The occurrence and habitat use of common dolphins (*Delphinus* sp.) in the central Bay of Plenty, New Zealand

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Abstract

This thesis investigated the occurrence and habitat use of common dolphins (*Delphinus* sp.) inhabiting the central Bay of Plenty (BOP), North Island, New Zealand. Although common dolphins are the most prevalent species of dolphin found off the east coast of the North Island of New Zealand, there has been no long term empirical investigation of the species in the central BOP area. Behaviour of common dolphins in the presence of the observation platform was also assessed to investigate habitat use. Additionally, data describing other cetacean species occurring within this region are presented in order to place into context the importance of these waters for *Delphinus*. Sightings data were collected between March 1998 and May 2011 during 2364 boat-based surveys on board platform of opportunity, tourism vessel *Gemini Galaxsea* (a 60 ft ketch sailboat). Variables examined included location, group size, composition, water depth, time of day, seasonality, behaviour and the presence of associated species.

Common dolphins were encountered during 54% (n = 1265) of surveys, in water depths ranging from 5.0 to 197.0 m. *Delphinus* sightings primarily occurred in the area between Motiti Island, Mayor Island and Waihi on the mainland. Group size ranged from one to 500+ individuals and was significantly affected by the time of day, month and depth of sightings. The most frequently recorded group size involved 50 to 100 animals, with larger aggregations more frequent during the warmer austral months when nutrient upwelling leads to increased prey availability in coastal waters off the BOP. Groups containing immature animals accounted for 16% of total sightings and occurred throughout the year, although neonate calves were only reported during the warmer austral summer months, supporting the concept of reproductive seasonality in this population. Common dolphin groups sighted within the central BOP were reported in association with five marine mammal species and 14 avian species, most frequently with various species of petrel (Procellariiformes) and the Australasian gannet (*Morus serrator*). The year round occurrence of common dolphins within central BOP waters indicates that this region maybe important for *Delphinus*.

Behavioural data were collected from 162 independent dolphin groups. Overall, forage, social and travel accounted for the majority of recorded behavioural states, while mill and rest were less frequent. Behaviour was influenced by water depth, with foraging dolphins encountered in the deepest waters. Behaviour also varied significantly according to group size, with

foraging occurring more often than expected in large groups and resting, socialising and milling occurring more often in smaller groups. The presence of immature animals also had a significant influence on common dolphin behaviour, with foraging occurring more often than expected in groups containing immature animals. The presence of associated species varied according to behaviour, with the majority of foraging groups occurring in the presence of Australasian gannets. Seasonal and diurnal peaks in behaviour were not evident. Social behaviours primarily occurred during summer when large nursery groups were also reported in the central BOP.

In order to place into context the use of central BOP waters for *Delphinus*, an investigation of other cetacean species using these waters was undertaken; eleven cetacean species (6 Mysticeti and 5 Delphinidae) were identified as utilising central BOP waters. Sightings primarily occurred in the area between Karewa Island, Mayor Island (Tuhua) and Motiti Island in the central BOP. The majority of delphinid sightings occurred in spring and involved the bottlenose dolphin, *Tursiops truncatus* (50.5%) and killer whale, *Orcinus orca* (42.9%). Pilot, *Globicephala* spp. (3.8%) and false killer whale, *Pseudorca crassidens* (2.9%) sightings were less frequent. Group sizes ranged from solitary to 200+ individuals. Calf presence was recorded for bottlenose dolphins during summer and autumn and killer whales during spring and autumn. Pilot and false killer whale calves were not recorded during the study period. The majority of baleen whale sightings occurred during winter and spring and involved minke, *Balaenoptera acutorostrata/bonaerensis* (44.3%), blue, *B. musculus* (19.0%) and Bryde's whales, *B. edeni* (16.5%). Humpback, *Megaptera novaeangliae* (10.1%), sei, *B. borealis* (8.9%) and southern right whale, *Eubalaena australis* (1.3%) sightings were less frequent. Group sizes ranged from solitary to four individuals, with results highly skewed towards solitary animals (79%). Cow-calf pairs were observed during spring for all baleen whales except sei and humpback. Cetaceans were primarily observed in association with the Australasian gannet as well as various species of petrel and shearwater (*Puffinus* spp.). Bottlenose dolphins and false killer whales were sighted together in mixed species groups. Bryde's whales were also sighted in association with common dolphins.

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1.1 Taxonomy

Since the first description of the common dolphin (*Delphinus delphis* – Linnaeus, 1758), the taxonomy of the species has been disputed by numerous sources. At present, two species are generally accepted: a long-beaked (*D. capensis*) and a short-beaked form (*D. delphis*) (Heyning & Perrin, 1994). However, the taxonomy is controversial (e.g. Natoli *et al.,* 2006) and a revision of the genus is required (Amaral *et al.,* 2009). Specific status for these two forms was based largely on the morphological and genetic analysis of two sympatric populations occurring along the coast of California, USA (Heyning & Perrin, 1994). Recent mitochondrial DNA analysis has revealed that South Australian and New Zealand *Delphinus* are most similar to the short-beaked form (Bilgmann, 2007; Stockin, 2008; Amaral *et al.,* 2012). However, pigmentation patterns of New Zealand *Delphinus* revealed similarities with both *D. delphis* and *D. capensis* (Stockin & Visser, 2005). Consequently, common dolphins identified within the present study are defined as *Delphinus* sp. hereafter.

1.2 Range and distribution

Common dolphins are widely distributed in all oceans, from temperate to tropical waters and show high mobility across their habitat, ranging from inshore waters to thousands of kilometres offshore (Sezler & Payne, 1988; Jefferson *et al.,* 1993; Evans, 1994; Perrin, 2002, Natoli *et al.,* 2006). Due to taxonomic uncertainty within the species, *Delphinus* distribution is somewhat confused. *D. delphis* are known to occur over continental shelf and pelagic waters of the Atlantic and Pacific Oceans (Figure 1.2a) (Reeves *et al.,* 2002); whereas, *D. capensis* seem to inhabit warmer shallower waters and generally occur closer to the coast than *D. delphis* (Figure 1.2b) (Perrin, 2002). The seasonal distribution of common dolphins varies worldwide, with some areas reporting transient populations (e.g. Californian coast, Forney & Barlow, 1998; North Atlantic Ocean, Mirimin *et al.,* 2009), while others are described as resident (e.g. Eastern Ionian Sea, Bearzi *et al.,* 2008).

