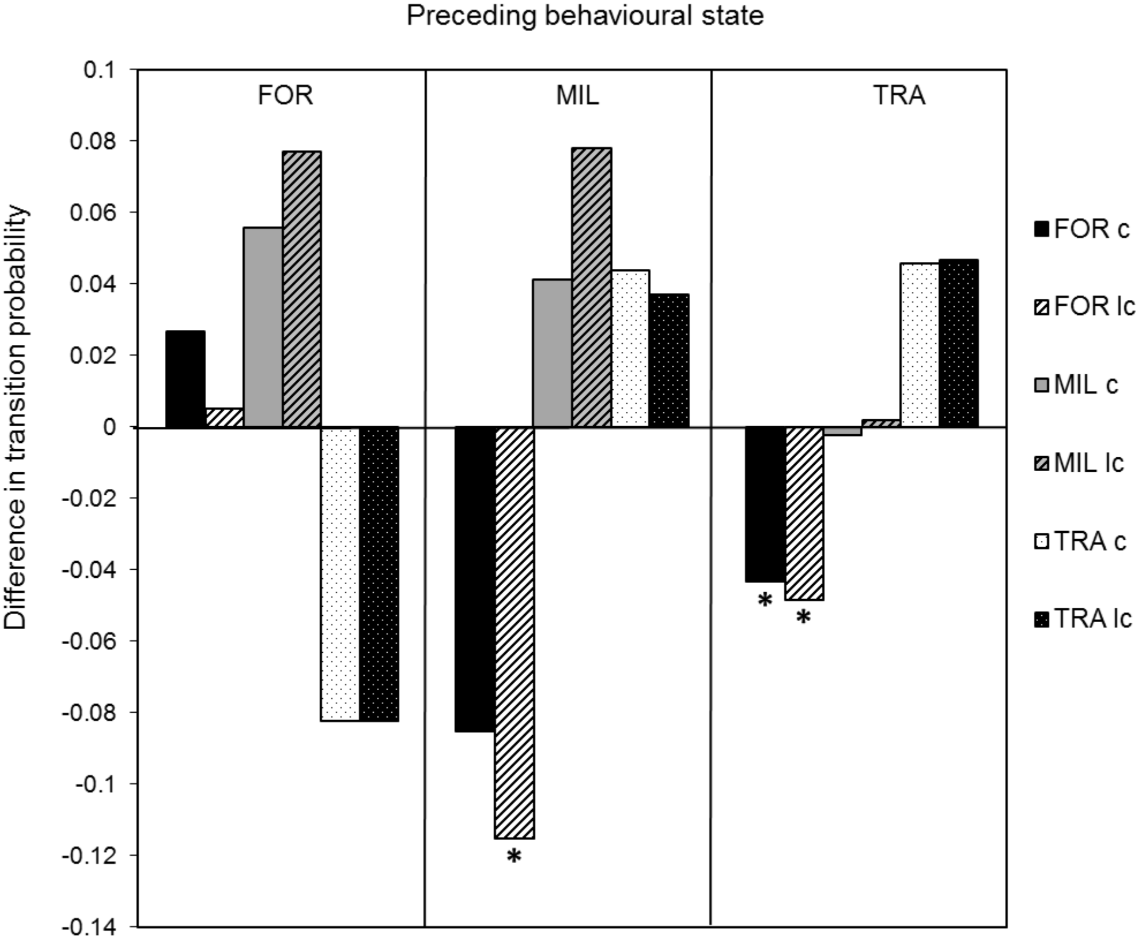

Figure 4.2: Effect of vessel presence on transitions between behavioural states of common dolphins, based on differences in transition probabilities $(p_{ij(\text{interaction})} - p_{ij(\text{control})})$ between November 2010 and May 2013 in the Bay of Plenty, New Zealand. A negative value means that the behavioural transition of the control chain is superior to that of the interaction chain. The graph is composed of three parts, one for each preceding state, separated by vertical lines. In each part, bars correspond to succeeding behavioural states. Transitions with a significant difference (p<0.05) are marked by an (*). Results shown after following the conservative approach (c) and the less conservative approach (lc). Note: FOR=foraging, MIL=milling, TRA=travelling.

Table 4.4: Probability of being in a particular behavioural state (π_j), number of 3min time units ($E(T_j)$) and amount of time (min) required to return to initial behavioural states during control scenarios (presence of the research vessel only) and during interaction scenarios (when in the presence of other vessels). Calculated and presented using the conservative/less conservative approaches, respectively.

	Control			**Interaction**		
Behaviour	π_j	$E(T_j)$	**Time (min)**	π_j	$E(T_j)$	**Time (min)**
Foraging	0.26 / 0.26	3.8 / 3.8	11.5 / 11.5	0.14 / 0.10	7.4 / 10.5	22.1 / 31.5
Milling	0.15 / 0.16	6.5 / 6.2	19.6 / 18.5	0.18 / 0.21	5.7 / 4.7	17.0 / 14.1
Travelling	0.59 / 0.58	1.7 / 1.7	5.1 / 5.2	0.69 / 0.69	1.5 / 1.4	4.4 / 4.3

Table 4.5: Average bout length ($\overline{t_{ii}}$) during control (presence of the research vessel only) and interaction scenarios (presence of other vessels). Numbers represent the conservative/less conservative estimates, respectively.

Behaviour	**Control** $\overline{t_{ii}}$	**Interaction** $\overline{t_{ii}}$
Foraging	4.05 / 4.03	4.55 / 4.11
Milling	2.58 / 2.65	2.89 / 3.33
Travelling	7.86 / 7.53	12.25 / 11.62

4.3.3 Levels of vessel traffic

Interactions between vessels and dolphins were monitored during 256 surveys undertaken from aboard the tour vessels and during the 35 focal follows monitored aboard the research vessel (*i.e.* 186 vessel-common dolphin interactions). Out of the 7,634min (*i.e.* 127.2h) of focal follows recorded by the research vessel, common dolphins were observed in the presence of vessels during 21.0% of the time (1,604min, *i.e.* 26.7h), of which 6.0% (459min, *i.e.* 7.7h) was with tour vessels only, 1.7% (133min, *i.e.* 2.2h) with non-tour vessels only and 13.3% (1,012min, *i.e.* 16.9h) with both types of vessels. Overall, common dolphin groups spent significantly more time in the presence of tour vessels (median=45min, IQR=38.5, n=11) than in the presence of non-tour vessels (median=9min, IQR=7.3, n=8, Kruskal-Wallis: H=5.17, df=1, $p<0.05$). Similarly, when assessing interactions per vessel, tour vessels spent significantly more time with common dolphins (median=37min, IQR=33.5, n=23) than non-tour vessels (median=1min, IQR=4, n=139, Kruskal-Wallis: H=55.31, df=1, $p<0.001$). Interactions monitored from aboard the tour vessels lasted between one and 148min (median=40.5min, IQR=38.8, n=256), exceeding the 90min time restriction specified in the permit regulations during 14.8% of encounters (n=38).

Generally, between one and three vessels interacted with a focal group of common dolphins (80.0% of the focal follows, n=28), although a maximum of 61 vessels approached dolphins on one occasion during the course of this study. This was observed inside Tauranga harbour and included tour vessels, in contravention of the permit regulations. Moreover, simultaneous interactions (n=29), where one vessel interacting with dolphins was joined by others, were relatively frequent (42.9% of focal follows, n=15), with the majority of interactions (75.9%, n=22) involved two or three vessels. While this was in compliance with the MMPR (1992), it was not unusual (24.1%, n=7) to observe four or more vessels interacting with the same group of dolphins, in breach of the regulations (MMPR, 1992). This included one occasion when a tour vessel arrived after two tour vessels and two non-tour vessels were already within 300m of the dolphins. Tour vessels primarily approached dolphins once (88.6%, n=39), but were occasionally observed interacting twice with the same focal group (11.4%, n=5). Similarly, non-tour vessels primarily approached dolphins once (90.1%, n=128), although some approached the same focal group twice (9.2%, n=13) or up to four times (7.0%, n=1).

Vessel types travelled at significantly different speeds (Kruskal-Wallis: H=76.080, df=5, p<0.001) when within 300m of dolphin groups. Non-motorised craft interacted with the dolphins below the “non-wake” speed (median=2.5kts, IQR=3.5, n=12). Motorised commercial vessels (median=7.0kts, IQR=7.0, n=19) and motorised recreational launches (median=10.0kts, IQR=5.8, n=20) typically passed within 300m of dolphins without altering either their course or speed. Motorised recreational trailer-launched vessels (median=10.0kts, IQR=14.0, n=71) and motorised personal craft (median=15.0kts, IQR=11.0, n=3) showed a wide range of speeds, reacting to dolphin presence via sudden altering of course and/or speed. Commercial tour vessels travelled around 5kts (median=5.5kts, IQR=3.0, n=275) but were observed 51.3% of the time (n=141) travelling over 5kts within 300m of dolphins, in breach of the regulations (MMPR, 1992).

4.3.4 Cumulative behavioural budget

Vessel traffic intensity exceeding 34.0 and 56.0% significantly affected common dolphin cumulative foraging and travelling behaviours, respectively (Figure 4.4a). Therefore, the overall vessel traffic intensity of 21.0% does not significantly affect dolphin cumulative behavioural budget over time (Figure 4.4a). However, when examining at a finer temporal scale, these critical levels were reached temporarily during the peak tourism season of 2012 and 2013 (Figure 4.4b).

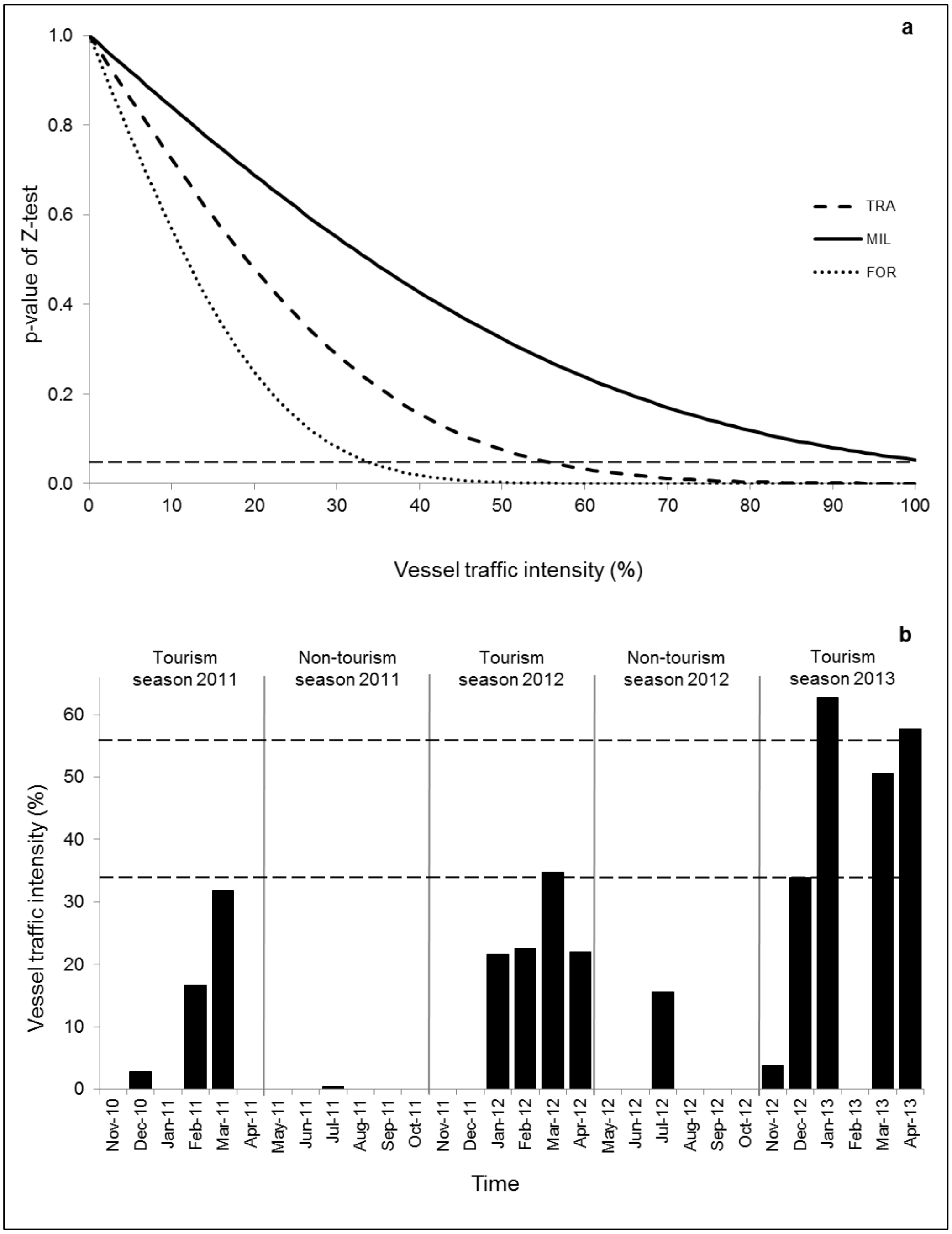

Figure 4.3: Effect of vessel traffic intensity on common dolphin behaviour a) P-values of the difference between the cumulative behavioural budget and the control behavioural budget for common dolphin activity. The proportion of time dolphins spent with interacting vessels was artificially varied from 0 to 100%. Each curve corresponds to different behavioural states (FOR=foraging, MIL=milling, TRA=travelling). The horizontal dashed line represents the statistical level of significance ($p<0.05$) b) Vessel traffic intensity throughout the study period (November 2010 to May 2013). The horizontal dashed lines represent 34.0 and 56.0% of traffic intensity above which the cumulative foraging and travelling behaviours, respectively, are significantly affected. The vertical lines separate the tourism and non-tourism seasons.

4.3.5 Swimming with the dolphins

Overall, 26 swim attempts were monitored during 12 swim encounters from the research vessel. Additionally, 67 swim attempts during 25 swim encounters were monitored from aboard the tour vessels. During the 12 swim encounters monitored from the research vessel, swimmers were primarily deployed by the tour vessels (83.3%, n=10), although recreational boats (*i.e.* motorised trailer-launched vessels) dropped single swimmers on two independent occasions (16.7%).

Swims lasted only 5.2min on average (SD=3.9, n=61), with the majority (59.0%, n=36) lasting less than 5min and only a small proportion (11.5%, n=7) lasting more than 10min. When monitored from aboard the tour vessels, the majority (77.1%, n=27) of swims occurred with small dolphin groups (1-10 individuals) containing only adults. Twenty percent (n=7) of the swims occurred with larger groups (11-30 individuals) containing adults and juveniles and on one occasion calves, in contravention to the MMPR (1992). Moreover, one swim encounter (2.9%) occurred with a group larger than 200 individuals which contained all age classes, in breach of the regulations (Marine Mammals Protection Regulations, 1992). Conversely, out of the 12 swim encounters monitored from the research vessel, calves were observed in the group during 50.0% of the swims (tour vessels n=5, recreational boat n=1), in breach of the MMPR (1992). Juveniles were present during all 12 swim encounters.

Swimmers were placed in the water when common dolphins were travelling (34.0%, n=17), foraging (26.0%, n=13), socialising (22.0%, n=11) or milling (18.0%, n=9). When swimmers were present in the water, the proportion of encounters where dolphins did not change their behavioural state (*i.e.* neutral) was significantly higher (56.8%, n=21, χ^2=11.73, df=2, p<0.05), compared to only 32.4% (n=12) and 10.8% (n=4) of observations where dolphins approached or avoided the swimmers, respectively. Swim encounters with common dolphins ended 70.1% of the time (n=47) because of skipper decision, 28.4% (n=19) of the time because of loss of sight of dolphins and 1.5% of the time (n=1) because of calf presence. Furthermore, during only half of the swim attempts (53.7%, n=39) were dolphins observed within 5m of the swimmers.

4.4 Discussion

In the history of marine mammal exploitation, tourism has often been considered positively compared to lethal whaling activities (Parsons and Draheim, 2009; Chen, 2011). In addition, watching free-ranging dolphins is becoming a popular alternative to viewing dolphins in captivity (Hughes, 2001; Draheim *et al.*, 2010; Luksenburg and Parsons, 2014). However, effects of commercial tourism activities on marine mammals are becoming difficult to ignore. Since the 1990s, research has raised concerns about the effects of commercial tourism on marine mammal behaviour, reporting various changes in the behaviour of numerous coastal species (*e.g.* Stensland and Berggren, 2007; Stockin *et al.*, 2008a; Arcangeli and Crosti, 2009; Christiansen *et al.*, 2010; Stamation *et al.*, 2010; Steckenreuter *et al.*, 2012). Regardless of either Markov approach applied, this study provides further evidence that commercial tourism induces significant changes in the behaviour of common dolphins using open oceanic waters. More specifically, the presence of interacting vessels affected the behavioural budget of common dolphins, which spent significantly less time foraging. Once disrupted, dolphins took at least twice as long to return to foraging when compared to control conditions. Furthermore, the probability of starting to forage while engaged in travelling decreased by two thirds. Conversely, dolphins increased their foraging bout length in the presence of interacting vessels (following the conservative approach). Given foraging tactics used by common dolphins include cooperative herding of the prey (Neumann, 2001b; Neumann and Orams, 2003; Burgess, 2006; de la Brosse, 2010), it is possible that the behavioural changes of some individuals, as a result of approaching vessels, could compromise the success of the overall foraging event.

Maneuvering a vessel through a group of dolphins, as it has been observed, may separate individuals within the dolphin group, disperse the prey and/or affect dolphin communication because of vessel underwater noise (Scarpaci *et al.*, 2000; Jensen *et al.*, 2009; Guerra *et al.*, 2014). In all scenarios, dolphins would presumably have to reestablish group cohesion and/or communication in order to successfully capture their prey, ultimately resulting in both increased time between foraging bouts and energy expenditure. Thus, findings presented here indicate that common dolphin foraging behaviour is significantly affected by the presence of interacting vessels in the BOP.

Foraging is a critical component for any predator and disruption to this behaviour can potentially result in energy intake reductions that can have long-term implications on demographic parameters (*i.e.* lower reproductive success, higher risk of mortality) influencing population size, even more so when individuals are limited by resource availability and a large proportion of the population is affected by the disturbance (Anthony and Blumstein, 2000; Williams *et al.*, 2006b; Christiansen *et al.*, 2013b, Lusseau, 2014). To illustrate, the level of vessel interaction with bottlenose dolphins in Doubtful Sound, South Island, is low (*i.e.* one encounter per hour), yet tourism activities are suspected to decrease calving success (Lusseau *et al.*, 2006). In contrast, bottlenose dolphins in Sarasota Bay, Florida, encounter a boat every 6min without apparent effects on their vital rates (Buckstaff, 2004). When exposed to a constraining environment, *i.e.* where prey resource is heterogeneous in time and space, dolphins are less likely to cope with interactions and have less opportunity to compensate for such disturbances, which in turn are more likely to lead to population-level consequences (Lusseau, 2014). In an environment like the BOP, where prey resources are unpredictable in distribution (Neumann, 2001a), interactions with vessels are likely to lead to a reduction in the overall energy acquisition. Notably, the majority of dolphin tourism in the region occurs during the austral summer, during the peak calving season (Schaffar-Delaney, 2004; Stockin *et al.*, 2008b), when there is a higher occurrence of common dolphins closer to the shore (Neumann, 2001c; Chapter 2 and 3). Results presented here show that the cumulative time spent foraging and travelling were significantly affected in the tourism seasons of 2012 and 2013. It is suggested that the intensity of vessel traffic in summers 2012 and 2013 was high enough to alter the overall dolphin cumulative behavioural budget.

Although the consequences of reduced feeding for nursing groups remain unclear, it is likely to have bigger effects on pregnant and lactating females, as their energy requirements are considerably higher especially during nursing (Perez and Mooney, 1986; Bernard and Hohn, 1989; Rechsteiner *et al.*, 2013; Malinowski and Herzing, 2015). Body condition of breeding female influence the calf birth mass and the lactation length, and consequently the offspring condition as it has been shown in various terrestrial and marine mammals (*e.g.* Bowen *et al.*, 1994, 2001; Wheatley *et al.*, 2006;

Lycett *et al.*, 1998). Tourism activities, and more specifically disruption of foraging, can therefore impact maternal investment (Boren, 2005; McClung *et al.*, 2004). If interactions occur during a critical phase of the calf development, they can have important impacts on the survival of the young (McMahon *et al.*, 2000) and ultimately lead to impacts at the population level. In addition, energy that females dedicate to evade vessels is diverted from maternal investment for the offspring (Lusseau, 2014). It has also been suggested that different boat avoidance strategies exist between male and female dolphins, with males diving while vessels were approaching, conversely to females diving only when vessels were in closer proximity (Lusseau, 2003b). Females were also observed to dive for shorter periods of time (Lusseau, 2003b). The difference in both strategies was suggested to be related to different energetic demands (Lusseau, 2003b) and raise concerns as females, and potentially their offspring, might be more likely to be exposed to intrusive interactions and consequently more at risk of injuries from vessel collision (*e.g.* Dwyer *et al.*, 2014). Therefore, disrupting the foraging behaviour of females and immature dolphins is likely to add physiological constraints to these individuals and could potentially reduce their reproductive success and negatively affect population dynamics on a long-term basis (Lusseau, 2003b). Whether the effects on cumulative behaviour in 2012 and 2013 were high enough to induce survival or reproduction impacts remains unknown, and would require data on life history (*i.e.* mortality, reproduction rates) to be tested. Unfortunately, those data are missing for common dolphin in New Zealand (Stockin and Orams, 2009), and more particularly in the BOP.