The distribution, abundance, and foraging success of top trophic level predators such as cetaceans may be determined by large-scale oceanographic patterns and their effects on prey distribution and abundance (Smith *et al.,* 1986; Tynan, 1999; Forney, 2000). Physical features such as sea surface temperature (SST) (Gaskin, 1968; Neumann, 2001a; Benson *et al.,* 2002) and sea surface salinity (Sezler & Payne, 1988) may vary on a seasonal (Barber & Smith, 1981) or interannual level (e.g. El Niño; Barber & Chavez, 1983; Neumann, 2001a;

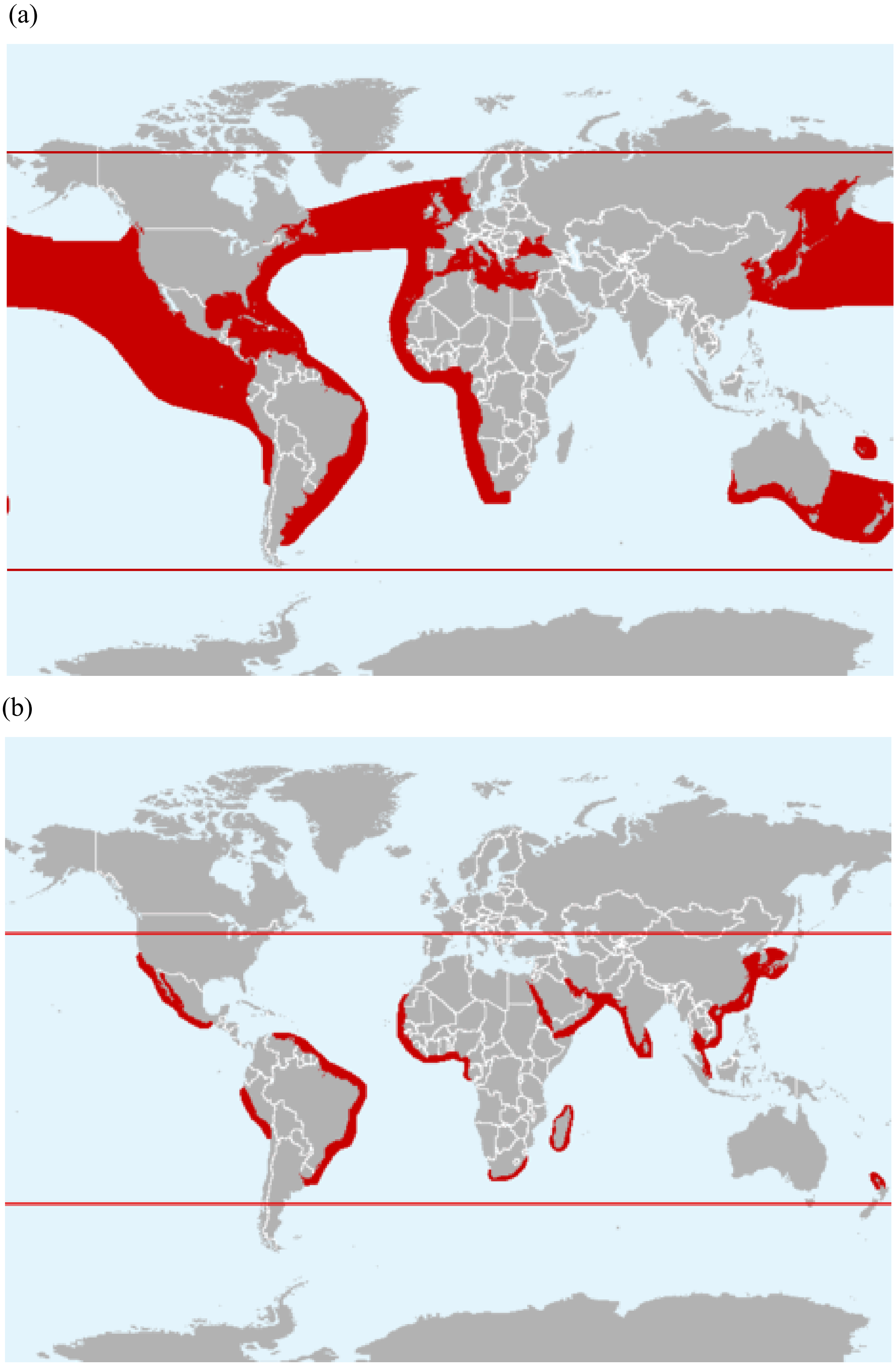

Figure 1.2: Approximate global distribution of (a) the short-beaked (*D. delphis*) and (b) the long-beaked common dolphin (*D. capensis*) (Source: Hammond *et al.,* 2008).

Benson *et al.,* 2002). In areas of high sea floor relief such variations bring changes in nutrient upwelling and zooplankton biomass (Blackburn *et al.,* 1970; Au and Perryman, 1985; Jefferson *et al.,* 2009), consequently altering prey availability (Blackburn *et al.,* 1970; Cockcroft & Peddemors, 1990; Neumann, 2001a).

There is limited information available on the distribution of *Delphinus* in the south Pacific region. Current information is mainly restricted to stranding (Kemper *et al.,* 2005; Ross, 2006) and incidental capture records (Bilgmann *et al.,* 2008; Hamer *et al.,* 2008). There are however, a small number of reports available on the distribution of free-ranging common dolphins in Australian (Filby *et al.,* 2010) and New Zealand waters (e.g. Hoek & Cleverly, 1996; Constantine & Baker, 1997; Würsig *et al*., 1997; Neumann, 2001a; Neumann *et al.,* 2002; Stockin *et al.,* 2008a; Meissner & Stockin, 2011; Gaborit-Haverkort & Stockin, in press). The only report available from Australian waters is from Gulf St. Vincent, South Australia (Filby *et al.,* 2010). The authors reported that the majority of common dolphin groups occurred in water depths ranging from 35 to 40 m and in areas 21 to 31 km from land (Filby *et al.,* 2010). In New Zealand, *Delphinus* appear to be largely confined north of the Subtropical Convergence and to a minimum surface temperature of approximately 14°c (Gaskin, 1968). The distribution of common dolphins in New Zealand waters has been reported on a regional level in the Bay of Islands (Constantine & Baker, 1997), Hauraki Gulf (Stockin *et al*., 2008a), Bay of Plenty (Hoek & Cleverly, 1996; Neumann, 2001a; Neumann *et al*., 2002; Gaborit-Haverkort & Stockin, in press), Gisborne (Clement, 2009; Gaborit-Haverkort & Stockin, in press), Cook Strait (Stockin & Orams, 2009), and Kaikoura (Markowitz, 2004) (Figure 1.3).

Gaborit-Haverkort and Stockin (in press) reported year round sightings of common dolphins within Bay of Plenty waters (Figure 1.3), although sightings were generally more prevalent in summer and autumn. Tour operators based in Tauranga (Figure 1.3) reported an 80 to 90% success rate of locating dolphins in summer and autumn and a 10 to 40% success rate in winter and spring (Gaborit-Haverkort & Stockin, in press). Stockin *et al.* (2008a) also reported a year round presence of common dolphins within the Hauraki Gulf (Figure 1.3), where dolphins were observed in SST ranging from 14.8 °C in the austral winter to 21.2 °C in the austral summer. Common dolphins were typically found in smaller groups (< 30 animals), with larger aggregations most frequent during the austral winter when nutrient upwelling typically leads to increased prey availability within the region (Stockin *et al.,* 2008a).

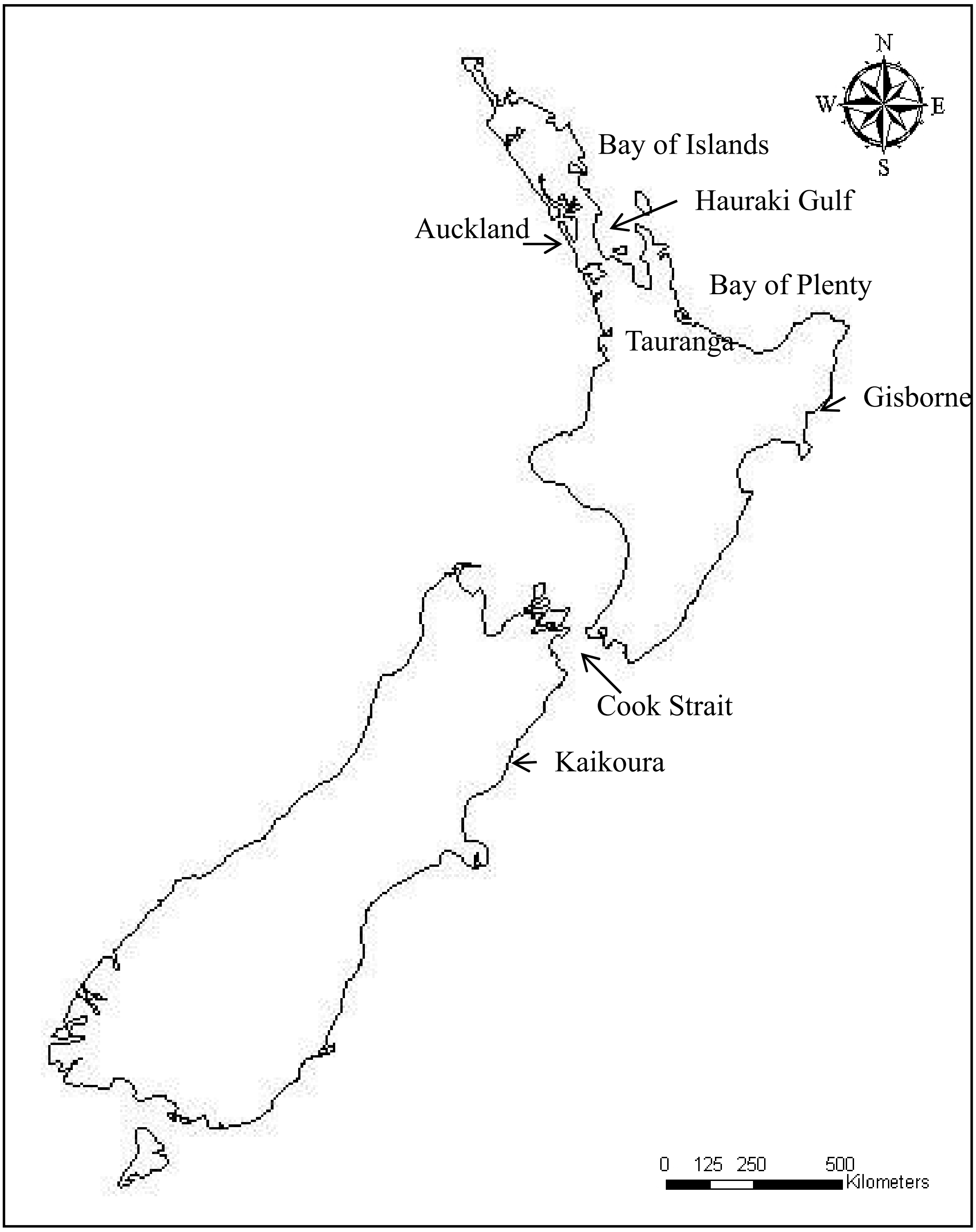

Figure 1.3: Location of areas with published information on common dolphin occurence in New Zealand waters.

Constantine and Baker (1997) also found a correlation between common dolphin distribution and SST in the Bay of Islands (Figure 1.3), where dolphins were found in shallow water during the austral winter, and in deeper waters in summer outside the Bay. Conversely, within the western Bay of Plenty Neumann (2001a) reported an offshore movement in the austral autumn and winter and an inshore movement in spring and summer. A similar movement pattern was reported by Goold (1998) in the Irish Sea, where common dolphins also moved further offshore in autumn as SST dropped. *Delphinus* in tropical regions may not display such seasonal variations in distribution. For example in the eastern tropical Pacific (ETP) Reilly (1990) reported that common dolphins did not vary in their occurrence or distribution on a seasonal basis, due to the upwelling-modified habitats, which they occupied year round, this indicates that physical factors such as SST only influence the distribution of *Delphinus* on a secondary level, with prey availability being the primary motivating factor.

1.3 Abundance

Common dolphins are the most frequently observed marine mammal species throughout the world's oceans (Gaskin, 1992). When prey is abundant, *Delphinus* populations may stay in stay in large schools that can reach thousands of individuals. When prey are scattered, however, they often separate into smaller social units of about 30 individuals (Evans, 1994; Bearzi *et al.,* 2003). There are a few regional abundance estimates available for the species (primarily from the northern hemisphere, Table 1.1); however, there are no succinct global estimates available. The only density estimate available for the south west Pacific region is an estimate of 1,957 individuals within the Gulf St. Vincent, South Australia (Filby *et al.,* 2010, Table 1.1).