Similarly to bottlenose dolphins (Dwyer *et al.*, 2014b; Zaeschmar *et al.*, 2014), movements of some common dolphins across neighbouring regions in the North Island have been confirmed (Neumann *et al.*, 2002). Indeed, several individuals identified in the Hauraki Gulf have previously or subsequently been observed in the Bay of Islands or in the BOP, 200km further north and southeast, respectively (Neumann *et al.*, 2002; Hupman, unpub. data.). Commercial tourism activities exist in all those regions and movements of dolphins across all regions further highlights the potential risk of cumulative effects within the home range of the population.

In the North Island, commercial swimming with common dolphins is permitted in the Bay of Islands, Hauraki Gulf and in the BOP. However, common dolphins seem to be less receptive to this activity compared to other species. For example, common dolphins in the BOP infrequently approached swimmers (32.4% of encounters), as previously observed in the east coast of the Coromandel Peninsula (20.5%, Neumann and Orams, 2006) and in the Bay of Islands (24.1%, Constantine and Baker, 1997). Thus, swim encounters where dolphins actively approach swimmers are less frequent for common dolphins than other delphinids (bottlenose, Hector's and dusky dolphins, *Lagenorhynchus obscurus*) targeted by swim-with-dolphins operators in New Zealand (Constantine, 1995; Barr, 1997; Bejder *et al.*, 1999; Martinez *et al.*, 2011), all of which approached swimmers during more than 50.0% of swim attempts. Similarly to Bay of Islands and the east coast of the Coromandel Peninsula (Constantine and Baker, 1997; Neumann and Orams, 2006), swimmers typically spent only 5min in the water, compared to longer durations with dusky or Hector's dolphins, which lasted 9.1 and 10-18.8min, respectively (Markowitz *et al.*, 2009; Martinez *et al.*, 2011). Moreover, only half of the swim attempts in the present study were deemed successful (*i.e.* dolphins were within 5m of the swimmers, as judged by the observer aboard the vessel). While this relatively low level of success could be explained by water turbidity or lack of swimmer confidence, dolphin group size and behavioural state are likely a key influence on swim success, with dolphins being more interactive when in larger socialising groups compared to when travelling or milling (Neumann and Orams, 2006). Finally, differences in vessel and change of speed during swim encounters (slowing down/stopping to place people in the water and then pursuing the dolphins) might also explain the limited interest of dolphins.

This study also highlighted non-compliance to some permit conditions and/or regulations (*e.g.* area of operation, speed and number of vessels interacting with a single group, maximum time permitted interacting with the dolphins and swimming with calves). Compliance also varied when recorded from aboard the research and tour vessels and could be explained by tour operators reacting to the presence of a researcher aboard their vessels and adhering more closely to the regulations. Alternatively, the researcher was likely to act as an independent observer alerting the skipper about breaches of regulation (*e.g.* warning about the presence of calves while not focusing on the swimmers). Adherence to management regulations has not only been shown to reduce effects of vessel interactions on dolphin behaviour (Lusseau, 2006), but also increase the probability of having an interaction with a dolphin group. For example, dolphins avoid high speed vessels and conversely associate for longer periods of time with slower craft (*e.g.* kayaks or sailing vessels, Martinez, 2010). Besides changes in dolphin behaviour (Nowacek *et al.*, 2001; Miller *et al.*, 2008), high speed driving can also result in an elevated risk of collision which can be fatal (Wells and Scott, 1997; Nichols *et al.*, 2001; Martinez and Stockin, 2013; Dwyer *et al.*, 2014a).

In New Zealand, common dolphins are currently classified as “not threatened” (Baker *et al.*, 2010) and are still lacking a species-specific Marine Mammal Action Plan (Suisted and Neale, 2004), despite numerous threats being identified (Stockin and Orams, 2009). In the light of the present results and previous studies, tourism has now clearly been identified as an additional human induced threat, as viewing and swimming activities significantly affect the species behaviour in various regions around New Zealand (Neumann and Orams, 2006; Stockin *et al.*, 2008a). Moreover, potential cumulative effects across dolphin home range are likely to exacerbate identified impacts. As previously described (*e.g.* Lusseau, 2006; Martinez, 2010), dolphins are likely to use the area until the costs of tolerance exceed the benefits of remaining in that habitat. In species such as dolphins, the long-term effects of tourism activities can take decades to detect (Wilson *et al.*, 1999; Thompson *et al.*, 2000). Common dolphins are therefore unlikely to immediately discontinue use of BOP waters, despite facing human disturbance (*e.g.* recreational vessel traffic, commercial pressure, *etc*), thus regular monitoring of the local population is required.

4.5 Conclusion

This study showed that tourism activities on common dolphins in open oceanic waters can be as detrimental as in inshore shallow coastal seas. Overall, interacting vessels significantly affected a biologically important behaviour, namely foraging. The magnitude of this effect is a cause for concern given its potential impact on common dolphin cumulative behavioural budget during the peak tourism season, which is also the calving and breeding season for this species in New Zealand waters. Not only is it the busiest period for commercial tourism activities, but recreational vessel traffic is at its highest. Therefore, future growth in commercial tourism activities as well as recreational interactions with common dolphins in this area need careful consideration. Given that non-compliance to the regulations (permit conditions and MMPR, 1992) was recorded, appropriate conservation management is recommended and should further encompass neighbouring regions so as to consider potential cumulative effects of vessel interactions across the home range of the population.

Chapter 5

An assessment of site fidelity and potential cumulative exposure of common dolphins (*Delphinus* sp.) to tourism operations in the Bay of Plenty, New Zealand

Individual ID_0063, "*Epsilon*", photographed from a tour vessel on 3rd February 2011 (left) and 10th January 2013 (right), in the Bay of Plenty.

5.1 Introduction

In New Zealand, the presence of common dolphins (*Delphinus* sp.) in near-shore waters makes the species of high interest to the marine mammal tourism industry, specifically along the northeast coast of the North Island (Constantine, 2001; Neumann and Orams, 2006; Stockin *et al.*, 2008a; Meissner *et al.*, 2014, 2015; Chapter 4). Indeed, common dolphins are the most frequently sighted cetacean in the Hauraki Gulf (O'Callaghan and Baker, 2002; Stockin *et al.*, 2008b; Dwyer, 2014) and the Bay of Plenty (BOP; Gaborit-Haverkort and Stockin, 2011; Meissner *et al.*, 2014, Chapter 2 and 3).

While effects of commercial tourism have been reported at the group level for each region (Neumann and Orams, 2006; Stockin *et al.*, 2008a; Meissner *et al.*, 2015; Chapter 4), the potential risk of cumulative exposure either within or between regions, as a consequence of repetitive individual interactions, has yet to be addressed. Indeed, focal follow methods, used in tourism impact studies (*e.g.* Lusseau, 2003a; Stockin *et al.*, 2008a; Christiansen *et al.*, 2010; Meissner *et al.*, 2015; Chapter 4), do not facilitate vessel interactions at the individual level to be assessed, owing to the difficulties of identifying individuals in the field (Neumann, 2001; Stockin *et al.*, 2009; Chapter 4). However, photo-identification (photo-ID) is a non-intrusive methodology (Würsig and Jefferson, 1990) that can be applied to address the question of potential cumulative exposure on individuals (Christiansen *et al.*, 2015).

Concerns are typically expressed for coastal dolphin populations as they are considered most susceptible to anthropogenic effects (*e.g.* Hartel *et al.*, 2014). This is owing to their high site fidelity, small group size and close proximity to human activities (*e.g.* tourism, boat strike, habitat degradation, fishery interactions, pollution, recreational net captures, Thompson *et al.*, 2000; Van Waerebeek *et al.*, 2004; Parra *et al.*, 2006; Stockin *et al.*, 2007, 2009b; Stockin and Orams, 2009; Gonzalvo *et al.*, 2014). To illustrate, it has been extensively demonstrated that marine mammals feeding in coastal habitats concentrate higher levels of contaminants in their tissues (Herman *et al.*, 2005; Borrell *et al.*, 2006; Kretzmann *et al.*, 2010; Adams *et al.*, 2014) and are more vulnerable to injury and/or mortality resulting from entanglement in fishing gear or vessel collision (Berkenbusch *et al.*, 2013; Torres *et al.*, 2013) compared with oceanic individuals (Herman *et al.*, 2005; Kiszka *et al.*, 2008; Kretzmann *et al.*, 2010; Berkenbusch *et al.*, 2013).

The potential for even transient or migratory populations to be adversely affected by human-induced disturbances while using coastal waters has further been addressed (Constantine and Bejder, 2008; Félix and Botero-Acosta, 2011). For instance, commercial fishing and shipping are considered significant factors contributing to northern right whales (*Eubalaena glacialis*) injuries and mortality in the western North Atlantic (Knowlton and Kraus, 2001). Similarly, southern right whales (*E. australis*) using shallow waters at Peninsula Valdés, Argentina, during the breeding season, show various scars from injuries resulting from shipping collisions and fishing gear entanglements (Rowntree *et al.*, 2001).

While New Zealand common dolphins are typically considered a pelagic species, they are found consistently within inshore shallow waters (Stockin *et al.*, 2008b; Dwyer, 2014). They are, therefore, subject to a number of anthropogenic coastal activities (Stockin *et al.*, 2007, 2008a, 2009b). For instance, they show similar loads of persistent organochlorine pesticides to those of coastal species such as Hector’s dolphins

(*Cephalorhynchus hectori hectori*) presumably due to the usage of coastal waters for feeding (Stockin *et al.*, 2007). Furthermore, incidental captures of common dolphins in trawl fisheries has also been explained by its occurrence in coastal waters (Stockin *et al.*, 2009b; Stockin and Orams, 2009).

While commercial fishing and maritime traffic can result in apparent and/or lethal injuries, other anthropogenic activities such as dolphin-based tourism activities are considered to cause indirect, less obvious impacts. For instance, Rowntree *et al.* (2001) reported changes in southern right whale distribution and establishment of new nursery grounds at Peninsula Valdés. Reasons associated with these changes remain unclear, although human disturbance, including tourism activities were suggested (Rowntree *et al.*, 2001). Furthermore, changes in feeding behaviour of humpback whales (*Megaptera novaeangliae*) have been reported following commercial tour vessel interactions in southeastern New South Wales, Australia (Stamation *et al.*, 2007). While the species migrates along the northeast coast of Australia, individuals are targeted by tourism activities in other regions along their migration routes, as revealed by photo-ID (*e.g.* Corkeron, 1995; Stamation *et al.*, 2010), potentially resulting in cumulative exposure across their home range (Constantine and Bejder, 2008).

The potential for cumulative effects of tourism, both within as well as across neighbouring regions has been previously suggested for New Zealand common dolphins (Neumann and Orams, 2006; Stockin *et al.*, 2008a; Meissner *et al.*, 2015; Chapter 4). For example, Neumann *et al.* (2002) documented movements of known individuals captured via photo-ID moving between areas exposed to tourism activities. In some instances, known individuals moved between the Hauraki Gulf (*ca.* 200km northwest of the current study area), the east coast of the Coromandel Peninsula (*ca.* 100km northwest of the study area) and eastern BOP (*i.e.* Whakatane, *ca.* 100km southeast of the study area, Neumann *et al.*, 2002).

Tourism pressure within the Hauraki Gulf and Whakatane remains lower than off Tauranga (Figures 1.2 and 1.3), nevertheless, increased tourism pressure, whether in terms of additional vessels/encounters or increased interaction duration, may exacerbate effects on targeted dolphins (Bejder *et al.*, 2006b; Stockin *et al.*, 2008a; Martinez, 2010). Similar concerns arise for individuals within a single region which face repetitive interactions by different tour platforms over relatively short temporal scales. For instance, in the Bay of Islands, bottlenose dolphin (*Tursiops truncatus*) individuals are typically exposed to 31 attempts of humans to swim with dolphins per year (Constantine, 2001). However, this estimation can reach 147 for individuals that are the most frequently encountered in the region (Constantine, 2001). Similarly, Martinez (2010) found that the most sighted Hector's dolphin individuals in Akaroa Harbour, Banks Peninsula, South Island, were exposed to a maximum of 237 vessel encounters per annum.

In order to investigate the potential for cumulative tourism exposure on common dolphins within the BOP waters, photo-ID was used in the present study to firstly assess site fidelity of individuals within the region. Subsequently, a minimum estimate of individuals repetitively interacting with different tour vessels within the region was determined. In order to assess different temporal scales, the potential for cumulative exposure was calculated at daily, seasonal and annual scales. Specifically, the objectives of this chapter were to:

- Investigate site fidelity for common dolphins in the BOP region.
- Estimate the minimum number of individuals exposed to local tourism activities in the BOP.
- Examine temporal cumulative exposure of individuals interacting with tour vessels within the BOP waters.
- Calculate an extrapolated cumulative exposure risk for individuals interacting with tour vessels in the BOP waters.

5.2 Methods

5.2.1 Study area

The BOP is an oceanic habitat, situated on the northeast coast of the North Island, New Zealand (Figure 5.1 Chapter 1, Section 1.5). The primary survey area was situated off Tauranga (37.6878°S and 176.1651°E), between Bowentown (37.2800°S and 175.5960°E) to the west, Mayor Island (37.1650°S and 176.1500°E) to the north and Plate Island (37.3990°S and 176.3350°E) to the east (Figure 3.1). This area was selected particularly as it includes the daily range covered by seven commercial dolphin tour vessels from November to April. The area extending between Whakatane (37.5700°S 177.0050°E) and White Island (37.3100°S and 177.1150°E, Figure 1.3) was additionally surveyed between November 2011 and February 2012, once permission had been granted by local tour operators for observers to access three extra tour vessels (Chapter 4, Section 4.2.2.1).

5.2.2 Data collection

5.2.2.1 Platforms of observation

Surveys were conducted between November 2010 and May 2013 from two platform types. A dedicated research vessel, departing from Tauranga harbour and seven commercial tour vessels departing from Tauranga and Whakatane (Figure 5.1, Chapters 3 and 4, Section 3.2.2.1 and 4.2.2.1, respectively, for full information on the platforms of observations).

5.2.2.2 Surveys

Platform height is known to affect the detectability of cetaceans at sea, therefore survey conditions were assessed in relation to the observational platform used (Hammond *et al.*, 2002, Chapter 3, Section 3.2.2.2 for full information on weather conditions during surveys).

When aboard the research vessel, a non-systematic survey design was employed in order to maximize time spent examining the behaviour of common dolphins interacting with the tour vessels (Chapter 4). Consequently, survey tracks were frequently based on the direction tour vessels were travelling. Survey tracks of the tour vessels were predominantly dependent on prevailing weather conditions, although dolphin encounters made during previous surveys were also taken into consideration. The research and tour vessel speed was maintained between 8 and 10kts and at least two experienced observers were actively searching for marine mammals by naked eye and/or binoculars (Tasco Offshore OS36 7x50 magnification), using continuous scanning methodology (Mann, 1999).

Sighting cues used to detect dolphins included splashes, silhouettes of dolphins, water disturbance due to surface activity of animals, sighting of dorsal fins, and/or the presence of feeding birds, especially Australasian gannets (*Morus serrator*). This species is known to associate with common dolphins during foraging (Stockin *et al.*, 2009a; Wiseman *et al.*, 2011).

A group of dolphins was defined as any number of animals observed in association, moving in a similar direction and usually engaged in a similar behavioural state (Shane, 1990). Members were assumed to be part of a group when they remained within 100m of each other (Bearzi *et al.*, 1997). Beyond this distance, the structure was qualified as sub-groups. Within a same day, encounters were considered independent if they were separated spatially (>5km) and temporally (>30min) to a degree that would prevent animals becoming resampled during the observation (Stockin *et al.*, 2009a). Photo-ID was used where feasible to further validate independence (Dwyer, 2014).

5.2.2.3 Photo-ID

Photo-ID was collected from the research and tour vessels following standardised methods (Würsig and Jefferson, 1990; Neumann *et al.*, 2002; Tezanos-Pinto, 2009), in favourable weather conditions (*e.g.* no rain, fog or glare, swell<1m, Beaufort sea state≤3) and in the presence and absence of interacting vessels. Images of individuals were taken randomly, irrespective of their level of marking (Bearzi, 1994).

Digital photo-ID of individuals was undertaken using two digital SLR Nikon D50 and D90 cameras fitted with high-speed auto-focus adjustable 18-105 and 70-300mm lenses, respectively. Only the left-side of the dorsal fin was photographed due to some individuals exhibiting small nicks and notches that may not be recognisable from both sides. When aboard the research vessel, photo-ID was undertaken, when possible, before and after each focal follow started and finished, respectively. Other data (related to dolphin behaviour, vessel interaction or environmental parameters) were not collected during photo-ID sessions. Images were collected by maintaining a parallel position and travelling at the same speed as the dolphins being photographed (Würsig and Jefferson, 1990). Photo-ID sessions would terminate when an image of each animal in the group was estimated to have been obtained, when weather conditions precluded further photo-ID (*e.g.* rain, fog, glare, swell>1m, Beaufort sea state>3) or when dolphins exhibited avoidance behaviour (*e.g.* moving away from the research vessel and/or changing direction). Photo-ID sessions on the tour vessels lasted throughout the encounter and ended only when the dolphins moved away from the vessel, when the skipper of the tour vessels ended the encounter or when weather conditions deteriorated.

5.2.3 Data analysis

5.2.3.1 Photograph grading

Images were downloaded and labelled with the following information:

- Location (BOP for Bay of Plenty).
- Date (YearMonthDate, *e.g.* 20130316).
- Encounter number (*e.g.* E1, E2, E3…).
- Frame number (4 digits).
- Platform of observation.
- Photographer initials.

For example, the first image taken by Anna M. Meissner (AMM) on the research vessel on 16 March 2013 during the second encounter was labelled as BOP_20130316_E2_0001_Aronui_AMM.

Following standard methods (Slooten *et al.*, 1992; Oremus *et al.*, 2007; Merriman *et al.*, 2009; Tezanos-Pinto *et al.*, 2013), the quality of the selected images was evaluated according to five attributes: focus (*i.e.* sharpness), exposure (*i.e.* light), size of the fin in relation to the photographic frame, angle (*i.e.* orientation of the body relative to the photographic frame) and image interference (*e.g.* water splash, bird, boat or other dolphin masking a part of the dorsal fin, Appendix 8). This process was undertaken using the original un-cropped image so the focus was not affected by pixilation (*i.e.* when the fin was enlarged due to cropping) and the size of the dorsal fin was easily estimated from the entire frame. Each attribute was rated 0 to 2 (Appendix 8). A combination of the five rated attributes determined the quality (excellent, good, fair, and poor) of the dorsal fin (Appendix 9). Only excellent and good quality images were considered for further analysis. High quality images were then cropped and cross-matched visually by one reader in order to identify unique individuals within each observation day.

Each individual fin was subsequently categorised by distinctiveness (*i.e.* very distinct, distinct, not distinct/unmarked, Appendix 10) based on the presence, shape and size of notches/nicks on the leading and/or trailing edge of the fin. Additionally, marks/scars on the fin and pigmentation were used in order to confirm matches. In contrast to other species, dorsal pigmentation patterns are stable at least seasonally (Neumann *et al.*, 2002; Rankmore *et al.*, 2013). Pigmentation patterns, dorsal fin scars (Berghan *et al.*, 2008), and lesions (Ransijn *et al.*, 2013) were therefore used as secondary features to confirm each match. Only very distinct and distinct individuals were considered for further analysis (Oremus *et al.*, 2007; Zaeschmar *et al.*, 2014) to reduce the likelihood of identifying one individual as two different ones (*i.e.* false negative errors, Friday *et al.*, 2000).

The best image of each individual was added to the New Zealand Common Dolphin Bay of Plenty Catalogue and associated database (Meissner, unpubl. data). Before adding a new individual, the best image was visually cross-matched chronologically to the rest of the catalogue. A second reader would further confirm each match to reduce the possibility of false positives (*i.e.* identifying two different individuals as the same one). Data on the individual was entered into the catalogue as a re-sighting if the match was confirmed or assigned a new identification number if no match was found. To avoid pseudo-replication, all duplicates of an individual photographed on the same day (whether from one or several platforms) were excluded from the catalogue, resulting in only one photographic record per individual per day (*e.g.* Parra *et al.*, 2006). However, where an individual was sighted more than once from different tour vessels within any single day, this data was recorded for subsequent assessment of cumulative exposure (Section 5.2.3.3).

5.2.3.2 Site fidelity

To examine common dolphin site fidelity, the following parameters were adapted from Ballance (1990) and Morteo *et al.* (2012):

- Sighting rate (*SR*), as the number of sightings of an individual over a given period:

$$\mathrm{SR_i} = \sum_{j=1}^{k} c_{i,j}$$

Where $c_{i,j}$ is a binary value indicating positive or negative sighting (1 or 0) of individual *i* on the sampling date *j* and *k* is the total number of sampled dates.