In New Zealand, *Delphinus* are the most frequently sighted marine mammal species off the east coast of the North Island, from the Bay of Islands (Constantine & Baker, 1997), Hauraki Gulf (Stockin *et al*., 2008a), Bay of Plenty (Hoek & Cleverly, 1996; Neumann, 2001a; Neumann *et al*., 2002; Gaborit-Haverkort & Stockin, in press; Meissner & Stockin, 2011) to Gisborne District waters (Clement, 2009; Gaborit-Haverkort & Stockin, in press). However, there are no abundance estimates available for New Zealand common dolphins; although a population analysis is underway for Hauraki Gulf (Rankmore, unpubl. data) and Bay of Plenty (Meissner, unpubl. data) waters using photo-identification catalogues (Stockin & Orams, 2009; Dwyer & Stockin, 2010; Meissner & Stockin, 2011). This lack of information emphasizes the importance of this thesis and other studies underway within New Zealand waters.

Table 1.1: Regional abundance estimates available for common dolphins (*Delphinus* spp.).

Species	**Location**	**Population estimate**	**Source**
Delphinus sp.	Eastern Tropical Pacific	3,127,203	Gerrodette *et al.,* 2008
Delphinus sp.	Black Sea	50,000 96,000	Yukhov *et al.,* 1986; Sokolov *et al.,* 1997
D. delphis	South western Mediterranean	19,428	Cañadas & Hammond, 2008
D. delphis	Western north Atlantic	121,000	Waring *et al.,* 2006
D. delphis	European continental shelf waters	63,400	Hammond *et al.,* 2006
D. delphis	Eastern north Atlantic	75,450	Hammond *et al.,* 2002
D. delphis	Gulf St. Vincent, South Australia	1,957	Filby *et al.,* 2010
D. delphis	Gulf of Corinth, Greece	28	Bearzi *et al.,* 2011
D. capensis	Californian coast, USA	22,000 69,000	Barlow & Forney, 2007; Gerrodette & Palacios, 1996
D. capensis	Western Mexican coast	55,000	Gerrodette & Palacios, 1996
D. capensis	South Africa	15,000 20,000	Cockroft & Peddemors, 1990

1.4 Reproduction

It is generally accepted that the length of gestation in odontocetes (toothed whales, dolphins and porpoises) tends to increase with the size of the animal (Whitehead & Mann, 2000), ranging from 16 months for the sperm whale (*Physeter macrocephalus*) to nine months for the harbour porpoise (*Phocoena phocoena*) (Marino, 1997). Common dolphin gestation periods range from nine (Asdell, 1964) to 11.5 months (Murphy, 2004; Westgate, 2005) (Table 1.2). The time interval between each birth is strongly influenced by gestational time and duration of lactation (Whitehead & Mann, 2000). Common dolphin calving intervals range from 1.3 to 2.6 years (Perrin & Reilly, 1984; Westgate, 2005, respectively) (Table 1.2).

Seasonal peaks in births have been observed in the majority of *Delphinus* populations worldwide. The primary reasons for this seasonal variability are prey availability, energy demands and SST (Whitehead & Mann, 2000). In temperate regions of the northern hemisphere seasonal peaks in births have been reported by numerous sources (Table 1.2), with calving peaking during the spring and summer months (between May and September) (Table 1.2). In the Eastern Tropical Pacific, calves are present year round (Danil & Chivers, 2007), which may be attributed to a lack of seasonal changes in SST. Data on the reproductive seasonality of common dolphins in the southern hemisphere are available from South African and New Zealand waters (Table 1.2). Mendolia (1989) reported seasonal peaks in births between September and October (austral spring) off the south east coast of South Africa. Stockin *et al.* (2008a) reported a year round presence of *Delphinus* calves within the Hauraki Gulf, New Zealand. However, there was a relatively high occurrence of neonates during December and January (austral summer), which supports the concept of reproductive seasonality in this population. Similar results were reported for common dolphin populations in the western and central Bay of Plenty (Neumann 2001a; Gaborit-Haverkort & Stockin, in press, respectively).

Table 1.2: Regional life history information available for common dolphin (*Delphinus* sp.).

Location	**Seasonal peaks in births**	**Gestation period (months)**	**Calving intervals (years)**	**Source**
France	May to June	Unknown	Unknown	Collet, 1981
Great Britain	May to August	Unknown	Unknown	Sabin *et al.,* 2002
Ireland	May to August	11.5	Unknown	Murphy & Rogan, 2006
Northwest Spain	July to August	Unknown	Unknown	López *et al.,* 2002
Black Sea	June to August	10 to 11	1.3	Tomilin, 1957; Perrin & Reilly, 1984
Northeast Atlantic	May to September	11.5	1.7	Murphy, 2004
Northwest Atlantic	July to August	11.5	2.6	Westgate, 2005; Westgate & Read, 2007
Eastern Tropical Pacific	Year-round	11.4	2.1	Danil & Chivers, 2007
Central North Pacific	Unknown	11.1	Unknown	Ferrero & Walker, 1995

South Africa	September to October	10 to 11	2	Mendolia, 1989
New Zealand	December to January	Unknown	Unknown	Webb, 1973; Bräger & Schneider, 1998; Neumann, 2001a; Schaffar-Delaney, 2004; Stockin *et al.,* 2008a; Gaborit-Haverkort & Stockin, in press

1.5 Behavioural ecology

Common dolphins are highly gregarious animals with groups generally composed of dozens to hundreds of individuals (Neumann, 2001a,b,c; Bearzi *et al.,* 2003; Jefferson *et al.,* 2007; Stockin *et al.,* 2008b; Gaborit-Haverkort & Stockin, in press). Despite the fact that it is one of the most widely distributed cetaceans, information on *Delphinus* behaviour is limited to a few studies and has mostly relied on direct observations (e.g. Neumann, 2001c; Neumann *et al.,* 2002; Bruno *et al.,* 2004; Stockin *et al.,* 2008b*,* 2009a) or genetic analysis of stranded and by-caught dolphins (e.g. Viricel *et al.,* 2008). *Delphinus* appear to have a fluid fission-fusion social structure (Bruno *et al.,* 2004), with some evidence for segregation in age and sex classes (Neumann *et al.,* 2002; Perrin 2009). However, there is evidence that kinship relationships are unlikely to be of importance (Viricel *et al.,* 2008). It has been suggested that this flexibility may enable the animals to adapt to environmental shifts and fluctuating prey availability (Bruno *et al.,* 2004).

Common dolphin behaviour within New Zealand waters was initially described by Constantine and Baker (1997) during a brief tourism impact assessment (primarily focused on bottlenose dolphins, *Tursiops truncatus*) conducted in the Bay of Islands. The most frequently recorded behavioural state was foraging (40%), followed by travelling (31%), milling (12%), resting (9%) and socialising (7%). The first comprehensive activity budget for free-ranging common dolphins within New Zealand waters was reported by Neumann (2001c). *Delphinus* in the north western Bay of Plenty spent 56% of their time travelling, 20% milling, 16% foraging, 7% socialising, and 1% resting (Neumann, 2001c). No seasonal or inter-annual variation was detected (Neumann, 2001c). In comparison, common dolphins in the Hauraki Gulf spent 47% of their time foraging, 29% travelling, 10% milling, 8%

resting and 7% socialising (Stockin *et al.,* 2009a). Behaviour varied seasonally, with the highest proportion of foraging and resting groups observed during the austral spring and autumn, respectively (Stockin *et al.,* 2009a). The higher proportion of time spent foraging by dolphins in the Hauraki Gulf could be attributed to prey species being more concentrated within the productive gulf waters, whereas, prey in Bay of Plenty waters are likely to be more patchy (Neumann, 2001c).

1.6 Diet

Common dolphins are abundant in both neritic (continental shelf, depth < 200 m) and oceanic habitats (>2000 m depth); which differ in terms of the nature of available prey species (Pusineri *et al.,* 2007). Consequently, common dolphins appear to feed opportunistically, their diet reflecting local prey abundance and availability (Young & Cockroft, 1994). The diet of *D. delphis* has been documented in neritic areas from stomach content analysis of stranded or by-caught animals (e.g. Young & Cockroft, 1994; Meynier, 2004; Santos *et al.,* 2004), with the bulk of the diet consisting of a combination of small pelagic schooling fish. In comparison, the diet of *D. delphis* in oceanic areas is less well known: *D. delphis* are thought to target small, mesopelagic fish in the surface layer during dusk and early night (Pusineri *et al.*, 2007). Neumann and Orams (2003) used underwater video footage to identify species taken by New Zealand *Delphinus* during foraging bouts, resulting in the identification of six potential prey species: jack mackerel (*Trachurus* sp.), kahawai (*Arripis trutta*), yellow-eyed mullet (*Aldrichetta forsteri*), flying fish (*Cypselurus lineatus*), parore (*Girella tricuspidata*), and garfish (*Hyporamphus ihi*). Meynier *et al.* (2008) reported that the most prevalent prey species for *Delphinus* stranded or by-caught in New Zealand waters included: arrow squid (*Nototodarus* sp.), jack mackerel and anchovy (*Engrauliis australis*). Both stranded and by-caught dolphins had fed on combination of neritic and oceanic prey species, suggesting an inshore/offshore movement of common dolphins on a diel basis within New Zealand waters (Meynier *et al.,* 2008; Stockin, 2008).

1.7 Platforms of Opportunity

Assessing distributions of highly mobile, wide ranging marine mammals presents a challenge to marine ecologists (Hauser *et al.,* 2006). Platforms of opportunity, such as whale watch vessels, have provided researchers with the opportunity to assess cetacean occurrence (e.g. Darling *et al.,* 1998; Weinrich *et al.,* 2000; Neumann, 2001a; Lusseau & Slooten, 2002;

Kiszka *et al.,* 2007; Stockin *et al.,* 2008a; Martinez *et al.,* 2010; Wiseman *et al.,* 2011; Gaborit-Haverkort & Stockin, in press), behaviour (e.g. Neumann, 2001c; Lusseau, 2003; Stockin *et al.,* 2008b,2009a; Martinez *et al.,* 2011; Meissner, unpubl. data) foraging strategies (e.g. Neumann & Orams, 2003; Burgess, 2006; Zaeschmar *et al.,* in press) and mother-offspring relationships (e.g. De la Brosse, 2010), without expensive survey effort. However, caution must be applied when using data collected from platforms of opportunity, with no control over where the vessel goes it is typically not possible to sample wide areas, thus limiting the quality of data collected (Evans & Hammond, 2004).

1.8 Anthropogenic effects

1.8.1 Fisheries interactions

Common dolphins are one of the most prominent species bycaught in pelagic purse-seine (Simmons, 1968; IATTC, 2006), driftnet (Julian & Beeson, 1998; Zerbini & Kotas, 1998; Tudela *et al*., 2004; Carretta *et al*. 2005) and trawl fisheries (Northridge, 2006). In the Eastern Tropical Pacific, the annual incidental mortality of *Delphinus* in the tuna (*Thunnus* sp.) purse-seine fishery has been as high as 24307 (in 1986) (IATTC, 2006). In South Australia, an estimated 1728 dolphins were encircled and 377 died in the purse-seine fishery during the 2004/2005 season (Hamer *et al.,* 2008). Common dolphins are also known to be bycaught in gillnet fisheries (Carretta *et al.,* 2005). In the western North Atlantic, 105 common dolphins are taken on average each year by sink gillnets and bottom trawls (Waring *et al*., 2006).

New Zealand's commercial trawl net fisheries can pose a serious threat to marine mammals (Duignan *et al.,* 2003; Boren *et al.,* 2006; Chilvers, 2008; Stockin & Orams, 2009). Between 1998 and 2008, 115 common dolphins were reported as incidental bycatch within commercial fisheries (Stockin & Orams, 2009; Stockin *et al.,* 2009b). Observer effort within the jack mackerel JMA fishery ranged from five to 40% during this period. Of the confirmed bycatch reported, 86% (*n* = 99) occurred within the commercial trawl fishery for jack mackerel (JMA), which includes the following species *T. declivis, T. murphyi* and *T. novaezelandiae* (Stockin & Orams, 2009). The remaining 14% of common dolphins were incidentally captured by vessels targeting hoki (*Macruronus novaezelandiae*), skipjack tuna (*Katsuwonus pelamis*), barracouta (*Thyrsites atun*), snapper (*Pagrus auratus*) and trevally (*Pseudocaranx dentex*) (Stockin & Orams, 2009). Additionally, there are confirmed reports of New Zealand *Delphinus* being incidentally killed within coastal set nets (Stockin *et al.,* 2009b).

There are also cases of purposeful targeting of *Delphinus* for meat (Romero *et al.,* 2001; Birkun, 2006). From 1946 – 1983 at least 840,000 dolphins were taken from the Black Sea until a ban of small cetacean hunting was declared in Turkey (Birkun, 2006). Large direct kills have also occurred around Margarita Island, off eastern Venezuela (Romero *et al*., 2001).