- Time lag (*TL*), as the time over which an individual was sighted, determined by the difference between its first and last sighting:

$$\mathrm{TL_i} = \mathrm{Max}(\mathrm{F}_c) - \mathrm{Min}(\mathrm{F}_c)$$

For all c=1, where F is the sampling periods (in days) for each individual i.

- Periodicity (*P*), as the recurrence of the individual, determined by the number of sightings and the inverse of the average intervals between consecutive sightings (days^{-1}):

$$\mathrm{P} = \frac{\sum_{j=1}^{k} c_j}{\sum_{j=1}^{k} \left(\mathrm{F}_{c_{j+1}} - \mathrm{F}_{c_j}\right)}$$

For all c=1, where F is the sampling period (in days).

Site fidelity for re-sighted individuals (*i.e.* encountered more than once) was further examined using a classification tree, providing the percentage (%) of the re-sighted individuals based on dolphin time lag (TL) and sighting rate (SR).

5.2.3.3 Exposure of individuals to tourism

5.2.3.3.1 Observed and extrapolated exposure to tour vessels

Individuals exposed to tourism activities were identified as dolphins photographed from aboard the tour vessels. The SR of dolphins exposed to tour vessels was calculated as the number of sightings of an individual made from aboard the tour vessels and therefore, based on the number of surveys for which tour vessels successfully photographed individuals included in the New Zealand Common Dolphin Bay of Plenty Catalogue. However, this calculation underestimated the real exposure of dolphins to tour vessels, given that all tour vessels operating in the area were not fitted with a photographer. An attempt was therefore made to correct the number of encounters common dolphins were exposed to, by extrapolating this estimate as it has been previously attempted in previous studies (Constantine, 2001; Martinez, 2010). However, in the absence of the exact total number of trips conducted by commercial operators in the present study (conversely to Constantine, 2001; Martinez, 2010), an extrapolation of the observed SR was calculated relying on the number of surveys undertaken on the tour vessels, but for which photographs were not necessarily taken or were not of good quality to identify an individual. This provided a minimum estimate only, with the median re-sight rate (±IQR) used to give a more conservative estimate of the tourism exposure (Constantine, 2001; Martinez, 2010).

5.2.3.3.2 Temporal and spatial exposure

Cumulative exposure on common dolphins was examined at different temporal resolutions. Daily cumulative exposure was investigated by examining days where multiple tour vessels were on the water concurrently. Photographs from each vessel were examined independently and then cross-matched to assess what proportion of individuals were photographed from more than one platform. Seasonal cumulative exposure was examined within each tourism season, defined as the period of the year tour vessels typically operated in the region (Meissner *et al.*, 2015; Chapter 4). The tourism season typically extends across austral summer (December to February) and austral autumn (March to May, Chapter 2, Section 2.2.3). This resulted in three tourism seasons (*i.e.* in 2011, 2012 and 2013) during the study period. Photographs were examined within each tourism season to determine the proportion of individuals photographed several times within the same season and assess the time separating two consecutive encounters within the same season. Finally, annual cumulative exposure was investigated by examining the proportion of individuals photographed by tour vessels over the years.

Photographs taken from aboard tour vessels were cross-matched between the eastern and western BOP. While the small number individuals identified off the eastern Bay of Plenty (n=17) prevented a quantitative investigation of cumulative exposure across different spatial scales, the minimum, medium and maximum distances (km) apart between re-sight days were calculated for qualitative purposes.

5.3 Results

5.3.1 Effort

A total of 294 days were spent in the field, resulting in 417 surveys conducted from the tour vessels (64%, n=267) and the research vessel (36%, n=150, Table 5.1). This resulted in 328 encounters with common dolphins, of which the majority (78.0%, n=256) occurred from aboard the tour vessels (Table 5.1). Photo-ID was attempted for 77.7% (n=255) of these sightings. A total of 92,721 images were collected between November 2010 and May 2013, of which 21.8% (n=20,193) were classified as either good or excellent quality. This resulted in a total of 1,418 individuals to be identified, cross-matched and further catalogued across the study period, of which 61.8% (n=876) were captured during photo-ID events aboard the tour vessels.

Given the extensive effort undertaken within the western BOP (95.2% of the surveys, n=397), the majority of catalogued individuals (98.4%, n=1,258) were photographed off Tauranga. Only a small proportion of individuals (1.3%, n=17) was photographed opportunistically in the eastern part of the region, off Whakatane. The remainder (0.2%, n=3) were photographed off Tauranga and off Whakatane.

5.3.2 Site fidelity

Overall, 1,278 common dolphin individuals were identified across 124 days, throughout a period of 882 days (*ca.* 2.4 years, Figure 5.2). SR varied between 1 and 5, with a large majority of dolphins (86.9%, n=1,111) sighted only once (Figure 5.3). A small proportion (13.1%, n=167) of identified individuals were sighted on two or more occasions: 10.7% (n=137), 1.8% (n=23), 0.4% (n=5) and 0.2% (n=2) were sighted on two, three, four and five occasions, respectively (Figure 5.3). The average SR for the study period was 1.2 (median=1).

Table 5.1: Photo-ID effort conducted from aboard the research (RV) and tour vessels (TV), on common dolphins between December 2010 and May 2013 in the Bay of Plenty, New Zealand. Note: the number of identified individuals represents the number of individuals (*) identified per season before cross-matching. Consequently, the total number does not equal the number of individuals reported in the catalogue.

		2011		**2012**		**2013**	
		Dec-May	**Apr-Nov**	**Dec-May**	**Apr-Nov**	**Dec-May**	**Total**
Number surveys	RV	25	22	44	30	23	150
	TV	88	10	66	7	196	267
	Total	**113**	**33**	**110**	**37**	**119**	**417**
Surveys with photo-ID included in catalogue	RV	6	1	14	3	12	36
	TV	52	0	19	0	56	127
	Total	**58**	**1**	**33**	**3**	**68**	**163**
Number sightings	RV	15	2	31	7	17	72
	TV	96	0	67	0	92	256
	Total	**111**	**2**	**98**	**7**	**109**	**328**
Sightings with photo-ID	RV	10	1	23	3	16	53
	TV	83	0	46	0	73	202
	Total	**93**	**1**	**69**	**3**	**89**	**255**
Total photographs	RV	2,590	233	8,342	8,926	17,949	38,040
	TV	18,328	0	8,854	0	27,499	54,681
	Total	**20,918**	**233**	**17,196**	**8,926**	**45,448**	**92,721**
Good + excellent photographs	RV	359	51	2,857	1,411	3,560	8,238
	TV	3,005	0	1,966	0	6,984	11,955
	Total	**3,364**	**51**	**4,823**	**1,411**	**10,544**	**20,193**
Identified individuals *	RV	35	4	240	79	184	542
	TV	353	0	168	0	318	839
	TV+RV	4	0	7	0	26	37
	Total	**392**	**4**	**415**	**79**	**528**	**1,418**

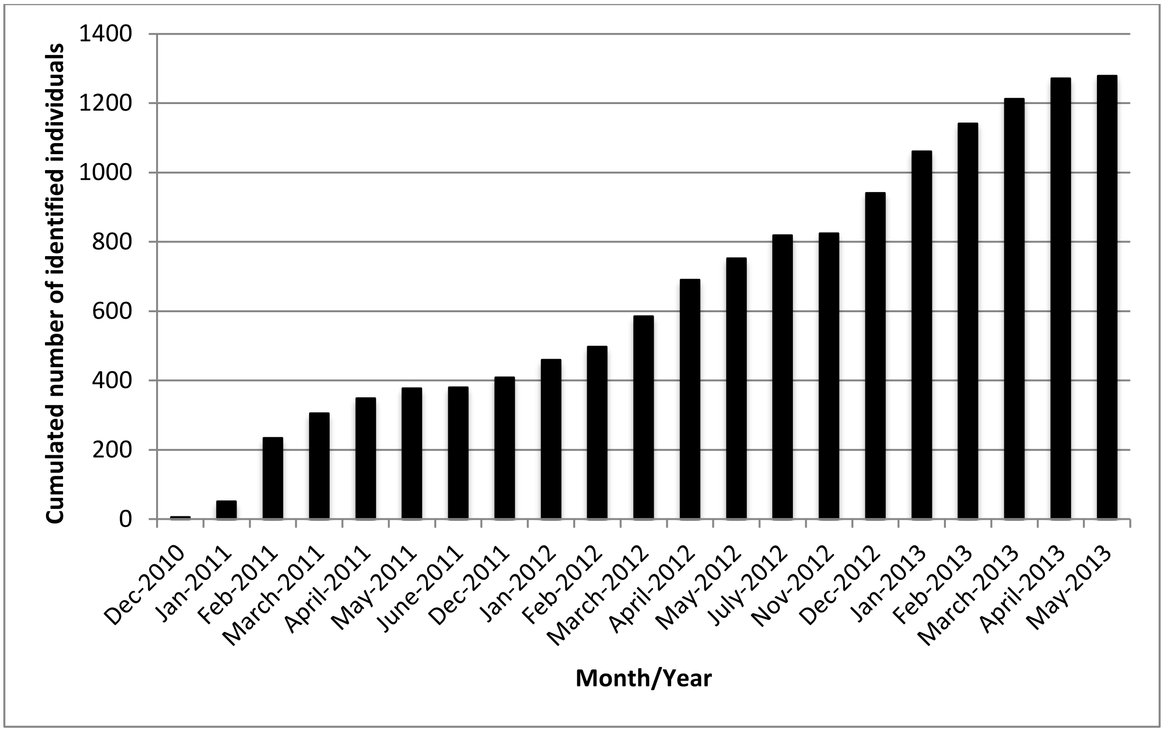

Figure 5.1: Cumulative number of identified common dolphins between November 2010 and May 2013 in the Bay of Plenty, New Zealand. Note: no photographs were collected in November 2010.

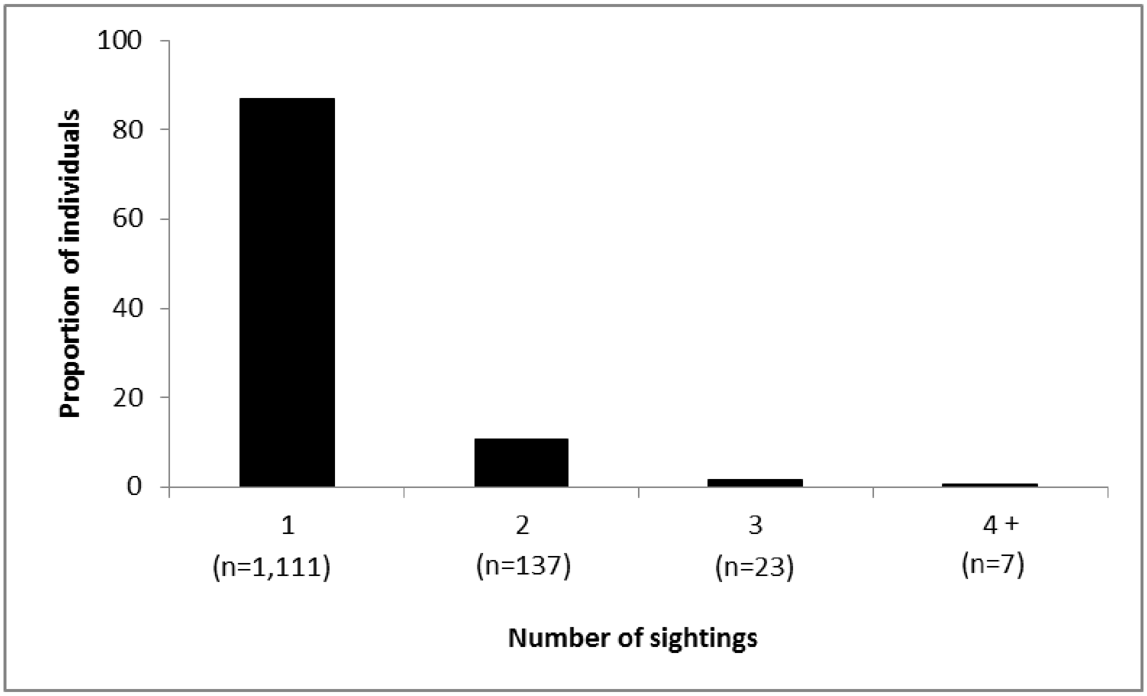

Figure 5.2: Frequency of re-sighted common dolphin individuals between November 2010 and May 2013 in the Bay of Plenty, New Zealand.

Half of re-sighted individuals were encountered within a year (*i.e.* TL<343 days, 50.9%, n=85, Figure 5.4) and were typically encountered twice (47.9%, n=80). The majority of these (77.6%, n=66) showed a time lag shorter than a season, with a large proportion (49.4%, n=42) captured within a month. Additionally, 28.1% of re-sighted individuals were encountered over a period of *ca.* two years (343<TL<603.5 days, n=47, Figure 5.4), of which the majority (91.5%, n=43) encountered twice. The rest of the individuals (21.0%, n=35) were re-sighted over the entire study period (TL>603.5 days, Figure 5.4). Those dolphins were encountered twice (40.0%, n=14) or three times (40.0%, n=14). Only a small proportion was re-sighted four or more times (20.0%, n=7).

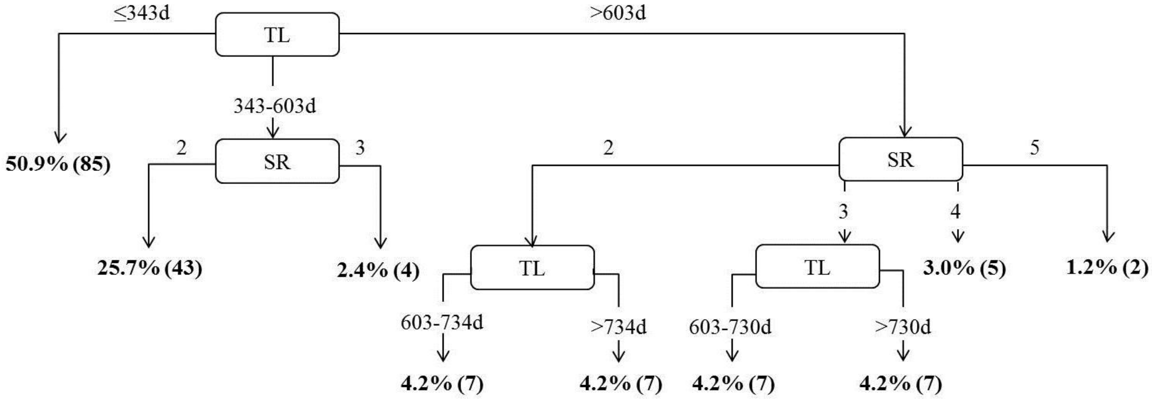

Figure 5.3: Classification tree characterising common dolphin site fidelity between November 2010 and May 2013 in the Bay of Plenty, New Zealand. The percentage (and number) of re-sighted individuals is based on dolphin time lag (TL) and sighting rate (SR).

5.3.3 Exposure of individuals to tourism

5.3.3.1 Observed and extrapolated exposure to tour vessels

While 38.3% (n=489) of identified individuals were captured only from the research vessel, 61.7% (n=789) of the dolphins were photographed from commercial vessels during 127 days of surveys undertaken aboard the tour vessels. The observed SR ranged between 1 and 5, with a large majority of dolphins (80.4%, n=634) sighted only once (Table 5.2). However, by extrapolation the SR to the number of surveys undertaken aboard the tour vessels (n=267, Table 5.1), SR typically doubled (Table 5.2). The most frequently sighted individuals were potentially exposed to a minimum of 10.5 encounters and a median of 2.1 encounters with tour vessels (IQR=0, n=789) during the course of this study. However, these numbers represent an underestimate, as calculations are based on the surveys undertaken aboard the tour vessels (Table 5.1), while more trips were undertaken by the tour vessels during that time period (pers. obs.).

Table 5.2: Observed and extrapolated sighting rate (SR) of common dolphins exposed to tourism between November 2010 and May 2013 in the Bay of Plenty, New Zealand.

Number of dolphins interacting with tour vessels	Observed SR	Extrapolated SR
675	1	2.1
93	2	4.2
18	3	6.3
2	4	8.4
1	5	10.5

5.3.3.2 Temporal and spatial exposure

Out of the 789 dolphins exposed to tourism in the BOP, two (0.3%) interacted with tour vessels in the western and eastern BOP, 298 and 355 days apart, and 76.5 and 67.1km apart, respectively (ID_0443 and ID_1039, respectively, Appendix 11). When re-sighted in the western BOP, dolphins were separated by a median distance of 12.4km and 75 days (IQR=8.5km and IQR=375days, n=139, Appendix 11).

Daily cumulative exposure was examined for those days (n=32) where photo-ID was independently collected off two tour vessels concurrently. This resulted in 385 (48.8%) identified individuals, out of the overall 789 dolphins that interacted with tour vessels. Of these, 2.6% (n=10) of the dolphins interacted with two tour vessels on the same day. The majority (80%, n=8) were photographed while the different platforms interacted with the same group simultaneously or consecutively. Additionally, a further two individuals (20%) were photographed by two platforms during encounters that were temporally (68 and 114min apart, respectively) and spatially (3 and 13km apart, respectively) separated.

Seasonal cumulative exposure was observed for 8.6% (n=68) of individuals that interacted with tour vessels (Table 5.3). These were characterised by two or three encounters per individual per tourism season (92.6%, n=63 and 7.4%, n=5, respectively). The median interval time between two consecutive encounters equalled 15 days (IQR=23, n=74).

Annual cumulative exposure was observed for 7.9% (n=62) of individuals, with 7.5% (n=59) and 0.4% (n=3) of identified dolphins interacting with tour vessels across two and three years, respectively (Table 5.3).

Table 5.3: Percentage (and number) of identified common dolphin individuals exposed to tour vessels seasonally and annually between November 2010 and May 2013 in the Bay of Plenty, New Zealand.

	Annual exposure to tour vessels			
Seasonal exposure	**Exposed in one year**	**Exposed in two years**	**Exposed in three years**	**Total**
One encounter /season	85.6 (675)	5.7 (45)	0.1 (1)	91.4 (721)
Multiple encounters /season	6.6 (52)	1.8 (14)	0.3 (2)	8.6 (68)
Total	**92.1 (727)**	**7.5 (59)**	**0.4 (3)**	**100 (789)**

5.4 Discussion

This study represents the first attempt to estimate the minimum number of common dolphins using the BOP waters and an initial assessment of how many of those are likely exposed to tourism activities. Between November 2010 and May 2013, at least 1,278 common dolphin individuals occurred within the BOP waters, including 61.7% (n=789) photographed from tour vessels. Owing to the lack of plateau in the cumulative discovery curve, only a subset of dolphins using the area has likely been identified. Therefore, it is suggested that individuals identified in the framework of this study form part of a larger population, as previously suggested by Neumann *et al.* (2002).

Over a period of 2.4 years, the large majority of identified individuals were only sighted once, resulting in a re-sight rate of just 13.1%. Although interspecies variations can be expected, comparisons with previous studies are difficult, given that photo-ID has predominantly been applied to coastal species, which typically exhibit higher re-sight rates. For example, Parra *et al.* (2006) reported a re-sight rate of 80.0% for snubfin (*Orcaella heinsohni*) and 59.3% for Indo-Pacific humpback dolphins (*Sousa chinensis*) in coastal waters off Queensland, Australia. In the Balearic Islands coastal waters, Gonzalvo *et al.* (2014) re-sighted 39.5% of identified bottlenose dolphins, of which the majority were re-sighted across all studied years. For Hector's dolphins, a re-sight rate of 42.0% was described in Akaroa harbour, New Zealand, with a maximum of 8.0% of individuals encountered more than 10 times (Martinez, 2010). Although it could be suggested that coastal species exhibit high site fidelity, similar rates were observed for some oceanic species. For instance, in Fiji, 70.0% of identified spinner dolphins (*Stenella longirostris*) were sighted on two or more occasions (Cribb *et al.*, 2012).

Spinner dolphins identified in French Polynesia were re-sighted more than once and up to 84 times (Oremus *et al.*, 2007). In Hawai'i, a re-sight rate of 75.0% was reported for rough-toothed dolphins (*Steno bredanensis*), with individuals encountered on two or more occasions (Baird *et al.*, 2008b).

While it is suggested that some of these oceanic species form small isolated communities (Karczmarski *et al.*, 2005; Oremus *et al.*, 2007; Baird *et al.*, 2009), it seems that site fidelity is likely related to areas of interest that populations or groups of dolphins visit preferentially. More specifically, site fidelity has also been reported for breeding areas in various species (New Zealand fur seals, *Arctocephalus forsteri*, Stirling, 1971; Bradshaw *et al.*, 2000b; southern right whales, Rowntree *et al.*, 2001; humpback whales, Wedekin *et al.*, 2010). Moreover, areas where prey resources can be spatially and temporally predicted have additionally been suggested to explain site fidelity across a wide variety of species also (snubfin and Indo-Pacific humpback dolphins, Parra *et al.*, 2006; rough-toothed dolphins, Baird *et al.*, 2008b; Atlantic humpback dolphins, *Sousa teuszii*, Weir, 2009; humpback whales, Boye *et al.*, 2010; New Zealand fur seal, Baylis *et al.*, 2012). This may be explained by increased foraging success presumably gained from local knowledge of the habitat and prey behaviour (Irons, 1998; Kenney *et al.*, 2001; Heithaus and Dill, 2002; Staniland *et al.*, 2004).

Similarly, prey availability and/or sheltered waters for nursing groups could explain site fidelity patterns in common dolphins in New Zealand. For instance, higher re-sight rates of common dolphins reported for the Hauraki Gulf (Hupman, unpub. data) may be due to high feeding opportunities in that region (Pyke *et al.*, 1977; Avgar *et al.*, 2011). This is supported by comparing activity budgets between both areas, with dolphins in the

Hauraki Gulf spending 46.7% of their time foraging compared with 24.6% in the BOP (Stockin *et al.*, 2008b; Meissner *et al.*, 2015; Chapter 4). This is also supported by seasonal movements of common dolphins to the Hauraki Gulf (Neumann *et al.*, 2002; Chapter 3), where foraging opportunities in winter are higher compared to the BOP (Chapter 3). Higher re-sight rates can also be explained by the geography of the Hauraki Gulf, a semi-enclosed body of water which physical attributes may affect dolphin movements from the Gulf to the open ocean (Avgar *et al.*, 2013), similarly to other physical barriers (*e.g.* basins, deep channel, different water masses) suggested to limit movements of various species in other areas (Carpinelli *et al.*, 2014; Kerr *et al.*, 2005; Möller *et al.*, 2011; Natoli *et al.*, 2005). Restricted movements often lead to limited gene flow resulting in genetic differentiation or isolation between populations (*e.g.* Bilgmann *et al.*, 2008; Möller *et al*, 2011; Viaud-Martinez *et al.*, 2008), and evidence of genetic differentiation, based on mitochondrial DNA, between dolphins sampled in the Hauraki Gulf and other areas along the New Zealand coast further supports the existence of higher site fidelity in the Hauraki Gulf (Stockin *et al.*, 2014).

While photo-ID has proven valuable in studying numerous cetacean species, it has been recognised that dolphin behaviour can affect the success of such studies. For instance, photo-ID is challenging for species that are gregarious, dispersed, inconspicuous or demonstrate reaction (avoidance or attraction) to vessels (Morton, 2000; Neumann, 2001a; Parra and Corkeron, 2001; Weir, 2008; Falcone *et al.*, 2009). Lower re-sight rates in the BOP may consequently be explained by the larger group sizes (Chapter 3) and predominance of travelling (Meissner *et al.*, 2015; Chapter 4) in the region compared to the Hauraki Gulf (Stockin *et al.*, 2008b; Dwyer, 2014). However, while dolphin group size and activity budgets are very similar between the BOP and the east coast of the Coromandel Peninsula (Neumann, 2001a), lower re-sight rate (4.4%) were obtained off the east coast of the Coromandel Peninsula (Neumann *et al.*, 2002).

Methodological differences can potentially best clarify discrepancies between regions. Low re-sight rates are likely explained by the opportunistic nature in which photo-ID was undertaken off the east coast of the Coromandel Peninsula (Neumann *et al.*, 2002) and during the present study. Moreover, Neumann *et al.* (2002) only used one platform, collected photographs with a single non-digital camera and cross-matched photographs based on slides. Conversely, higher re-sight rates in the Hauraki Gulf likely result from dedicated photo-ID surveys, higher effort (*i.e.* where time spent with dolphins was dependent on the likelihood of all individuals being photographed) and the semi-enclosed geography of the region.

Considering only re-sighted individuals, a large proportion (39.5%) was encountered within one tourism season and more specifically within one month during the present study. This may suggest that the individuals identified in the BOP waters likely use the region infrequently and that such seasonality could act as an effective buffer against over-exposure to tourism effects, as previously suggested for dusky dolphins (*Lagenorhynchus obscurus*) in Kaikoura (Lundquist, 2012). Alternatively, such seasonality may instead be more a reflection of the opportunistic nature of the photo-ID surveys conducted within the present study. Regardless, documented re-sightings between the eastern and western BOP, as well as reported between BOP and Hauraki Gulf waters (Neumann *et al.*, 2002), imply at least a proportion of this population is exposed to tour vessel encounters across its broader home range. While the level of individuals reported between different regions remains low and thus, not indicative of cumulative effects at the population level, the potential for a larger overlap between the regions cannot be dismissed. This is particularly true in light of the opportunistic manner in which photo-ID has been conducted in the BOP waters compared with the Hauraki Gulf. Tourism activities focused around common dolphins in both regions have consistently shown short-term behavioural effects resulting in significant reduction in foraging and increase in travelling activities (Neumann and Orams, 2006; Stockin *et al.*, 2008a; Meissner *et al.*, 2015, Chapter 4). However, it remains unknown whether the low risk of cumulative exposure observed in this study could be greater than demonstrated herein or whether this cumulative exposure could exacerbate the tourism effects determined independently at each study site.

Cumulative exposure to tourism activities were observed on a daily, seasonal and annual level for 2.6, 8.6 and 7.9% of dolphins that interacted with tour vessels in the BOP, respectively. While this proportion is low, it is likely underestimated given that these results are only based on photographs collected opportunistically and from two platforms. A total of seven tour vessels typically target dolphins off Tauranga, with evidence that four simultaneously interact with a single group (Meissner *et al.*, 2015; Chapter 4). Consequently, the cumulative exposure proportion reported here should be regarded as conservative as it represents the absolute minimum of repeated encounters. Indeed, this is demonstrated by the difference calculated between observed and extrapolated exposure to tour vessels, which also represents an underestimation of the exact exposure level. Accurate exposure could have been calculated if tourism trips had been consistently and accurately reported to the Department of Conservation, as is required as a condition of marine mammal tourism permits (Martinez and Stockin, 2011). It is also recommended to perform dedicated photo-ID in the region in order to estimate the population using the BOP waters and the proportion of the population exposed to tourism activities. This will indeed determine whether vessels interactions are likely to cause impacts at the population level (Lusseau, 2014).

Reasons for temporal cumulative exposure can best be explained by tour operators returning to areas where dolphins were previously observed (Methods, Section 5.2.2.2). Furthermore, tour operators often cooperatively search for dolphins (Hauser *et al.*, 2006), communicate dolphin positions to each other and in many cases “hand over” a group of dolphins at the end of an encounter onto another commercial vessel (Meissner *et al.*, 2014). The practice of “handing over” likely results in dolphins being exposed to prolonged encounters throughout a day. For example, Hector’s dolphins in Akaroa were found to potentially collectively be exposed up to 11h of vessel interactions (Nichols *et al.*, 2001; Martinez, 2010). In order to avoid potential cumulative impacts on dolphins, a maximum of three vessels of any type are allowed within 300m of a group of dolphins in New Zealand (Marine Mammal Protection Regulations, 1992). While tour operators in the BOP usually comply with this regulation (Meissner *et al.*, 2015; Chapter 4), results presented here suggest even encounters spatially and temporally separated can still potentially result in cumulative exposure. However, given the low percentage of affected individuals reported here, to what extent this is of concern remains unclear.

5.5 Conclusion

The present study constitutes the first attempt to assess site fidelity and tourism exposure in BOP waters based on photo-ID. Initial results suggest site fidelity and exposure to tourism activities remain low and therefore, possibly not indicative of cumulative exposure at the population level. However, the potential for a larger overlap between the regions cannot be dismissed, especially owing the opportunistic nature in which photo-ID was conducted during the present study. It is therefore recommended that dedicated photo-ID effort be undertaken to assess the proportion of local population exposed to tourism activities and to accurately evaluate exchanges between regions within the broader home range of the species.

Chapter 6

Conclusions

Common dolphin encountered in the Bay of Plenty.

6.1 Introduction

Over recent decades, marine mammal tourism has become the subject of great attention owing to its fast and international expansion (Hoyt, 2001; O'Connor *et al.*, 2009). However, with this growing demand, concerns have been expressed as to whether encounters with humans can affect targeted populations and if so, to what extent (*e.g.* Lusseau, 2003a; Neumann and Orams, 2006; Stensland and Berggren, 2007; Stockin *et al.*, 2008a; Christiansen *et al.*, 2010). In an attempt to mitigate potential effects and ensure sustainability of tourism activities, legislation and regulations have been established by various management agencies worldwide (Orams, 2004; Carlson, 2012; Kessler and Harcourt, 2013). However, the success and expansion of the industry in some countries has outpaced management authorities (Newsome *et al.*, 2005).

While New Zealand is considered a leader in marine mammal conservation internationally (Orams, 2004), its ability to protect marine mammals from tourism impacts has been questioned (Higham and Hendry, 2008). For example, while tourism activities indicated negative effects on common dolphins (*Delphinus* sp.) within the Hauraki Gulf, North Island (Stockin *et al.*, 2008a), the introduction of a second permit still proceeded without further monitoring of the population. In Fiordland, South Island, despite various evidence demonstrating the unsustainability of the local dolphin-watching tourism (Lusseau, 2003a; b; 2004; 2005; 2006; Lusseau and Higham, 2004), the industry has been allowed to continue to operate. This is despite clear population-level impacts being identified on nationally endangered bottlenose dolphins (*Tursiops truncatus*) and the predicted decline and likelihood of population extinction within the next 40 years (Lusseau *et al.*, 2006; Currey *et al.*, 2007).

Despite a well-established industry – which has been in operation since the 1990s – and growing evidence of impacts on New Zealand fur seals (*Arctocephalus forsteri*) (Boren *et al.*, 2001) and common dolphins (Neumann and Orams, 2006; Stockin *et al.*, 2008a), little attention has been given to marine mammal management and conservation in the Bay of Plenty (BOP), North Island (Cowling *et al.*, 2014; Meissner *et al.*, 2015). As such, the focus of the present thesis was to assess marine mammal tourism, its context and ecological parameters that can affect this industry within the region.

In the absence of systematically collected data and due to the rapid expansion of the tourism industry within the BOP region, examination of data collected opportunistically was deemed important to understand which species could potentially be targeted by tourism activities. Seasonality and distribution of marine mammal species encountered in the area was therefore investigated. Besides the primary tourism interest in common dolphins, the development of New Zealand fur seal tourism in the BOP and the associated concerns regarding potential negative effects (Neumann and Orams, 2006; Stockin *et al*., 2008a; Cowling *et al.*, 2014) highlighted the urgent need to understand the ecology of those two species. Consequently, their distribution, density and group dynamics were further examined. The level of vessel interactions with common dolphins was investigated and their effects on dolphin behaviour were assessed. Compliance of tourism activities with regard to their adherence to regulations were studied. Finally, given that the fitness of animals repeatedly exposed to tourism activities can be compromised and can subsequently result in population level effects (*e.g.* survival, reproductive success and habitat use) (IWC, 2006), the number of common dolphin individuals closely interacting with tour vessels was estimated, their site fidelity examined and dolphin-vessel interactions quantified to assess for potential cumulative exposure.

6.2. Summary of findings

Opportunistic data collected from a range of platforms of opportunities, including tour vessels, were stratified, to assess the reliability of trends reported for historical marine mammal occurrence within the BOP region (**Chapter 2**). This was achieved by assessing the degree of notable diagnostic features for each reported species/group of species against the proportion of sightings originating from different experience classes of observer (*i.e.* experts, tour operators and mariners). Fourteen species of dolphins, whales and pinnipeds were encountered in the region between December 2000 and November 2010. Data from easily distinguishable species (*i.e.* common and bottlenose dolphins, killer whales, *Orcinus orca*, and New Zealand fur seals) allowed confident interpretation of their distribution but also revealed discrepancies with previous findings (*e.g.* higher use of shallower waters by common dolphins), possibly explained by inherent biases to the opportunistic dataset.

Dedicated surveys, conducted between November 2010 and May 2013, investigated common dolphin and New Zealand fur seal distribution, density and group dynamics in the region (**Chapter 3**). Both species exhibited a strong seasonality with contrasting occurrence. The probability of encountering common dolphins within coastal waters increased during the warm season (*i.e.* summer and autumn), suggesting movements into deeper offshore waters and/or potentially to neighbouring regions (*i.e.* the Hauraki Gulf) during the cold season (*i.e.* winter and spring). Fur seals showed the opposite seasonality to common dolphins, occurring predominantly during the cold season and supporting the evidence of a non-breeding colony in the western BOP region. Based on group sizes on shore and encounter rates out at sea, results indicated that colonies in the BOP region are in an early stage of establishment. Higher density of common dolphins and fur seals was identified over the shelf break and reefs and is suggested to be linked to foraging reasons and enhanced productivity.

Effects of commercial tourism were identified at the group level in **Chapter 4.** Tour vessel interactions resulted in significant changes in the behaviour of common dolphins using the BOP waters. Specifically, dolphins spent less time foraging and took considerably longer to return to foraging once disrupted via tour vessel interactions. Disruption to any biologically important behaviour (*e.g.* foraging) can potentially lead to a reduction in the overall energy acquisition that can have long-term implications, particularly when prey resources are limited, dispersed and/or unpredictable.

Cumulative exposure, as a consequence of repetitive individual interactions with tour vessels, was further investigated in **Chapter 5**. Between November 2011 and May 2013, an estimated minimum of 1,278 common dolphin individuals frequented BOP waters, including 61.7% exposed to tour vessel interactions. Spatial (*i.e.* between the western and eastern sub-regions) and temporal (*i.e.* daily, seasonal and annual) cumulative exposure to tourism activities was observed for less than 10% of these identified individuals. Temporal cumulative exposure observed can best be explained by “handing over” tactics typically used by tour operators and tour vessels returning to areas preferentially frequented by dolphins (*i.e.* presumed foraging hotspots).

6.3. Limitations of the study

Besides providing new insights into marine mammal species ecology and tourism activities in the region, this thesis identified limitations that need to be considered from a management perspective. Indeed, while opportunistic data can substantially benefit research and conservation, limited diagnostic differences between some species and proportion of sightings reported by different observer types, can result in insufficient confidence to discern sightings correctly to the species level (Chapter 2). In the present study, a detailed species-specific examination of distribution and seasonality was of limited scope for bottlenose dolphins and prevented for *Balaenopteridae* and blackfish. If changes occur in those populations as a result of anthropogenic activities, they could potentially go unnoticed. This is of particular concern for bottlenose dolphins and southern right whales (*Eubalaena australis*), both classified as nationally endangered (Baker *et al.*, 2010) but also of relevance for blackfish, owing to the extremely limited knowledge of their ecology within New Zealand waters.

It is recognised that opportunistic platforms frequently enable coverage of wider regions compared with dedicated surveys (Robbins and Mattila, 2000; Hupman *et al.*, 2014). However, it is also common for opportunistic surveys to be unevenly distributed (Kiszka *et al.*, 2007b; Martinez *et al.*, 2010) as they are typically restricted by the operational range of observer activities, often concentrated within coastal waters (Robbins and Mattila, 2000). In the present study, this explains the absence of deep water species (*i.e.* blackfish, sperm, *Physeter macrocephalus*, beaked, *Ziphiidae*, and southern right whales) in the western region, as their potential habitat is unlikely to have been sampled adequately.

Opportunistic data can also be restricted by limited temporal coverage (Robbins and Mattila, 2000; Kiszka *et al.*, 2007b; Martinez *et al.*, 2010). The majority of the data analysed herein were collected by tour operators, conducting trips primarily during summer and autumn. This, for instance, prevented any clear examination of seasonal habitat use or distribution of the genus *Balaenopteridae*.

While opportunistic platforms usually limit the collection of some types of data (*e.g.* Redfern *et al*., 2006, Kiszka *et al*., 2007b), logistical considerations of the “parent project” can also restrict acquisition of data collected during research survey. In the present study, constraints imposed by the primary objective to evaluate changes in dolphin behaviour (Meissner *et al.*, 2015; Chapter 4) prevented the implementation of a robust systematic approach for photo-identification (photo-ID) of common dolphins (Chapter 5). Low cumulative exposure of common dolphins to vessel interactions found herein is therefore only indicative of the absolute minimum of repeated interactions common dolphins experience in the region.

While the present research provides baseline information on fur seals at sea, assessment of fur seal haul out distribution was non-systematic (Chapter 3). Consequently, this thesis provides the first, albeit conservative, insights into the potential reestablishment of New Zealand fur seal colonies in the western BOP region for further management consideration. A better assessment of fur seals on terrestrial sites is required to improve the current understanding of the expansion this species has undergone within the region and clarify their use as breeding or non-breeding areas.

6.4 Contribution of present findings, implications for management and perspectives on future research

Assessment of changes in species distribution and/or behaviour, and consequently effective conservation efforts, requires a good understanding of species ecology at the local scale (Orams, 2004). However, as highlighted in the present study, many species have an oceanic distribution, considerably limiting the ability of investigation via dedicated research surveys (Kiszka *et al.*, 2004; Tepsich *et al.*, 2014; New *et al.*, 2015). While it has also been recognised that platforms of opportunity may have restricted ranges (*i.e.* tour operators being primarily operating in coastal waters), the use of various platforms of opportunity (*i.e.* tour and fishing vessels, cruise and cargo ships), can potentially mitigate some of these issues (Evans, 2004). Moreover, if combined with rigorous, standardised sampling protocols collected by experts or trained staff (Martinez and Stockin, 2011; Davidson *et al.*, 2014), biases such as species misidentification can further be reduced.

Operator participation can enhance the reputation of the company (New *et al.*, 2015), increase education among tourists (Higginbottom *et al.*, 2001; Zeppel, 2008; Lück, 2015), enable operators a better understanding of the species and potentially establish a collaborative exchange of information between operators and scientists (IWC, 2011). Such information can be critical for predicting and/or adjusting tourism activities according to changes in dolphin occurrence over time (Lambert *et al.*, 2010). This is especially pertinent in regions such as the BOP which have received no systematic pre-evaluation prior to the establishment and growth of the tourism industry.

Understanding species spatial and temporal distribution and assessing their density is of great importance to mitigate negative effects of human activities (Forney *et al.*, 2015). The finding that BOP reefs and shelf breaks are important locations for foraging common dolphins, yet targeted by tour operators, has notable management implications. This is exacerbated by evidence that current tourism activities disrupt common dolphin foraging behaviour (Chapter 4, Meissner *et al.*, 2015). In addition, although the consequences of reduced feeding for nursing groups remain unclear, it is likely to have significant effects on pregnant and lactating females (Chapter 4). Future research should therefore seek to address the effects of vessel interactions at the group type level (*i.e.* adult only, nursery groups, Constantine, 2001; Guerra *et al.*, 2014). Moreover, in an attempt to minimise potential long-term physiological effects, management initiatives such as “no interaction” zoning could be implemented in the form of exclusion areas (*e.g.* Lusseau and Higham, 2004; Martinez, 2010; Hartel *et al.*, 2014), time out periods (*e.g.* Martinez, 2010, Tyne *et al*., 2015) or activity restricted interactions (*e.g.* Meissner *et al.*, 2014) surrounding these reefs and shelf breaks. Future monitoring of the population could further examine the scope and effectiveness of these management strategies.

Examination of common dolphin activities revealed discrepancies in their behaviour in the BOP compared with the Hauraki Gulf, with and without the presence of vessels (Stockin *et al.*, 2008a). This provides further evidence that impact studies should be specific to species and location (Orams, 2004; Seddon and Ellenberge, 2008). While behavioural changes have been identified for common dolphins in the BOP, assessment of tourism effects on common dolphins in the region should not be regarded as complete. Indeed, time-restricted studies, like the present research, often have limited ability to infer long-term effects on targeted species, especially long-lived, slow reproducing marine mammals (Orams, 2004; Bejder *et al.*, 2006a). However, short-term effects have been linked to long-term consequences (Lusseau, 2004, 2005; Bejder *et al.*, 2006b; Currey *et al.*, 2007), although a comprehensive understanding of the physiological costs associated with behavioural changes is often extremely challenging to obtain for cetaceans and remains lacking (Constantine, 1999; Gill *et al.*, 2001; Orams, 2004; Higham and Lück, 2008a; Higham *et al.*, 2008; Lundquist, 2012; Guerra *et al.*, 2014; New *et al.*, 2015). Therefore, regular and continuous monitoring of the common dolphin population is necessary, especially with the expansion of the industry (Kessler and Harcourt, 2013). Furthermore, besides assessing behavioural changes, other parameters indicative of chronic stress (*e.g.* animal swim heading and speed, group cohesion, acoustic activity) deserve to be further addressed in order to examine potential physiological long-term effects (Jay, 2000; Orams, 2004; Travis, 2008; Rolland *et al.*, 2012).

Besides short-term behavioural changes identified for common dolphins in the present study (Meissner *et al.*, 2014; Meissner *et al.*, 2015; Chapter 4), the possibility that other changes may have occurred over recent decades should not be excluded (*i.e.* changes in common dolphin occurrence and distribution as suggested in Chapter 2; Hartel *et al.*, 2014) and this potentially applies to species other than just common dolphins. Indeed, impact studies are typically conducted on frequently targeted species (*e.g.* common, bottlenose, dusky, *Lagenorhynchus obscurus*, Hector's dolphins, *Cephalorhynchus hectori hectori*) but are overlooked for infrequently encountered species (*e.g.* killer, humpback, *Megaptera novaeangliae*, and Bryde's whales, *Balaenoptera brydei*, Orams, 2004). Moreover, detected effects on a focal species can have subsequent consequences on the rest of the community (Burgin and Hardiman, 2015). For instance, in the Hauraki Gulf, changes in common dolphin foraging behaviour has raised concerns on the effects tourism can have on associated feeding species (*i.e.* Australasian gannet, *Morus serrator*, and Bryde's whales, Stockin *et al.*, 2008a).