Prey depletion caused by overfishing may also pose a serious threat to common dolphin populations. For example, prey depletion was considered the main cause for the decline of *D. delphis* in the Mediterranean (Bearzi *et al*. 2006) and Black Sea (Bushuyev, 2000; Birkun, 2006). Jack mackerel, anchovy and squid are important prey species for common dolphins in New Zealand waters (Meynier *et al*., 2008) and their protection is vital for the conservation of these animals. Anchovy are not a commercially targeted species in New Zealand waters; however, unknown levels of bycatch occur in the pilchard (*Sardinops neopilchardus*) fishery (MFish, 2011a). Arrow squid are primarily fished from the waters surrounding the Auckland Islands and the South Island of New Zealand (MFish, 2011b). There are no estimates of the sustainable yield of arrow squid in New Zealand waters (MFish, 2011b). On the east coast of the North Island 10,000 tonnes of jack mackerel are taken by commercial trawlers each year, the majority of which occurs in BOP waters (MFish, 2011c). It is not known whether the current jack mackerel catch levels are sustainable in the long-term (MFish, 2011c). There is a concern that reducing anchovy, arrow squid and jack mackerel populations could disrupt marine food chains as they are a prey item for many marine mammal species as well as other fish species. There is a general lack of basic biological information for these species and no species specific management plans set in place.

1.8.2 Pollution

Environmental pollutants are increasingly implicated (both directly and indirectly) with the onset of infectious disease and related mortality incidents in marine mammals (De Guise *et al.,* 1994; Kuiken *et al.,* 1994; Busbee *et al.,* 1999; Jepson *et al.,* 2005). The release of chemicals into the marine environment and the subsequent bio-accumulation up the food chain may pose a serious threat to marine mammals inhabiting contaminated areas (Busbee *et al.,* 1999). It is widely acknowledged that dolphins living in near-shore waters close to agricultural and industrial activity tend to accumulate higher concentrations of toxins (O'Shea, 1999). The current conception for oceanic cetaceans such as common dolphins is that wider habitat usage places them at lower risk from inshore activities. However, as highlighted by Stockin *et al.* (2007), polychlorobiphenyl (PCB) concentrations for New Zealand *Delphinus* span a similar range to those reported for Hector's dolphins (*Cephalorhynchus hectori*) (Stockin *et al.,* 2007). This may reflect high usage of coastal waters by New Zealand common dolphins, thus highlighting the potential vulnerability of this species to coastal anthropogenic effects.

The Bay of Plenty comprises Tauranga, one of the fastest growing cities in New Zealand. Tauranga harbour is a large (*ca* 200 km^2) tidal estuary, with numerous rivers feeding into it. These rivers flow through farmland, where pesticide and fertilizer runoff frequently occurs (Parshotam *et al.,* 2009), and urban areas, where storm drains also have an impact on water quality (Paul & Meyer*,* 2008). Burggraaf *et al.* (1994) reported higher levels of PCBs and dichlorodiphenyl trichloroethane (DDT) in sediments from two stormwater drains which flow into Tauranga harbour. Increased concentrations of environmentally persistent resin acids such as dehydroabietic acid (DHAA) have also been found in sediments below storm water outlets from the log handling area at the Port of Tauranga (Tian *et al.,* 1997). Assessing the full impact of Persistent Organic Pollutants (POPs) on cetaceans within Bay of Plenty waters, therefore, requires further research.

Tauranga Port is the busiest in New Zealand (Port of Tauranga, 2012), with dozens of container ships arriving each week. These large vessels (160 – 320 m long) pose a threat to the marine environment in terms of the amount of fuel and dangerous goods (e.g. chemical fertilisers) carried on board. In October 2011, a container ship (*Rena*) grounded on Astrolabe Reef, 3 nm north of Motiti Island, resulting in over 350 tonnes of heavy fuel oil being spilled into the surrounding ocean. The pollutants released following oil spills have been implicated with cetacean mortalities (Loughlin, 1994; Matkin *et al.,* 2008; Williams *et al.,* 2011) as well as long term health effects including reproductive failure (e.g. Neff, 1990; Engelhart, 1983; Geraci, 1990; Baines *et al.,* 1997; Gilbert, 1998; Busbee *et al.,* 1999; Schwacke *et al.,* 2002; Fossi & Marsili, 2003; Borrell & Aguilar, 2005; Wells *et al.,* 2005; Pierce *et al.,* 2008). These hydrocarbons have considerable environmental persistence (e.g. Blumer & Sass, 1972) and do bio-accumulate up the food chain (Baines *et al.,* 1997), consequently, any marine mammals inhabiting affected areas are under serious threat.

Another potential risk associated with the grounding of the *Rena* is the ingestion of plastic debris including resin pellets and bags, as well as foam from refrigerated container linings. The ingestion of plastics by marine mammals may result in: wounds (internal and external), suppurating skin lesions and ulcerating sores; blockage of digestive tract, leading to death; reduction in quality of life and reproductive capacity; drowning and limited predator avoidance; impairment of feeding capacity (e.g. Gregory, 1978; Mato *et al.,* 2001; Derraik, 2002; Laist 1997, 2006). Despite there being no reported mortalities of cetaceans directly related to the *Rena*, historic evidence suggests that only 2% of cetacean carcasses may be recovered following an oil spill (e.g. Williams *et al.,* 2011), therefore, the long term impacts of the *Rena* on marine mammal occurrence and reproductive success in the Bay of Plenty region will need to be assessed and this thesis may help provide a baseline for future research.

1.8.3 Tourism

Cetacean-watching, an industry based upon taking tourists to watch, swim and interact with dolphins and whales in the wild has expanded rapidly over the past few decades (Hoyt, 1995, 2001; O'Connor *et al.,* 2009). It is now a large and geographically dispersed activity, which occurs in 119 countries and territories worldwide (O'Connor *et al.,* 2009). A number of studies have been undertaken to investigate potential effects associated with both dolphin-watching and/or swim-with dolphin activities (e.g. Leitenberger, 2001; Erbe, 2002; Lusseau, 2003; Constantine *et al.*, 2004; Bejder *et al.*, 2006a,b; Neumann & Orams, 2006; Williams *et al.,* 2006; Dans *et al.,* 2008; Stockin *et al.,* 2008b; Lusseau *et al.,* 2009; Markowitz *et al.,* 2009; Christiansen *et al.,* 2010; Martinez *et al.,* 2011; Visser *et al.,* 2010). It has been suggested that due to commercial cetacean-watching vessels spending extended periods of time with target species, they have a greater potential to disturb species of interest than general vessel traffic (e.g. recreational vessels). During an impact assessment in the Hauraki Gulf, New Zealand, common dolphin foraging and resting bouts were significantly disrupted by boat interactions to a level that raised concern about the sustainability of this activity (Stockin *et al.,* 2008b). Furthermore, foraging dolphins took significantly longer to return to their initial behavioural state in the presence of the tour boat (Stockin *et al.,* 2008b). Impacts identified in Stockin *et al.* (2008b) were similar to those also reported for Hector's dolphin (Martinez, 2010) and bottlenose dolphin (e.g. Lusseau, 2003; Constantine *et al.,* 2004), two coastal species which are typically considered to be more susceptible to cumulative anthropogenic effects within New Zealand waters.