Besides investigating the behavioural effects of anthropogenic activities, assessing the proportion of the local population affected by the tourism interactions is also of great importance for conservation management purposes (Samuels and Bejder, 2004; Martinez, 2010; Lusseau, 2014). Similarly, understanding how the species uses a habitat in terms of site fidelity and movement patterns is also crucial to mitigate potential anthropogenic impacts. While only opportunistic photo-ID was conducted herein, the present study provides evidence that spatial and temporal cumulative exposure occurs in the region and should be carefully considered from a management perspective. Furthermore, while the seasonality of common dolphins occurring in the BOP could potentially prevent over-exposure to tourism effects, documented re-sightings within the broader home range of the species (Neumann *et al.*, 2002) imply at least a proportion of the population is exposed to tour vessel interactions across the northeast coast of the North Island. Further dedicated photo-ID surveys are therefore required to establish abundance estimates for the BOP waters, quantify the proportion of local population exposed to tourism activities and to accurately evaluate exchanges between regions within the broader home range of the species.

While no significant changes in fur seal behaviour has yet been reported in the eastern BOP (Cowling *et al.*, 2014), this assessment has been conducted with a low tourism pressure (*i.e.* only one tour vessel interacting with the animals), with the colony being presumably established for 10 years in this part of the sub-region (Cowling *et al*., 2014). However, in the western sub-region, seven vessels can potentially interact with fur seals. Furthermore, the recent establishment of the colony in the western BOP may potentially result in seals being more vulnerable to human disturbance compared with well-established colonies (Cowling *et al.*, 2014), which may affect a successful recolonisation and compromise future tourism activities in the region. Finally, as tourism operates in the warm season (*i.e.* the breeding season for the species), potential effects of disturbance of immatures and lactating/nursing females require careful consideration. Only dedicated systematic surveys will enable species- and site-specific guidelines (Orams, 2004; Seddon and Ellenberge, 2008), minimising effects of human disturbance and ensuring the continued recovery of the population along the BOP coastline.

6.5. Concluding statement

In light of current knowledge and possible long-term effects that the tourism industry can have on marine mammal populations in the BOP region, the present thesis supports stronger enforcement of legislation and adaptive management through restriction of spatial, temporal and/or behavioural interactions. Moreover, in order to meet the protection ambitions of New Zealand (as expressed in the Marine Mammals Protection Act and Regulations, 1992), robust and long-term research is needed. As presently demonstrated, opportunistic data are recommended to be collected by platforms of opportunity, including but not limited to tour vessels, as they represent a potential volume of knowledge which otherwise is not affordable via dedicated scientific research and conservation monitoring. However, those data should be complemented by dedicated research surveys where limitations inherent to opportunistic platforms prevent further assessment of species ecology. More attention should also be given to areas exempt of tourism industry with studies examining the distribution and behaviour of marine mammal species undertaken prior to the establishment of the tourism activities (*e.g.* Dwyer et al., 2014), so as to provide a baseline pre-evaluation. With the continued rapid expansion of the tourism sector in the BOP region, it is recommended that vigilance be increased to detect potential further population effects (*e.g.* cumulative individual exposure in common dolphins, effect of tourism interaction on fur seal behaviour in the western sub-region) for mitigation purposes.

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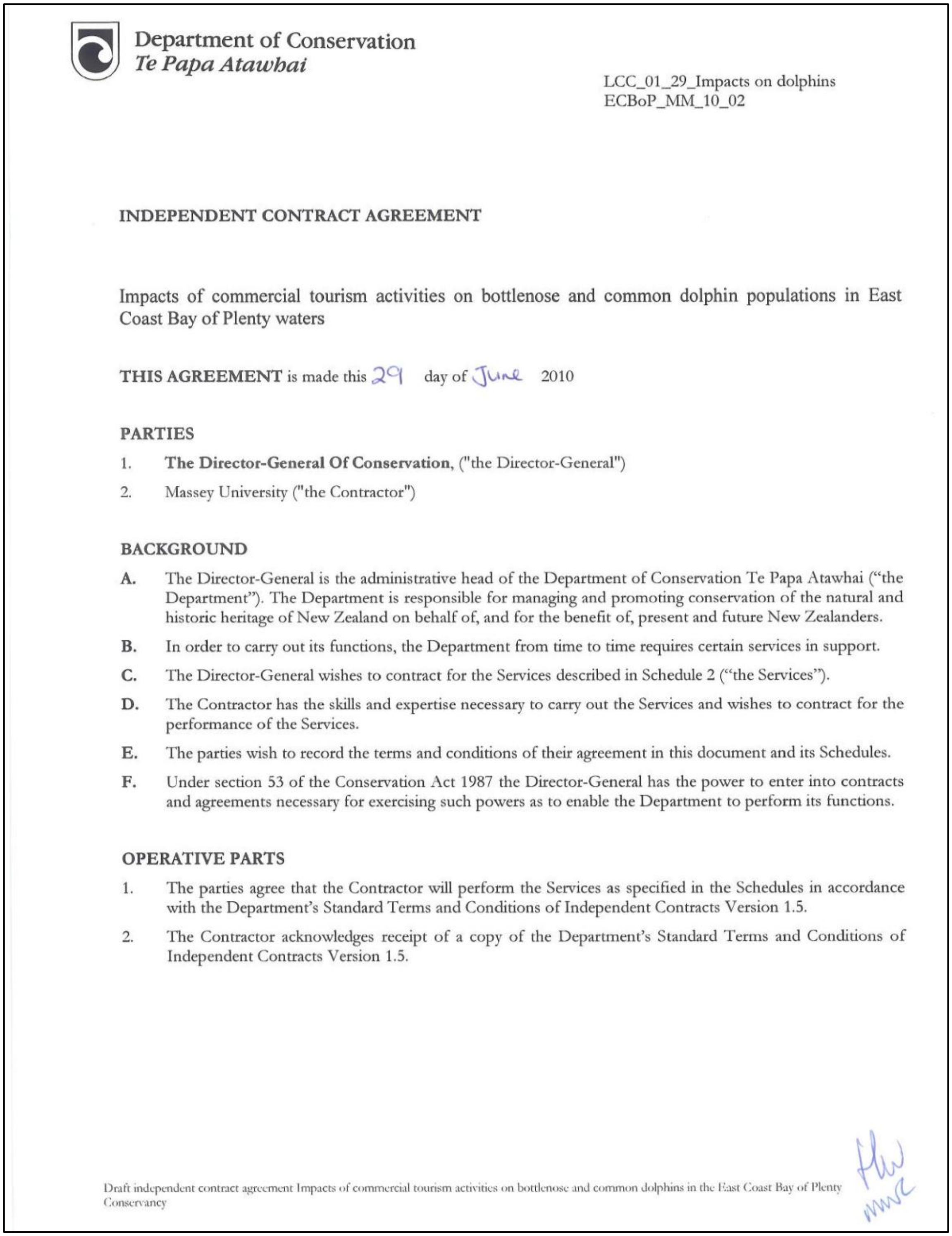
Appendices

Appendix 1 - Contract agreement between the Department of Conservation and Massey University.



Department of Conservation
Te Papa Atawhai

LCC_01_29_Impacts on dolphins
ECBoP_MM_10_02

INDEPENDENT CONTRACT AGREEMENT

Impacts of commercial tourism activities on bottlenose and common dolphin populations in East Coast Bay of Plenty waters

THIS AGREEMENT is made this 29 day of June 2010

PARTIES

1. **The Director-General Of Conservation**, ("the Director-General")
2. Massey University ("the Contractor")

BACKGROUND

A. The Director-General is the administrative head of the Department of Conservation Te Papa Atawhai ("the Department"). The Department is responsible for managing and promoting conservation of the natural and historic heritage of New Zealand on behalf of, and for the benefit of, present and future New Zealanders.

B. In order to carry out its functions, the Department from time to time requires certain services in support.

C. The Director-General wishes to contract for the Services described in Schedule 2 ("the Services").

D. The Contractor has the skills and expertise necessary to carry out the Services and wishes to contract for the performance of the Services.

E. The parties wish to record the terms and conditions of their agreement in this document and its Schedules.

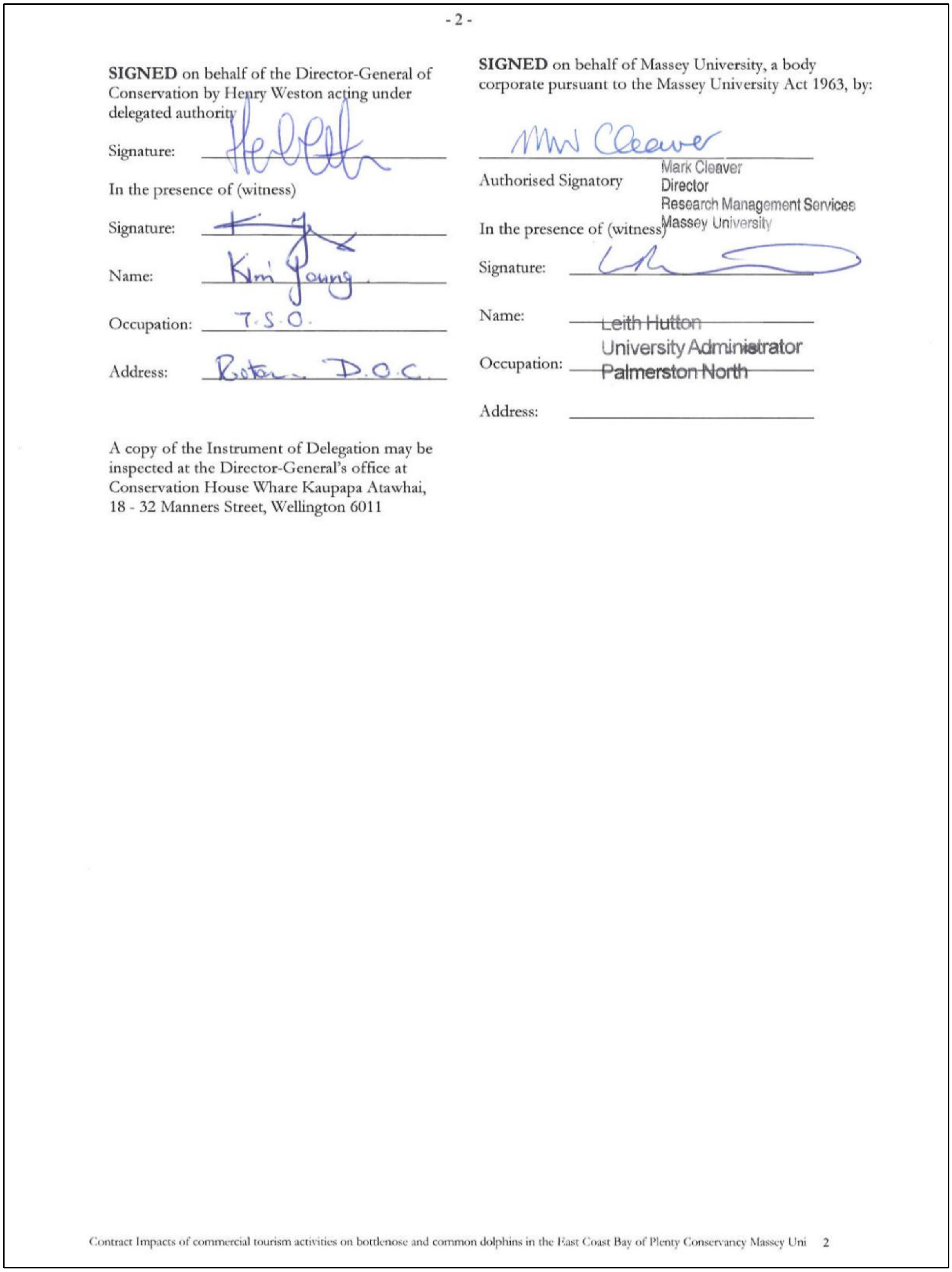
F. Under section 53 of the Conservation Act 1987 the Director-General has the power to enter into contracts and agreements necessary for exercising such powers as to enable the Department to perform its functions.

OPERATIVE PARTS

1. The parties agree that the Contractor will perform the Services as specified in the Schedules in accordance with the Department's Standard Terms and Conditions of Independent Contracts Version 1.5.
2. The Contractor acknowledges receipt of a copy of the Department's Standard Terms and Conditions of Independent Contracts Version 1.5.

Draft independent contract agreement Impacts of commercial tourism activities on bottlenose and common dolphins in the East Coast Bay of Plenty Conservancy

Appendix 1 (*continued*)



- 2 -

SIGNED on behalf of the Director-General of Conservation by Henry Weston acting under delegated authority

Signature:

In the presence of (witness)

Signature:

Name: Kim Young.

Occupation: T.S.O.

Address: Rotorua D.O.C.

A copy of the Instrument of Delegation may be inspected at the Director-General's office at Conservation House Whare Kaupapa Atawhai, 18 - 32 Manners Street, Wellington 6011

SIGNED on behalf of Massey University, a body corporate pursuant to the Massey University Act 1963, by:

MW Cleaver

Authorised Signatory

Mark Cleaver
Director
Research Management Services
Massey University

In the presence of (witness)

Signature:

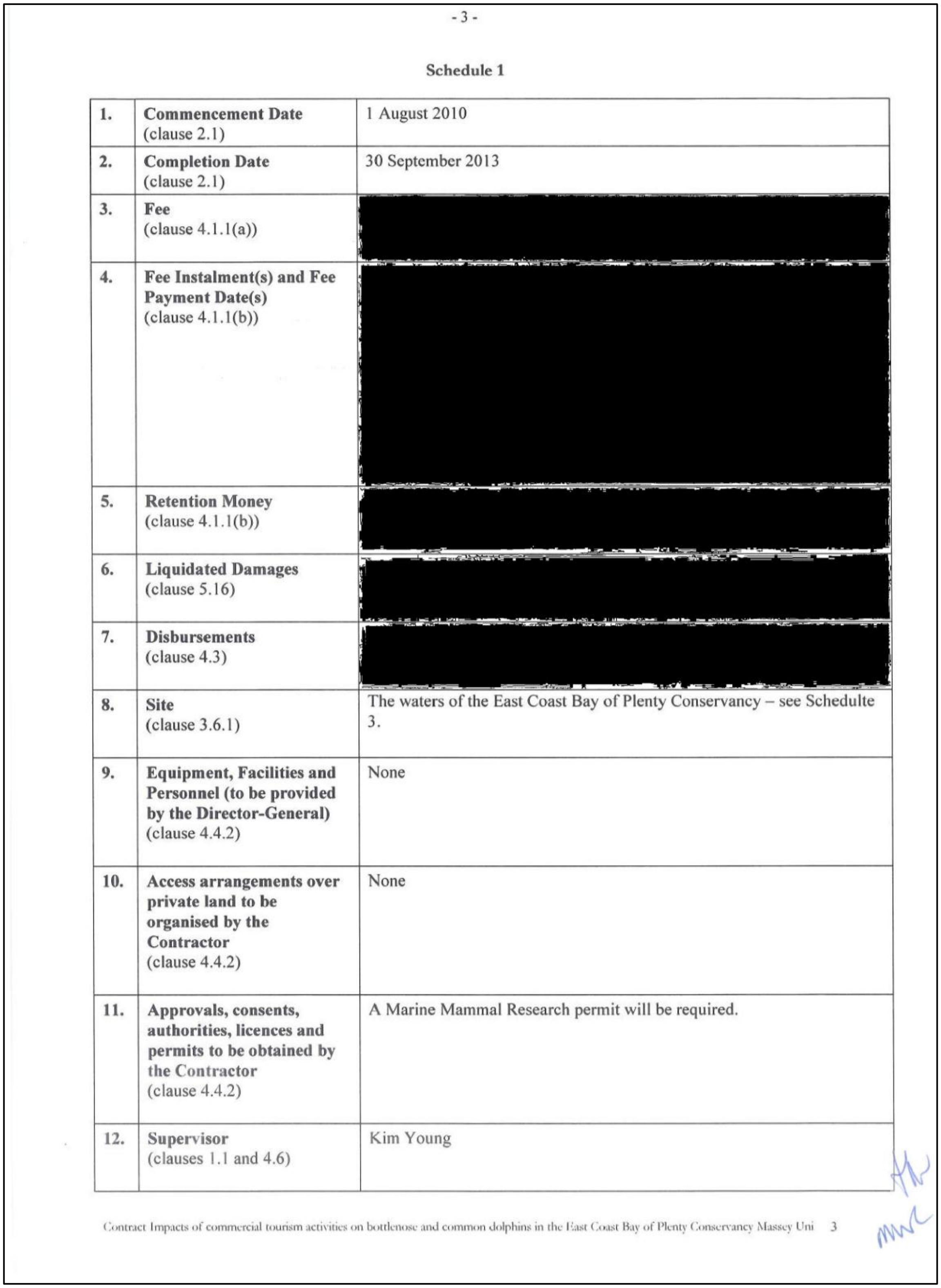
Name: Leith Hutton

Occupation: University Administrator
Palmerston North

Address:

Contract Impacts of commercial tourism activities on bottlenose and common dolphins in the East Coast Bay of Plenty Conservancy Massey Uni 2

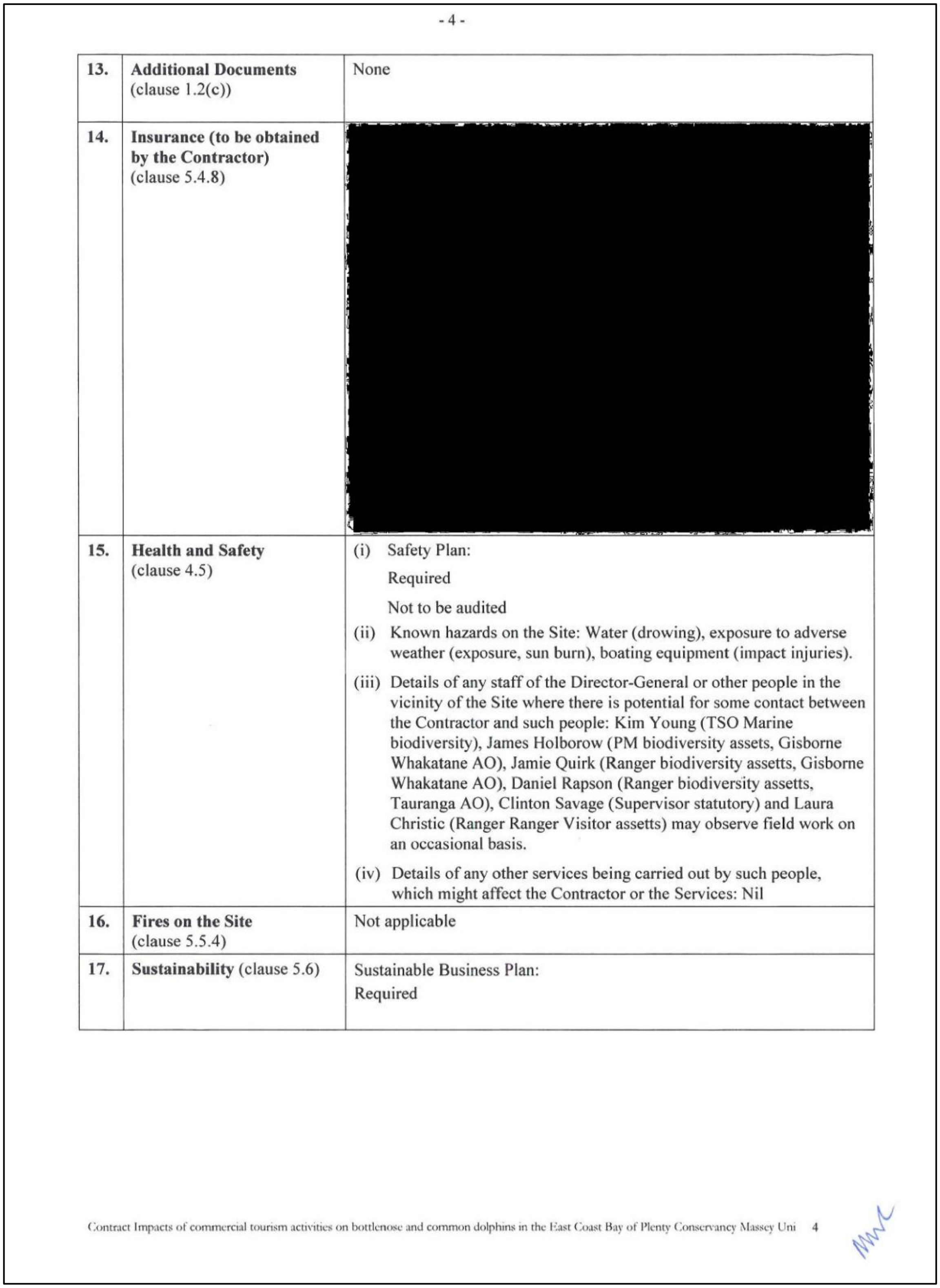
Appendix 1 (*continued*)



Schedule 1

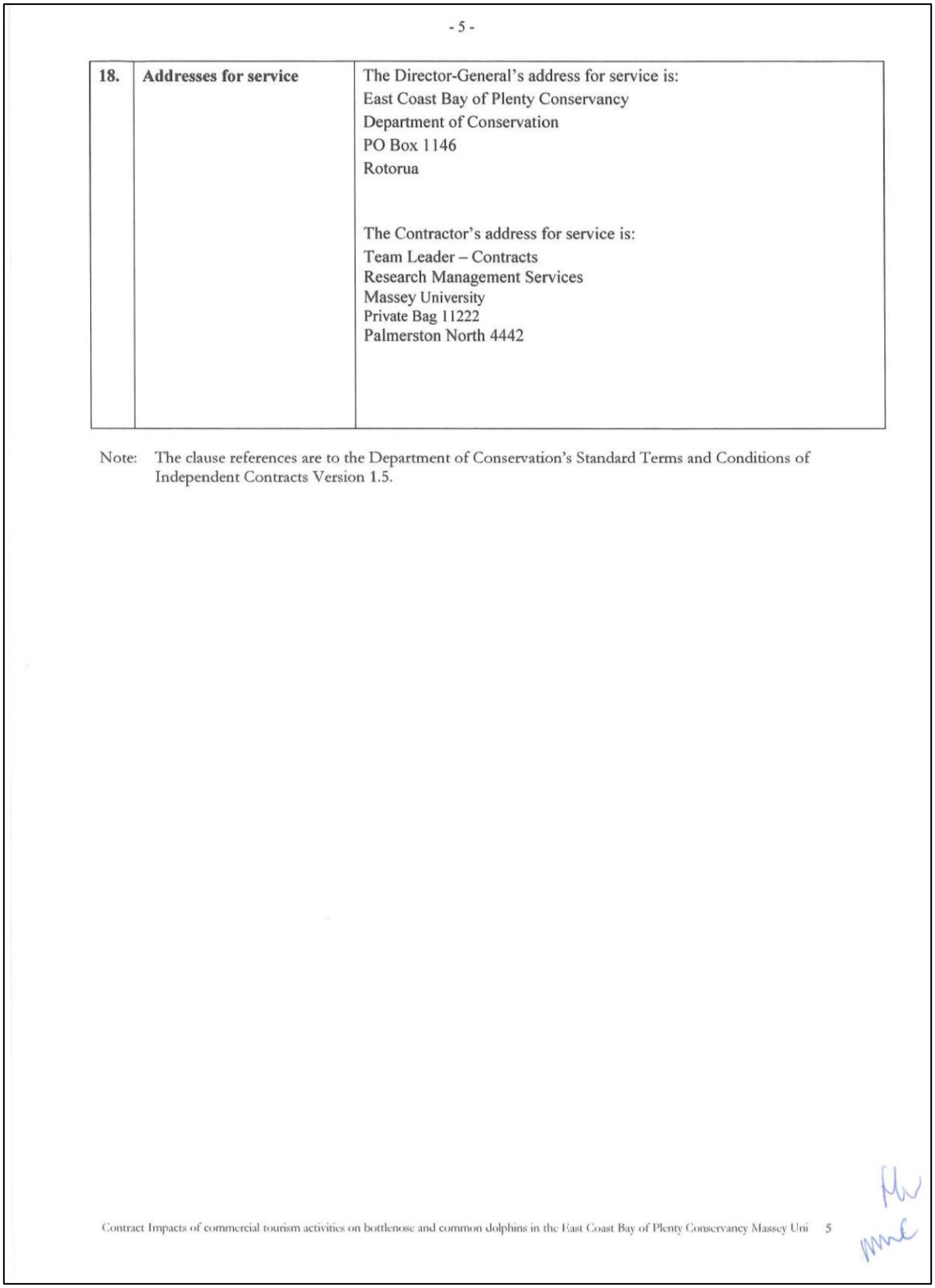
1.	**Commencement Date** (clause 2.1)	1 August 2010
2.	**Completion Date** (clause 2.1)	30 September 2013
3.	**Fee** (clause 4.1.1(a))	[redacted]
4.	**Fee Instalment(s) and Fee Payment Date(s)** (clause 4.1.1(b))	[redacted]
5.	**Retention Money** (clause 4.1.1(b))	[redacted]
6.	**Liquidated Damages** (clause 5.16)	[redacted]
7.	**Disbursements** (clause 4.3)	[redacted]
8.	**Site** (clause 3.6.1)	The waters of the East Coast Bay of Plenty Conservancy – see Schedulte 3.
9.	**Equipment, Facilities and Personnel (to be provided by the Director-General)** (clause 4.4.2)	None
10.	**Access arrangements over private land to be organised by the Contractor** (clause 4.4.2)	None
11.	**Approvals, consents, authorities, licences and permits to be obtained by the Contractor** (clause 4.4.2)	A Marine Mammal Research permit will be required.
12.	**Supervisor** (clauses 1.1 and 4.6)	Kim Young

Appendix 1 (*continued*)



13.	**Additional Documents** (clause 1.2(c))	None
14.	**Insurance (to be obtained by the Contractor)** (clause 5.4.8)	[redacted]
15.	**Health and Safety** (clause 4.5)	(i) Safety Plan: Required Not to be audited (ii) Known hazards on the Site: Water (drowing), exposure to adverse weather (exposure, sun burn), boating equipment (impact injuries). (iii) Details of any staff of the Director-General or other people in the vicinity of the Site where there is potential for some contact between the Contractor and such people: Kim Young (TSO Marine biodiversity), James Holborow (PM biodiversity assets, Gisborne Whakatane AO), Jamie Quirk (Ranger biodiversity assetts, Gisborne Whakatane AO), Daniel Rapson (Ranger biodiversity assetts, Tauranga AO), Clinton Savage (Supervisor statutory) and Laura Christic (Ranger Ranger Visitor assetts) may observe field work on an occasional basis. (iv) Details of any other services being carried out by such people, which might affect the Contractor or the Services: Nil
16.	**Fires on the Site** (clause 5.5.4)	Not applicable
17.	**Sustainability** (clause 5.6)	Sustainable Business Plan: Required

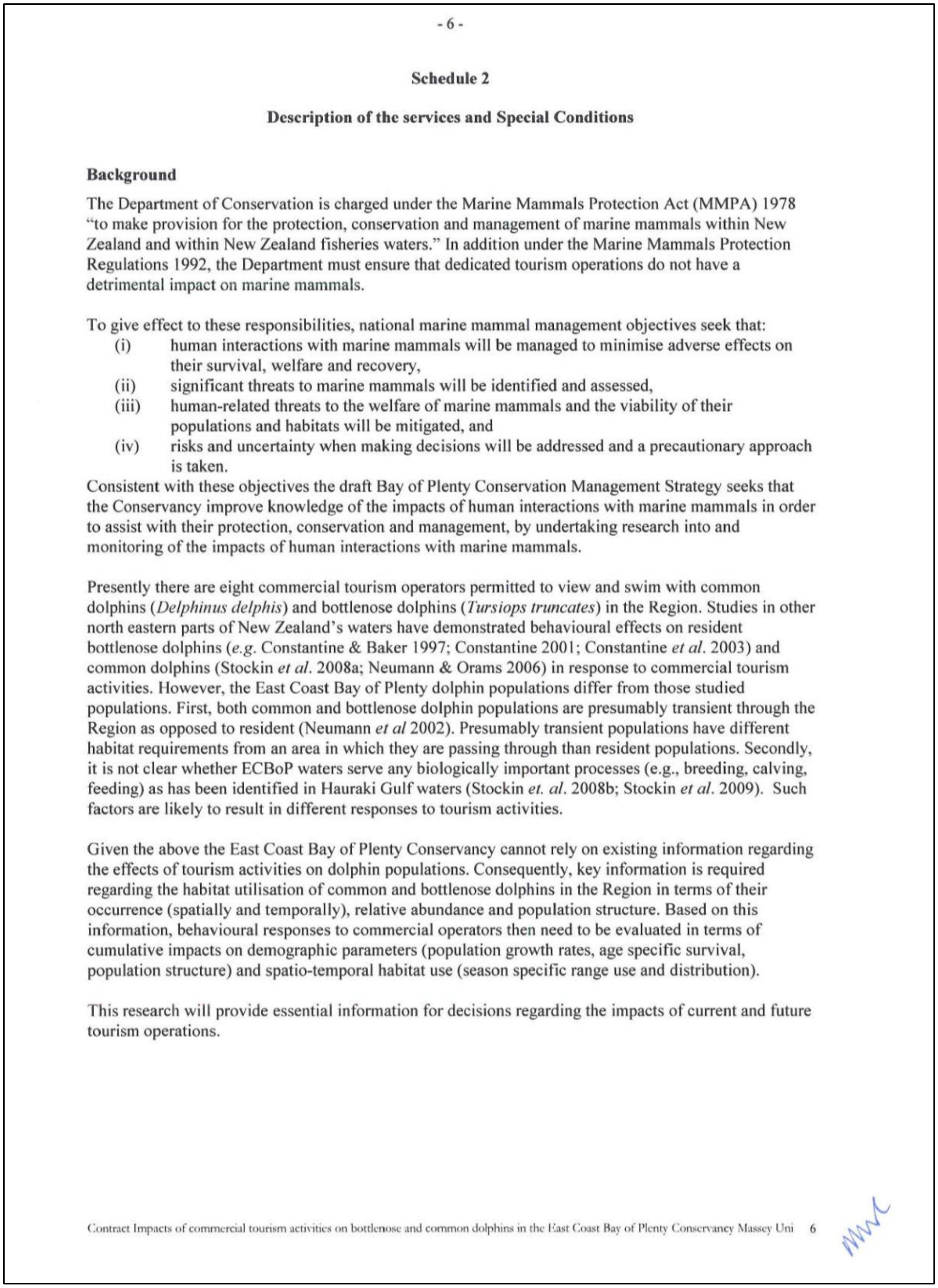
Appendix 1 (*continued*)



18.	**Addresses for service**	The Director-General's address for service is: East Coast Bay of Plenty Conservancy Department of Conservation PO Box 1146 Rotorua The Contractor's address for service is: Team Leader – Contracts Research Management Services Massey University Private Bag 11222 Palmerston North 4442

Note: The clause references are to the Department of Conservation's Standard Terms and Conditions of Independent Contracts Version 1.5.

Appendix 1 (*continued*)



Schedule 2

Description of the services and Special Conditions

Background

The Department of Conservation is charged under the Marine Mammals Protection Act (MMPA) 1978 "to make provision for the protection, conservation and management of marine mammals within New Zealand and within New Zealand fisheries waters." In addition under the Marine Mammals Protection Regulations 1992, the Department must ensure that dedicated tourism operations do not have a detrimental impact on marine mammals.

To give effect to these responsibilities, national marine mammal management objectives seek that:
(i) human interactions with marine mammals will be managed to minimise adverse effects on their survival, welfare and recovery,
(ii) significant threats to marine mammals will be identified and assessed,
(iii) human-related threats to the welfare of marine mammals and the viability of their populations and habitats will be mitigated, and
(iv) risks and uncertainty when making decisions will be addressed and a precautionary approach is taken.

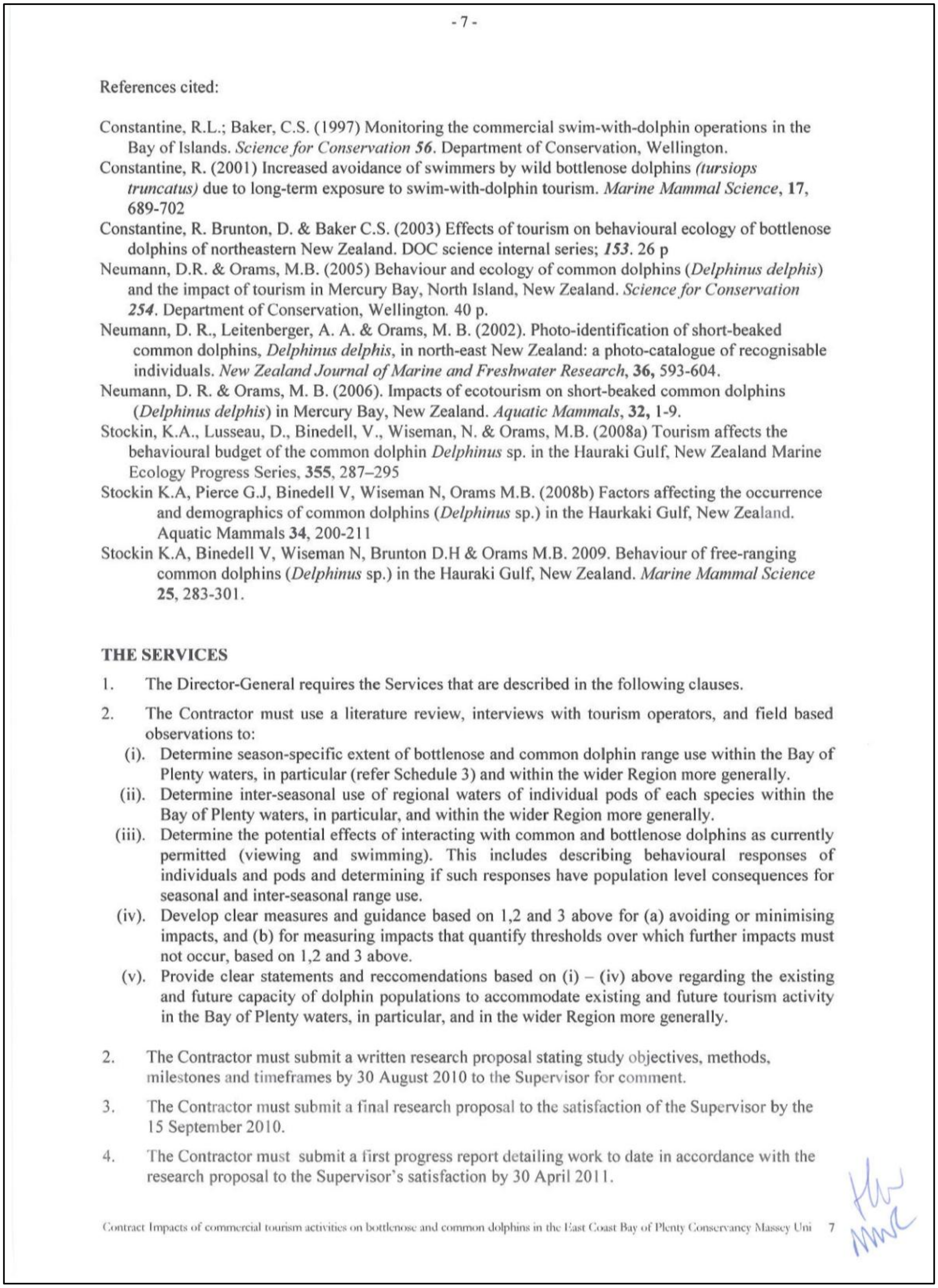
Consistent with these objectives the draft Bay of Plenty Conservation Management Strategy seeks that the Conservancy improve knowledge of the impacts of human interactions with marine mammals in order to assist with their protection, conservation and management, by undertaking research into and monitoring of the impacts of human interactions with marine mammals.

Presently there are eight commercial tourism operators permitted to view and swim with common dolphins (*Delphinus delphis*) and bottlenose dolphins (*Tursiops truncates*) in the Region. Studies in other north eastern parts of New Zealand's waters have demonstrated behavioural effects on resident bottlenose dolphins (*e.g.* Constantine & Baker 1997; Constantine 2001; Constantine *et al*. 2003) and common dolphins (Stockin *et al*. 2008a; Neumann & Orams 2006) in response to commercial tourism activities. However, the East Coast Bay of Plenty dolphin populations differ from those studied populations. First, both common and bottlenose dolphin populations are presumably transient through the Region as opposed to resident (Neumann *et al* 2002). Presumably transient populations have different habitat requirements from an area in which they are passing through than resident populations. Secondly, it is not clear whether ECBoP waters serve any biologically important processes (e.g., breeding, calving, feeding) as has been identified in Hauraki Gulf waters (Stockin *et. al*. 2008b; Stockin *et al*. 2009). Such factors are likely to result in different responses to tourism activities.

Given the above the East Coast Bay of Plenty Conservancy cannot rely on existing information regarding the effects of tourism activities on dolphin populations. Consequently, key information is required regarding the habitat utilisation of common and bottlenose dolphins in the Region in terms of their occurrence (spatially and temporally), relative abundance and population structure. Based on this information, behavioural responses to commercial operators then need to be evaluated in terms of cumulative impacts on demographic parameters (population growth rates, age specific survival, population structure) and spatio-temporal habitat use (season specific range use and distribution).

This research will provide essential information for decisions regarding the impacts of current and future tourism operations.

Appendix 1 (*continued*)



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THE SERVICES

1. The Director-General requires the Services that are described in the following clauses.

2. The Contractor must use a literature review, interviews with tourism operators, and field based observations to:

   (i). Determine season-specific extent of bottlenose and common dolphin range use within the Bay of Plenty waters, in particular (refer Schedule 3) and within the wider Region more generally.

   (ii). Determine inter-seasonal use of regional waters of individual pods of each species within the Bay of Plenty waters, in particular, and within the wider Region more generally.

   (iii). Determine the potential effects of interacting with common and bottlenose dolphins as currently permitted (viewing and swimming). This includes describing behavioural responses of individuals and pods and determining if such responses have population level consequences for seasonal and inter-seasonal range use.

   (iv). Develop clear measures and guidance based on 1,2 and 3 above for (a) avoiding or minimising impacts, and (b) for measuring impacts that quantify thresholds over which further impacts must not occur, based on 1,2 and 3 above.

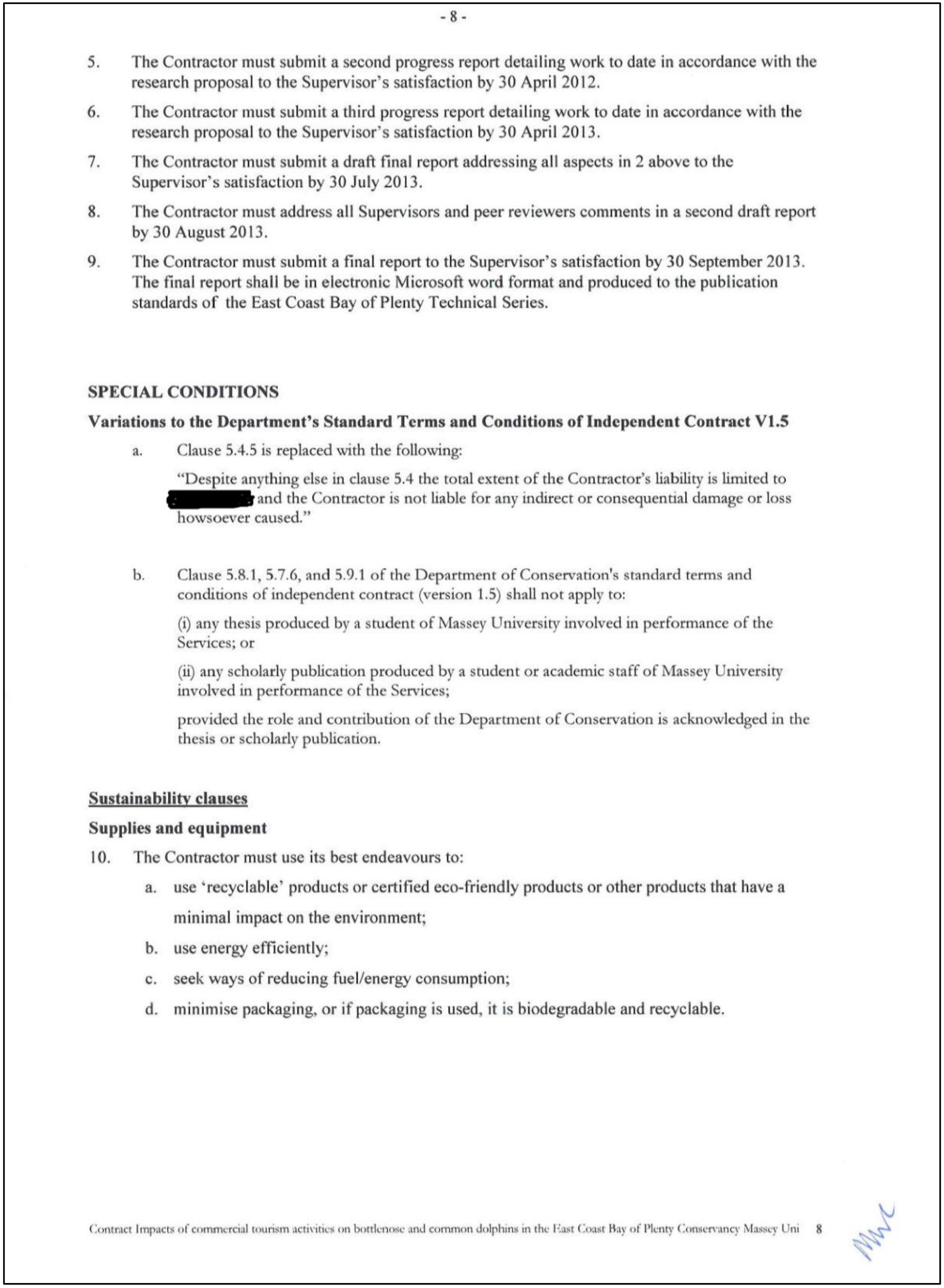
   (v). Provide clear statements and reccomendations based on (i) – (iv) above regarding the existing and future capacity of dolphin populations to accommodate existing and future tourism activity in the Bay of Plenty waters, in particular, and in the wider Region more generally.