Common dolphins are the focus of eight commercial tour operators within the Bay of Plenty Conservancy (Gaborit-Haverkort & Stockin, in press). A specific study is, therefore, currently being undertaken by Massey University to assess the effects of such ventures on *Delphinus* behaviour within Bay of Plenty waters (Meissner & Stockin, 2011). Tour boats are widely used as Platforms of Opportunity (PoO) by marine mammal researchers (Constantine *et al.*, 2004; Bejder *et al.*, 2006a,b; Neumann & Orams, 2006; Williams *et al.,* 2006; Dans *et al.,* 2008; Stockin *et al.,* 2008b; Lusseau *et al.,* 2009; Markowitz *et al.,* 2009; Christiansen *et al.,* 2010; Martinez *et al.,* 2011). Data collected on board the the longest running (1998 to 2012) commercial tour operation within the Bay of Plenty region (*Butlers swim-with dolphins*) forms the basis of this thesis.

1.9 Conservation status

At present *D. delphis* are listed globally as a species of *least concern* by the International Union for the Conservation of Nature (IUCN) due to global abundance; despite some threats to local populations (Hammond *et al.,* 2008). *D. capensis* are listed as *data deficient* due to a lack of global abundance data (Hammond *et al.,* 2008). In New Zealand, there is vast paucity in our knowledge of *Delphinus*, with basic data required for management (e.g. abundance, life history, taxonomy) still absent for this population. Currently, Baker *et al.* (2010) list common dolphins as *not threatened* within New Zealand waters due to a lack of evidence showing a population decline. However, there is no population estimate available for this species on which to base this assumption. Consequently, a classification as *data deficient* would appear more appropriate (Stockin & Orams, 2009).

1.10 Current Management

Common dolphins are listed in Appendix II of the Convention of International Trade of Endangered Species (CITES), with the Mediterranean population listed in Appendices I and II of the Convention on Migratory Species (CMS). Common dolphins, as with other species impacted by the eastern Tropical Pacific tuna purse-seine fishery, are managed both nationally by the coastal countries and internationally by the Inter American Tropical Tuna

Commission (IATTC). The IATTC has imposed annual stock mortality limits on each purse seiner and has promulgated regulations regarding the safe release of dolphins (Bayliff, 2001). In the eastern North Pacific, the American drift gillnet fishery has been required to use acoustic warning devices since 1996 to reduce cetacean bycatch; however, some bycatch of *D. delphis* has continued (Carretta *et al*. 2005).

Site protection, compliance and awareness plans are being enforced on regional and national levels in many countries; although, there is a general lack of species specific management plans for common dolphins (Hammond *et al.,* 2008). In New Zealand, the Department of Conservation (DOC) is charged under the Marine Mammals Protection Act (MMPA, 1978) to provide for the protection, conservation and management of marine mammals within New Zealand waters. However, despite the commonality and year round occurrence of common dolphins in New Zealand waters, they remain the only resident cetacean to lack species specific management objectives (Suisted & Neale 2004).

1.11 Thesis outline

Although common dolphins are the most prevalent species of dolphin found off the east coast of the North Island of New Zealand (Gaskin 1968; Neumann, 2001a; Stockin & Orams, 2009; Gaborit-Haverkort & Stockin, in press), there has been no long term empirical investigation of the species in the central Bay of Plenty (BOP) area (Figure 1.3). Butlers swim with dolphin (www.swimwithdolphins.co.nz) skippers have been recording common dolphin sightings with central Bay of Plenty waters since 1998. Additionally, four years of data (2008-2011) were collected by the author of this thesis. This dataset represents the longest record of *Delphinus* in the area, and provides a unique opportunity to examine the effects of abiotic factors on common dolphin long-term occurrence patterns and to explore how these patterns change over time. The data collection process has been largely standardized from 2000 onwards, allowing researchers access to a large dataset that would be difficult to build and maintain without tour operator support. Analyses of these sightings data will offer valuable information about the occurrence and habitat use of common dolphins and other cetacean species found in the central BOP. These data are crucial to determine important management areas.

1.12 Thesis aims

The specific aim of this study was to investigate the occurrence and habitat use of common dolphins (*Delphinus* sp.) inhabiting the central Bay of Plenty (BOP), North Island, New Zealand. In order to investigate habitat use, the behaviour of common dolphins in the presence of the observation platform was assessed. Additionally, data describing other cetacean species occurring within this region are presented in order to place into context the importance of these waters for *Delphinus*. This thesis includes an introductory chapter (Chapter One) followed by three research chapters (Chapters Two to Four) and a general discussion chapter (Chapter Five). A publication format is used for the three research chapters, detailed as follows:

Chapter One: Introduces the present study and gives an overview of relevant literature.

Chapter Two: Examines the occurrence and group dynamics of *Delphinus* in the central BOP, New Zealand. Habitat use is examined in relation to environmental parameters, group dynamics and the presence of associated species.

Chapter Three: Examines the influence of environmental parameters, group dynamics and associated species on common dolphin behaviour in the presence of the observation platform in the central BOP, New Zealand.

Chapter Four: Identifies all other cetacean species observed from the same PoO within the central BOP, New Zealand, so as to provide comparison and context to the *Delphinus* data presented within the other data chapters. Species are further examined in relation to group dynamics and environmental parameters.

Chapter Five: Concludes by synthesising the present findings of each research chapter from a conservation and management perspective.

Chapter Two: Occurrence and group dynamics of common dolphins in the central Bay of Plenty

Figure 2.1: Common dolphin mother and calf sighted in the central Bay of Plenty (BOP), New Zealand (Photo: Hayden Butler).