2. The Contractor must submit a written research proposal stating study objectives, methods, milestones and timeframes by 30 August 2010 to the Supervisor for comment.

3. The Contractor must submit a final research proposal to the satisfaction of the Supervisor by the 15 September 2010.

4. The Contractor must submit a first progress report detailing work to date in accordance with the research proposal to the Supervisor's satisfaction by 30 April 2011.

Appendix 1 (*continued*)



- 8 -

5. The Contractor must submit a second progress report detailing work to date in accordance with the research proposal to the Supervisor's satisfaction by 30 April 2012.

6. The Contractor must submit a third progress report detailing work to date in accordance with the research proposal to the Supervisor's satisfaction by 30 April 2013.

7. The Contractor must submit a draft final report addressing all aspects in 2 above to the Supervisor's satisfaction by 30 July 2013.

8. The Contractor must address all Supervisors and peer reviewers comments in a second draft report by 30 August 2013.

9. The Contractor must submit a final report to the Supervisor's satisfaction by 30 September 2013. The final report shall be in electronic Microsoft word format and produced to the publication standards of the East Coast Bay of Plenty Technical Series.

SPECIAL CONDITIONS

Variations to the Department's Standard Terms and Conditions of Independent Contract V1.5

a. Clause 5.4.5 is replaced with the following:

"Despite anything else in clause 5.4 the total extent of the Contractor's liability is limited to [redacted] and the Contractor is not liable for any indirect or consequential damage or loss howsoever caused."

b. Clause 5.8.1, 5.7.6, and 5.9.1 of the Department of Conservation's standard terms and conditions of independent contract (version 1.5) shall not apply to:

(i) any thesis produced by a student of Massey University involved in performance of the Services; or

(ii) any scholarly publication produced by a student or academic staff of Massey University involved in performance of the Services;

provided the role and contribution of the Department of Conservation is acknowledged in the thesis or scholarly publication.

<u>Sustainability clauses</u>

Supplies and equipment

10. The Contractor must use its best endeavours to:
    a. use 'recyclable' products or certified eco-friendly products or other products that have a minimal impact on the environment;
    b. use energy efficiently;
    c. seek ways of reducing fuel/energy consumption;
    d. minimise packaging, or if packaging is used, it is biodegradable and recyclable.

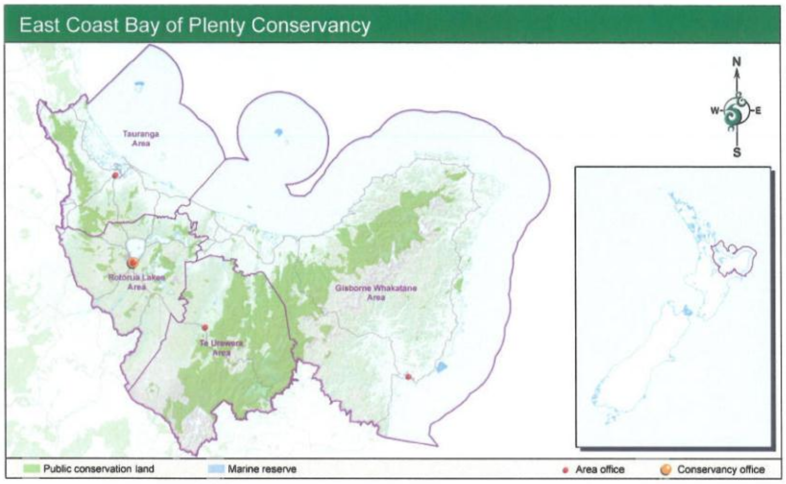
Contract Impacts of commercial tourism activities on bottlenose and common dolphins in the East Coast Bay of Plenty Conservancy Massey Uni 8

Appendix 1 (*continued*)

Schedule 3

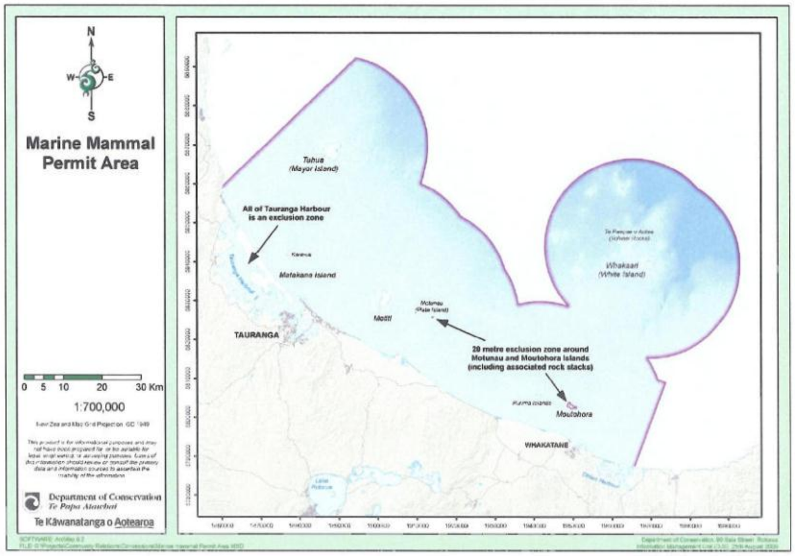
The Site

The coastal area within 12 nautical miles of the shore shown in light blue, extending from Orokawa Bay in the west to Gisborne in the east.



The Bay of Plenty waters

The coastal area within 12 nautical miles of the shore shown in light blue, extending from the northmost end of Orokawa Bay in the west to the to the eastern-most end of Ohiwa Harbour entrance in the east



Draft independent contract agreement Impacts of commercial tourism activities on bottlenose and common dolphins in the East Coast Bay of Plenty Conservancy

Appendix 2 - Selection of the best fitted model explaining occurrence of common dolphins opportunistically reported between December 2000 and November 2010 in the Bay of Plenty, New Zealand.

Analysis began with the full model 1, which included all variables (Chapter 2, Methods, Section 2.2.5) and a backward selection procedure was applied (models 2 to 7, Table a). Model 7 was identified as the optimal model based on the lowest Akaike's Information Criteria (AIC=1021.693). The variable "Aspect of the sea bed" was therefore removed from the original model and further selection procedures continued (models 8 to 12). Model 7 remained optimal and the significance of the variables was examined (Table b). The variable Chl-a was not significant and was therefore removed from the model. Model 8 became optimal and the selection procedure continued (models 13 to 16). Model 8 remained optimal based on the lowest AIC (1221.143) and the significance of the variables was examined (Table c). All variables included in model 8 were significant.

Table a: Variables included in the tested models, respective degree of freedom (df) and Akaike's Information Criteria (AIC).

Model	Variables included in the model	df	AIC
1	Presence~ s(Chl-a) + s(SST) + s(logFront) + s(logSlope) + (logDepth)*(Season) + factor(Aspect)	27.121	1029.857
2	Presence~ s(SST) + s(logFront) + s(logSlope) + (logDepth)*(Season) + factor(Aspect)	32.205	1225.727
3	Presence~ s(Chl-a) + s(logFront) + s(logSlope) + (logDepth)*(Season) + factor(Aspect)	24.683	1078.618
4	Presence~ s(Chl-a) + s(SST) + s(logSlope) + (logDepth)*(Season) + factor(Aspect)	22.963	1114.031
5	Presence~ s(Chl-a) + s(SST) + s(logFront) + (logDepth)*(Season) + factor(Aspect)	25.700	1036.988
6	Presence~ s(Chl-a) + s(SST) + s(logFront) + s(logSlope) + factor(Aspect)	25.114	1045.505
7	Presence~ s(Chl-a) + s(SST) + s(logFront) + s(logSlope) + (logDepth)*(Season)	20.185	1021.693
8	Presence~ s(SST) + s(logFront) + s(logSlope) + (logDepth)*(Season)	25.312	1221.143
9	Presence~ s(Chl-a) + s(logFront) + s(logSlope) + (logDepth)*(Season)	17.920	1069.417
10	Presence~ s(Chl-a) + s(SST) + s(logSlope) + (logDepth)*(Season)	15.933	1106.946
11	Presence~ s(Chl-a) + s(SST) + s(logFront) + (logDepth)*(Season)	18.654	1029.489
12	Presence~ s(Chl-a) + s(SST) + s(logFront) + s(logSlope)	18.390	1037.608
13	Presence~ s(logFront) + s(logSlope) + (logDepth)*(Season)	20.879	1340.320
14	Presence~ s(SST) + s(logSlope) + (logDepth)*(Season)	21.546	1317.384
15	Presence~ s(SST) + s(logFront) + (logDepth)*(Season)	17.248	1251.571
16	Presence~ s(SST) + s(logFront) + s(logSlope)	18.945	1237.373

Appendix 2 (*continued*)

Table b: Parameter estimates of the variables selected in Model 7 (GAM with binomial distribution and logit link function). Significance codes are "***" 0.001, "**" 0.01, "*" 0.05, "-" 1.

Variable	df	χ^2 statistic	p-value
Chl-a	1.678	1.031	0.621
SST	5.351	15.388	0.025 *
Log(Front)	4.156	16.070	0.008 **
Log(Slope)	1.001	9.592	0.002 **
	df	Deviance	p-value
(LogDepth)*(Season)	-1.796	-19.506	4.262^{e-05}***

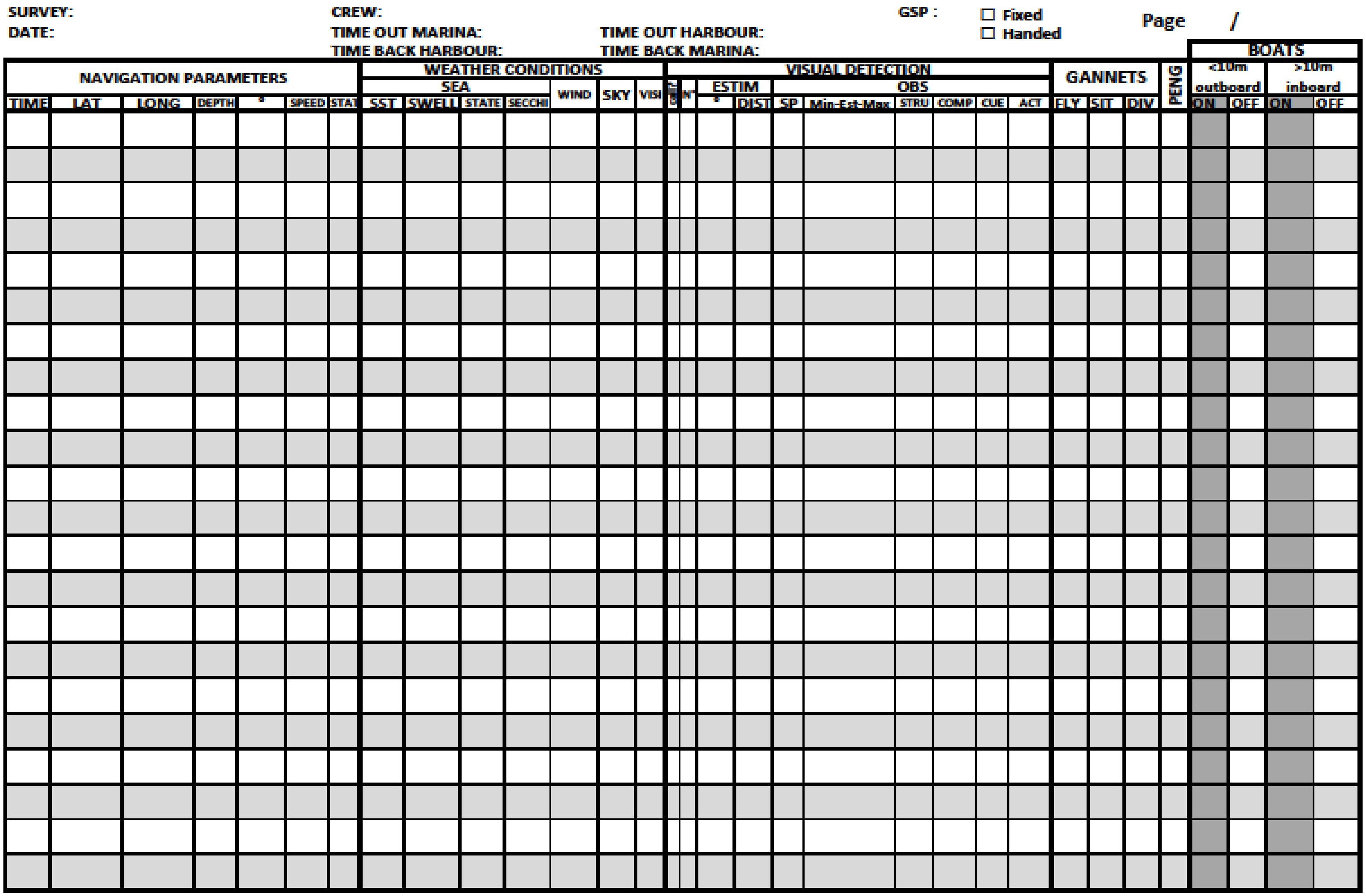
R^2=0.17, Deviance explained = 17.2%, n=1209

Table c: Parameter estimates of the variables selected in Model 8 (GAM with binomial distribution and logit link function). Significance codes are "***" 0.001, "**" 0.01, "*" 0.05, "-" 1.

Variable	df	χ^2 statistic	p-value
SST	5.703	19.280	0.007**
Log(Front)	3.891	19.770	0.001**
Log(Slope)	7.718	42.800	1.890^{e-06}***
	df	Deviance	p-value
(LogDepth)*(Season)	-6.367	-28.964	8.578^{e-05} ***

R^2=0.167, Deviance explained = 17.3%, n=1453

Appendix 3 - Data form completed every 10 minutes while searching for marine mammals, *i.e.* surveys *on effort*.



SURVEY:
DATE:
CREW:
TIME OUT MARINA:
TIME BACK HARBOUR:
TIME OUT HARBOUR:
TIME BACK MARINA:
GSP : ☐ **Fixed** ☐ **Handed**
Page /

																												BOATS			
NAVIGATION PARAMETERS							WEATHER CONDITIONS							VISUAL DETECTION										GANNETS			PENG	<10m outboard		>10m inboard	
							SEA				WIND	SKY	VISI		N°	ESTIM		OBS													
TIME	LAT	LONG	DEPTH	°	SPEED	STAT	SST	SWELL	STATE	SECCHI						°	DIST	SP	Min-Est-Max	STRU	COMP	CUE	ACT	FLY	SIT	DIV		ON	OFF	ON	OFF

Appendix 4 - Selection of the best fitted model explaining occurrence of common dolphins encountered between November 2010 and May 2013 in the western Bay of Plenty, New Zealand.

Analysis began with the full model 1, which included all variables (Chapter 3, Methods, Sections 3.2.3.6 and 3.2.3.7) and a backward selection procedure was applied (models 2 to 9, Table a). Model 7 was identified as the optimal model based on the lowest Akaike's Information Criteria (AIC=516.089). The variable "Aspect of the sea bed" was therefore removed from the original model and further selection procedures continued (models 10 to 16). Model 15 was identified as optimal based on a lowest AIC (513.942) compared to model 7. The variable "Year" was therefore removed and further selection procedures continued (models 17 to 22). Model 15 remained optimal and the significance of the variables was examined (Table b). All the variables included in the model 15 were significant.

Table a: Variables included in the tested models, respective degree of freedom (df) and Akaike's Information Criteria (AIC).

Model	Variables included in the model	df	AIC
1	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform)	20.003	521.196
2	Presence~ s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform)	13.632	587.540
3	Presence~ s(Effort) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform)	18.107	521.527
4	Presence~ s(Effort) + s(Chl-a) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform)	17.147	519.386
5	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform)	19.388	532.409
6	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + factor(Aspect) + factor(Year) + factor(Plateform)	19.512	534.964
7	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Year) + factor(Plateform)	14.826	516.089
8	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Plateform)	15.918	518.577
9	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year)	19.619	533.338
10	Presence~ s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Year) + factor(Plateform)	12.974	589.903
11	Presence~ s(Effort) + s(SST) + s(Slope) + s(Depth) + factor(Year) + factor(Plateform)	14.263	517.725
12	Presence~ s(Effort) + s(Chl-a) + s(Slope) + s(Depth) + factor(Year) + factor(Plateform)	13.289	514.802
13	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Depth) + factor(Year) + factor(Plateform)	15.438	525.539
14	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + factor(Year) + factor(Plateform)	15.591	532.793
15	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Plateform)	12.114	513.942

Appendix 4 (*continued*)

Table a (*continued*): Variables included in the tested models, respective degree of freedom (df) and Akaike's Information Criteria (AIC).

Model	Variables included in the model	df	AIC
16	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Year)	15.664	528.344
17	Presence~ s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Aspect)	12.015	587.925
18	Presence~ s(Effort) + s(SST) + s(Slope) + s(Depth) + factor(Aspect)	12.283	516.008
19	Presence~ s(Effort) + s(Chl-a) + s(Slope) + s(Depth) + factor(Aspect)	11.285	515.771
20	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Depth) + factor(Aspect)	10.985	524.710
21	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + factor(Aspect)	14.583	531.114
22	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth)	11.200	525.484

Table b: Parameter estimates of the variables selected in the Model 7 (GAM with binomial distribution and logit link function). Significance codes are "***" 0.001, "*" 0.05, "." 0.1.

Variable	df	χ^2 statistic	p-value
Effort	2.803	62.384	2.130^{e-13} ***
Chl-a	2.710	8.601	0.034 *
SST	1.000	4.514	0.034 *
Slope	1.833	5.438	0.067 .
Depth	1.767	22.061	2.240^{e-05} ***
	df	Deviance	p-value
Plateform	-0.914	-13.371	2.143^{e-04}***

R^2= 0.279, Deviance explained = 30.8%, n=842

Appendix 5 - Selection of the best fitted model explaining occurrence of New Zealand fur seals encountered between November 2010 and May 2013 in the western Bay of Plenty, New Zealand.

Analysis began with the full model 1, which included all variables (Chapter 3, Methods, Sections 3.2.3.6 and 3.2.3.7) and a backward selection procedure was applied (models 2 to 9, Table a). Model 10 was identified as the optimal model based on the lowest Akaike's Information Criteria (AIC=346.9333). The variable "Bi-season" was therefore removed and further selection procedures continued (models 11 to 18). Model 12 was identified as optimal based on a lowest AIC (345.9164) compared to model 10. The variable "Chl-a" was therefore removed and further selection procedures continued (models 19 to 25). Model 12 remained optimal and the significance of the variables was examined (Table b). The variables "Slope" and "Plateform" were not significant and were therefore removed from model 12 and further selection procedures continued (models 26 to 31). Removing further variables from model 26 did not improve the AIC, therefore model 26 was considered as optimal. The significance of the variables included in this model was examined (Table c). All variables included in model 26 were significant. Model 26 was therefore estimated as the best fitted model. For the variable "Year", the model was repeated using each year (*i.e.* 2010 to 2013) as the basis for comparison (Table d).

Table a: Variables included in the tested models, respective degree of freedom (df) and Akaike's Information Criteria (AIC).

Model	Variables included in the model	df	AIC
1	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform) + factor(Bi-season)	19.518	348.590
2	Presence~ s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform) + factor(Bi-season)	17.681	370.034
3	Presence~ s(Effort) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform) + factor(Bi-season)	17.693	346.992
4	Presence~ s(Effort) + s(Chl-a) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform) + factor(Bi-season)	18.578	347.334
5	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform) + factor(Bi-season)	17.175	351.180
6	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + factor(Aspect) + factor(Year) + factor(Plateform) + factor(Bi-season)	19.563	354.311
7	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Year) + factor(Plateform) + factor(Bi-season)	14.710	356.641
8	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Plateform) + factor(Bi-season)	16.487	351.590
9	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Bi-season)	18.994	349.001
10	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform)	17.958	346.933
11	Presence~ s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform)	15.970	368.465

Appendix 5 (*continued*)

Table a (*continued*): Variables included in the tested models, respective degree of freedom (df) and Akaike's Information Criteria (AIC).

Model	Variables included in the model	df	AIC
12	Presence~ s(Effort) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform)	16.485	345.916
13	Presence~ s(Effort) + s(Chl-a) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform)	17.365	348.463
14	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform)	16.052	349.247
15	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + factor(Aspect) + factor(Year) + factor(Plateform)	17.081	358.036
16	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Year) + factor(Plateform)	13.186	355.442
17	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Plateform)	15.478	349.724
18	Presence~ s(Effort) + s(Chl-a) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year)	17.449	347.565
19	Presence~ s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform)	14.021	367.112
20	Presence~ s(Effort) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform)	14.863	369.584
21	Presence~ s(Effort) + s(SST) + s(Depth) + factor(Aspect) + factor(Year) + factor(Plateform)	14.612	348.992
22	Presence~ s(Effort) + s(SST) + s(Slope) + factor(Aspect) + factor(Year) + factor(Plateform)	15.591	357.417
23	Presence~ s(Effort) + s(SST) + s(Slope) + s(Depth) + factor(Year) + factor(Plateform)	12.466	354.030
24	Presence~ s(Effort) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Plateform)	13.817	362.413
25	Presence~ s(Effort) + s(SST) + s(Slope) + s(Depth) + factor(Aspect) + factor(Year)	15.662	347.481
26	Presence~ s(Effort) + s(SST) + s(Depth) + factor(Aspect) + factor(Year)	13.8204	350.936
27	Presence~ s(SST) + s(Depth) + factor(Aspect) + factor(Year)	11.271	371.836
28	Presence~ s(Effort) + s(Depth) + factor(Aspect) + factor(Year)	12.083	369.829
29	Presence~ s(Effort) + s(SST) + factor(Aspect) + factor(Year)	12.593	381.878
30	Presence~ s(Effort) + s(SST) + s(Depth) + factor(Year)	9.7921	358.999
31	Presence~ s(Effort) + s(SST) + s(Depth) + factor(Aspect)	11.084	367.775

Appendix 5 (*continued*)

Table b: Parameter estimates of the variables selected in Model 12 (GAM with binomial distribution and logit link function). Significance codes are "***" 0.001, "**" 0.01.

Variable	df	χ^2 statistic	p-value
Effort	1.944	20.030	4.740^{e-05} ***
SST	1.396	17.510	1.530^{e-04} ***
Slope	2.051	4.830	0.119
Depth	2.094	14.460	0.002 **
	df	Deviance	p-value
Aspect	-4.019	-16.151	0.003 **
Year	-2.668	-21.833	4.650^{e-05} ***
Plateform	0	0	

R^2= 0.124, Deviance explained = 28.3%, n=1298

Table c: Parameter estimates of the variables selected in Model 26 (GAM with binomial distribution and logit link function). Significance codes are "***" 0.001, "**" 0.01.

Variable	df	χ^2 statistic	p-value
Effort	1.927	20.890	3.080^{e-05} ***
SST	1.595	16.150	3.140^{e-04} ***
Depth	2.298	30.030	1.470^{e-06} ***
	df	Deviance	p-value
Aspect	-4.028	-16.120	0.003 **
Year	-2.736	-22.312	4.027^{e-05} ***

R^2= 0.105, Deviance explained = 25.9%, n=1298

Table d: Parameter estimates of multi-comparisons of the variable "Year" in Model 26. Significance codes are "***" 0.001, "**" 0.01.

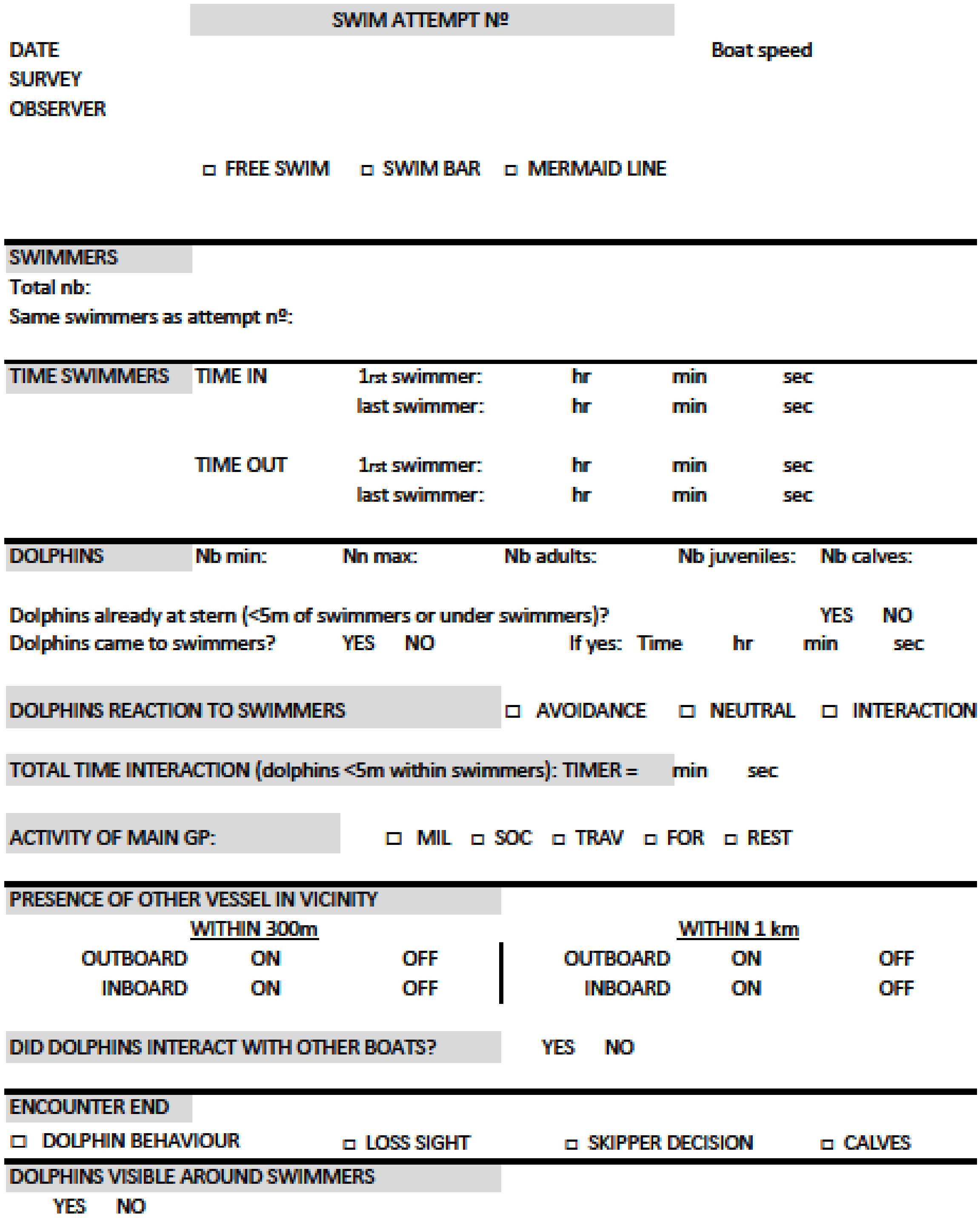
Baseline Year	Compared to	df	Estimate Standard	z-value	p-value
2010	2011	-0.537	1.085	-0.495	0.621
2010	2012	-1.637	1.106	-1.480	0.139
2010	2013	-45.080	4.259^{e+06}	0.000	1.000
2011	2012	-1.100	0.320	-3.432	5.990^{e-04} ***
2011	2013	-44.53	4.259^{e+06}	0.000	1.000
2012	2013	-43.43	4.259^{e+06}	0.000	1.000

Appendix 6 - Data form completed every 3 minutes during a dolphin focal follow.

DATE:

TIME	POSITION				GROUP				GANNET (F/S/D)	COMMENTS
(3')	LAT	LONG	DEPTH	SPEED	ACT	STRUCTURE	SIZE	COMPOSITION		

Appendix 7 - Data form completed during a swim attempt.



SWIM ATTEMPT Nº

DATE
SURVEY
OBSERVER

Boat speed

☐ FREE SWIM ☐ SWIM BAR ☐ MERMAID LINE

SWIMMERS

Total nb:
Same swimmers as attempt nº:

TIME SWIMMERS	TIME IN	1rst swimmer:	hr	min	sec
		last swimmer:	hr	min	sec
	TIME OUT	1rst swimmer:	hr	min	sec
		last swimmer:	hr	min	sec

DOLPHINS Nb min: Nn max: Nb adults: Nb juveniles: Nb calves:

Dolphins already at stern (<5m of swimmers or under swimmers)? YES NO
Dolphins came to swimmers? YES NO If yes: Time hr min sec

DOLPHINS REACTION TO SWIMMERS ☐ AVOIDANCE ☐ NEUTRAL ☐ INTERACTION

TOTAL TIME INTERACTION (dolphins <5m within swimmers): TIMER = min sec

ACTIVITY OF MAIN GP: ☐ MIL ☐ SOC ☐ TRAV ☐ FOR ☐ REST

PRESENCE OF OTHER VESSEL IN VICINITY

WITHIN 300m			WITHIN 1 km		
OUTBOARD	ON	OFF	OUTBOARD	ON	OFF
INBOARD	ON	OFF	INBOARD	ON	OFF

DID DOLPHINS INTERACT WITH OTHER BOATS? YES NO

ENCOUNTER END

☐ DOLPHIN BEHAVIOUR ☐ LOSS SIGHT ☐ SKIPPER DECISION ☐ CALVES

DOLPHINS VISIBLE AROUND SWIMMERS

YES NO

Appendix 8 - Description of the five attributes used to evaluate the quality of dorsal fin photographs of common dolphins between November 2010 and May 2013, in the Bay of Plenty, New Zealand. The quality of the selected images was evaluated following Slooten *et al.* (1992), Oremus *et al.* (2007), Merriman *et al.* (2009), Tezanos-Pinto *et al.* (2013).

Attributes	Rating description	Illustration
Focus	0 - entire dorsal fin is blurred	
	1 - dorsal fin is partially blurred: the trailing edge is not sharp but some details on the fin (*i.e.* pigmentation) are in focus, and vice versa	
	2 - entire dorsal fin is sharp and in focus	

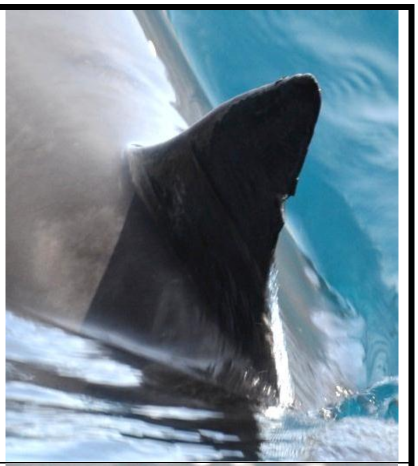
Appendix 8 (*continued*)

Exposure	0 - dorsal fin is either over or under exposed and only the outline of the dorsal fin is visible	
	1 - dorsal fin is partially under or over exposed, but the outline of the dorsal fin and some details are visible	
	2 - outline and all the details of the dorsal fin are visible	

Appendix 8 (*continued*)

Size	0 - dorsal fin occupies < 25% of the frame	
	1 - dorsal fin occupies 25-50% of the frame	
	2 - dorsal fin occupies >50% of the frame	

Appendix 8 (*continued*)

Angle	0 - dorsal fin is 60-90° relative to the photographer	
	1 - dorsal fin is 30-60° relative to the photographer	
	2 - dorsal fin is 0-30° relative to the photographer	

Appendix 8 (*continued*)

Environmental Interference	0 - <1/3 of the dorsal fin is free of interference	
	1 - 1/3 – 2/3 of the dorsal fin is free of interference	
	2 - >2/3 of the dorsal fin is free of interference	

Appendix 9 - Description of the quality of the dorsal fin photographs of common dolphins, between November 2010 and May 2013, in the Bay of Plenty, New Zealand. The quality of the selected images was evaluated following Slooten *et al.* (1992), Oremus *et al.* (2007), Merriman *et al.* (2009), Tezanos-Pinto *et al.* (2013).

Quality of the photograph	Rating description	Illustration
Poor	≥3 attributes were rated 0	
Fair	2 attributes were rated 0	
Good	1 attribute was rated 0	
Excellent	No attributes were rated 0	

Appendix 10 - Description of the distinctiveness of the dorsal fin of common dolphins between November 2010 and May 2013, in the Bay of Plenty, New Zealand. The quality of the selected images was evaluated following Oremus *et al.* (2007) and Zaeschmar *et al.* (2014).

Distinctiveness	Rating description	Illustration
Not distinct/ Unmarked	The absence of notches/nicks or the presence of very small commonly observed notches/nicks on the trailing edge, the absence of marks/scars on the fin, and a uniform colouration of the dorsal fin; unable to identify and compare the individual to the catalogue even on an excellent quality photograph	
Distinct	The presence of small to large notches/nicks on the trailing edge, and/or the presence of marks/scars on the fin, and/or some recognisable details in the pigmentation; able to identify and compare the individual to the catalogue	
Very distinct	The presence of medium to large uniquely shaped notches/nicks on the trailing edge, and/or notches on the anterior edge of the dorsal fin, and/or the presence of marks/scars on the fin, and/or very unique pigmentation; able to identify and compare the individual to the catalogue even on a poor quality photograph	

Appendix 11 - Resighthings of common dolphins exposed to tour vessels: Individual catalogue number (*i.e.* ID_xxxx), dates of sightings (S1 to S5), time lag (TL) between two resightings (*i.e.* TL_{1-2} is the number of days between S1 and S2) and distance (D in km) between two resightings (*i.e.* D_{1-2} is the distance between S1 and S2) between December 2010 and May 2013, in the Bay of Plenty, New Zealand.

Individual	S1	S2	TL1-2	D1-2	S3	TL2-3	D2-3	S4	TL3-4	D3-4	S5	TL4-5	D4-5
ID_0008	31-12-10	15-01-11	15	12.7									
ID_0308	03-01-11	12-01-11	9	23.6	01-02-11	20	16.8						
ID_0048	03-01-11	15-01-11	12	20.8	09-01-13	725	8.4						
ID_0145	03-01-11	03-02-11	31	15.1									
ID_0156	03-01-11	03-02-11	31	15.1									
ID_0615	03-01-11	21-02-11	49	16.3									
ID_0630	03-01-11	21-02-11	49	16.3									
ID_0227	03-01-11	26-02-11	54	21.8									
ID_0443	03-01-11	27-02-11	55	7.1	22-12-11	298	76.5						
ID_0028	08-01-11	24-01-13	747	2.1									
ID_0054	12-01-11	08-03-11	55	11.1									
ID_0056	15-01-11	03-02-11	19	12.9									
ID_0057	15-01-11	23-02-11	39	5.5	27-02-11	4	13.6						
ID_0059	15-01-11	31-01-13	747	17.5									
ID_0063	26-01-11	03-02-11	8	6.6	24-03-12	415	8.8	02-01-13	284	11.3	10-01-13	8	5.0
ID_0075	28-01-11	14-02-11	17	11.3									
ID_0130	30-01-11	07-02-11	8	14.8	14-02-13	738	11.6						
ID_0150	30-01-11	07-02-11	8	14.8	07-04-13	790	21.0						
ID_0138	30-01-11	07-02-11	8	14.8									
ID_0211	30-01-11	30-01-12	365	28.2									
ID_0232	01-02-11	02-02-11	1	21.5									
ID_0302	01-02-11	03-03-11	30	8.6	09-01-13	678	24.5						
ID_0495	01-02-11	03-03-11	30	8.6									
ID_0133	01-02-11	19-01-12	352	22.9									
ID_0316	01-02-11	25-01-12	358	35.6									
ID_0111	02-02-11	07-02-11	5	19.9	05-01-12	332	10.7	14-02-13	406	22.0			
ID_0117	02-02-11	18-02-11	16	22.4									
ID_0098	02-02-11	08-03-11	34	9.9	24-03-12	382	9.7						
ID_0013	02-02-11	08-03-11	34	9.9									

Appendix 11 (*continued*)

Individual	S1	S2	TL1-2	D1-2	S3	TL2-3	D2-3	S4	TL3-4	D3-4	S5	TL4-5	D4-5
ID_0127	02-02-11	14-03-11	40	14.6									
ID_0136	02-02-11	30-04-11	87	4.0									
ID_0128	02-02-11	21-12-11	322	10.9									
ID_0092	02-02-11	24-03-12	416	9.8									
ID_0122	02-02-11	27-03-12	419	12.5									
ID_0120	02-02-11	14-02-13	743	5.1									
ID_0146	03-02-11	19-02-11	16	16.9	20-02-11	1	12.2						
ID_0158	03-02-11	26-02-11	23	18.0									
ID_0140	03-02-11	09-01-13	706	7.94									
ID_0147	03-02-11	02-01-13	699	2.7	17-02-13	46	21. 9						
ID_0166	03-02-11	25-01-13	722	16.9									
ID_0832	21-02-11	09-02-13	719	12.2									
ID_0249	26-02-11	09-02-13	714	19.3									
ID_0264	07-02-11	26-02-11	19	8.6									
ID_0364	07-02-11	27-02-11	20	4.9									
ID_0347	07-02-11	20-12-11	316	8.7									
ID_0080	07-02-11	21-12-11	317	20.8	24-03-12	94	18.8						
ID_0184	13-02-11	08-03-11	23	10.3									
ID_0022	13-02-11	16-03-12	397	20.4									
ID_0178	13-02-11	03-03-13	749	26.7									
ID_0367	14-02-11	23-02-11	9	12.4	03-03-11	8	8.5	09-04-13	768	9.7			
ID_0370	14-02-11	23-02-11	9	12.4									
ID_0379	14-02-11	16-03-11	30	7.5									
ID_0368	14-02-11	05-03-12	385	14.2	12-02-13	344	9.7						
ID_0369	14-02-11	06-03-12	386	18.6									
ID_0094	15-02-11	24-03-12	403	16.0									
ID_0458	19-02-11	27-02-11	8	15.7									
ID_0775	20-02-11	21-12-11	304	16.7									
ID_0779	20-02-11	21-12-11	304	16.7									

Appendix 11 (*continued*)

Individual	S1	S2	TL1-2	D1-2	S3	TL2-3	D2-3	S4	TL3-4	D3-4	S5	TL4-5	D4-5
ID_0082	20-02-11	16-03-12	390	9.1									
ID_0043	20-02-11	16-03-12	390	9.1									
ID_0081	20-02-11	16-03-12	390	9.1									
ID_0233	21-02-11	26-02-11	5	5.8									
ID_0412	23-02-11	26-02-11	3	11.2									
ID_0104	23-02-11	24-03-12	395	9.3									
ID_0240	26-02-11	11-02-12	350	15.9									
ID_0242	26-02-11	11-02-12	350	15.9									
ID_0237	26-02-11	21-01-13	695	7.9	14-02-13	24	1.6						
ID_0248	26-02-11	27-03-13	760	3.0									
ID_0464	27-02-11	14-03-11	15	8.3									
ID_0476	27-02-11	14-03-11	15	8.3									
ID_0442	27-02-11	20-03-11	21	16.4									
ID_0462	27-02-11	16-03-12	383	13.8									
ID_0459	27-02-11	16-03-12	383	13.8									
ID_0492	03-03-11	16-03-11	13	17.1									
ID_0491	03-03-11	14-02-12	348	19.2									
ID_0502	03-03-11	13-01-13	682	5.8	10-02-13	28	11.2						
ID_0762	03-03-11	24-01-13	693	6.4									
ID_0508	03-03-11	13-01-13	682	5.8									
ID_0970	08-03-11	16-03-11	8	8.4	02-03-13	717	15.1						
ID_0791	08-03-11	19-03-11	11	7.6	20-03-11	1	3.2						
ID_0018	08-03-11	16-03-12	374	10.3									
ID_0960	08-03-11	24-03-12	382	9.7									
ID_0967	08-03-11	17-02-13	712	7.3									
ID_0808	14-03-11	08-03-13	725	10.3									
ID_0975	16-03-11	06-03-13	721	5.6	11-03-13	5	21.7						
ID_0983	16-03-11	11-03-13	726	16.3									
ID_0331	30-04-11	21-12-11	235	7.7									
ID_0776	21-12-11	10-03-12	80	11.5									
ID_0778	21-12-11	05-04-13	471	4.4									

Appendix 11 (*continued*)

Individual	S1	S2	TL1-2	D1-2	S3	TL2-3	D2-3	S4	TL3-4	D3-4	S5	TL4-5	D4-5
ID_1039	22-12-11	11-12-12	355	67.1									
ID_0541	05-01-12	05-04-13	456	28.9									
ID_0555	19-01-12	24-01-13	371	8.9									
ID_0568	19-01-12	10-02-13	388	6.6									
ID_1056	11-02-12	17-02-13	372	25.8									
ID_0702	05-03-12	16-03-12	11	8.7									
ID_0703	05-03-12	16-03-12	11	8.7									
ID_1077	10-03-12	03-03-13	358	14.4									
ID_0046	16-03-12	24-03-12	8	5.8									
ID_1121	27-03-12	14-02-13	324	17.2	17-02-13	3	17.2						
ID_1362	09-12-12	21-01-13	43	13.3									
ID_1425	09-01-13	11-01-13	2	17.1									
ID_1433	10-01-13	25-01-13	15	13.5									
ID_1432	10-01-13	03-03-13	52	22.3									
ID_1436	10-01-13	03-03-13	52	22.3									
ID_0486	13-01-13	24-01-13	11	14.5									
ID_1482	13-01-13	09-04-13	86	9.4									
ID_0853	17-01-13	23-01-13	6	20.1									
ID_0527	24-01-13	25-01-13	1	7.0									
ID_0500	24-01-13	10-02-13	17	11.7									
ID_0404	24-01-13	09-04-13	75	16.0									
ID_0855	11-02-13	17-02-13	6	11.3									
ID_0873	06-03-13	11-03-13	5	21.7									
ID_1582	06-03-13	11-03-13	5	21.7									
ID_1583	06-03-13	11-03-13	5	21.7									