2.1 Abstract

Common dolphins (*Delphinus* sp.) occur year round in central Bay of Plenty (BOP) waters, North Island, New Zealand. This chapter investigates the occurrence and group dynamics of common dolphins in the region in relation to temporal trends, water depth and associated species. Common dolphin occurrence is discussed in relation to prey availability, predation, competition and reproduction. Sightings data were collected between March 1998 and May 2011 during 2364 boat-based surveys on board tourism vessel *Gemini Galaxsea.* Common dolphins were encountered during 54% (n = 1265) of these surveys, in water depths ranging from 5.0 to 197.0 m. *Delphinus* sightings primarily occurred in the area between Motiti Island, Mayor Island and Waihi on the mainland, which is likely attributed to the operational limits of the tour vessel. Group size ranged from one to 500+ individuals and was significantly affected by the time of day, month and depth of sightings. The most frequently recorded group size involved 50 to 100 animals, with larger aggregations more frequent during the warmer months when nutrient upwelling leads to increased prey availability in coastal waters of the BOP. Groups containing immature animals accounted for 16% (n = 201) of total sightings and occurred throughout the year, although neonates were only reported during the warmer austral summer months, supporting the concept of reproductive seasonality in this population. Common dolphin groups sighted within the central BOP were reported in association with five marine mammal species and 14 avian species, most frequently with various species of petrel (Procellariiformes) and the Australasian gannet (*Morus serrator*). The year round occurrence of common dolphins in the central BOP indicates that this region provides habitat for the species.

2.2 Introduction

The distribution and abundance of cetaceans may be influenced by large-scale oceanographic patterns (Smith *et al.,* 1986; Tynan, 1999; Forney, 2000). However, biotic factors such as prey availability (Blackburn *et al.,* 1970; Cockcroft & Peddemors, 1990; Neumann, 2001a), predation (Corkeron & Connor, 1999; Heithaus & Dill, 2006; MacLeod *et al.,* 2007) and competition (Clapham & Brownell, 1996; Spitz *et al.,* 2006) are considered to be the primary motivating factors in cetacean distribution. There is evidence that common dolphins (*Delphins* sp.) in New Zealand waters move inshore during the main reproductive season (Bräger & Schneider, 1998; Neumann, 2001a; Stockin *et al.,* 2008a). However, it is not known whether seasonal inshore movements are attributed to reproductive requirements or seasonal changes in prey availability, both factors are likely to play a role in common dolphin distribution.

Common dolphins are widely distributed in all oceans, from temperate to tropical waters and show high mobility across their habitat, ranging from inshore waters to thousands of kilometres offshore (Selzer & Payne, 1988; Jefferson *et al.,* 1993; Evans, 1994; Perrin, 2002, Natoli *et al.,* 2006). Despite being the most frequently observed marine mammal species throughout the world's oceans (Gaskin, 1992); there is a distinct lack of abundance estimates for common dolphins on both a regional and global scale. Common dolphins in New Zealand waters are particularly prevalent off the east coast of the North Island, from the Bay of Islands (Constantine & Baker, 1997), Hauraki Gulf (Stockin *et al*., 2008a), Bay of Plenty (Hoek & Cleverly, 1996; Neumann, 2001a; Neumann *et al*., 2002; Meissner & Stockin, 2011; Gaborit-Haverkort & Stockin, in press) to Gisborne District waters (Clement, 2009; Gaborit-Haverkort & Stockin, in press) and appear to be largely confined north of the subtropical convergence and to a minimum surface temperature of approx 14°c (Gaskin, 1968). There are no abundance estimates available for New Zealand common dolphins; although a population analysis is underway for Hauraki Gulf and Bay of Plenty waters using photo-identification catalogues (Stockin & Orams, 2009; Dwyer & Stockin, 2010; Meissner & Stockin, 2011). This lack of information emphasizes the importance of this thesis and other studies underway within New Zealand waters. Despite the commonality and year round occurrence of common dolphins in New Zealand waters, they remain the only resident cetacean to lack species specific management objectives (Suisted & Neale 2004).

This chapter provides a preliminary insight into the occurrence and group dynamics of common dolphins in the central BOP in relation to temporal trends, water depth and associated species. Habitat use is discussed for the region in relation to prey availability, predation, competition and reproduction.

2.3 Methods

2.3.1 Study site

The BOP (Figure 2.2) is situated on the east coast of the North Island of New Zealand extending from Waihi east to Lottin Point near Cape Runaway (latitude 37°25' to 37°33' S; longitude 175°55' to 178°10' E; Figure 2.2). Water depths in the BOP can exceed 1000 m (within Tauranga and White Island trenches); however, within the operational area covered during this study (Figure 2.2) the water depth does not exceed 600 m. The continental shelf (max depth 100 m) extends up to 20 miles off shore in the central BOP, providing shallow waters for nursing/breeding dolphins. The main feature dominating offshore waters is the warm East Auckland Current (EAUC), which flows from east to west through the BOP (Heath, 1980; Ridgeway & Greig, 1986). Consequently, offshore waters can be up to 3°C warmer than inshore waters, where upwelling of colder nutrient-rich water occurs (Chang *et al.,* 1996; Neumann, 2001a; Park & Longdill, 2006; Longdill *et al.,* 2008). The BOP provides foraging habitat for common dolphins, with peaks in the abundance of prey species such as anchovy (*Engraulis australis*) and arrow squid (*Nototodarus* sp.) in coastal waters during warmer months (Ayling & Cox, 1982; MFish, 2011a, b), and jack mackerel (*Trachurus* sp.) in offshore waters of the BOP during between June and November (MFish, 2011c). Common dolphins have also been observed foraging on kahawai (*Arripis trutta*), yellow-eyed mullet (*Aldrichetta forsteri*), flying fish (*Cypselurus lineatus*), parore (*Girella tricuspidata*), and garfish, (*Hyporamphus ihi*) within the region (Neumann & Orams, 2003).

2.3.2 Data collection

Observations were conducted between March 1998 and May 2011, from a Platform of Opportunity (PoO), cetacean-watching vessel, *Gemini Galaxsea* (a 60 ft ketch sailboat; Figure 2.3). Tours were weather dependent (< 5 beaufort sea state), departed at 0830 h, from Tauranga harbour (37°40’ S, 176°10’ E) and departing between the northern permit limits and Motiti Island (rarely venturing further east) (Figure 2.2). The survey speed varied between 5 to 8 kts and the direction taken differed daily depending on sea conditions.

Data were collected by experienced observers using both naked eye and binoculars (Steiner Commander 7 x 50). Dolphin groups were detected using sighting cues such as the splashing and/or silhouettes of porpoising animals, water disturbance, sightings of dorsal fins and the presence of key indicator species (mainly the Australasian gannet) (Stockin *et al.,* 2008b).

Once within 400 m of a group of dolphins, the vessel would reduce speed (< 5 kts) on approach. As soon as the vessel engaged with dolphins (i.e. the dolphins were on the bow), the start time and location for the encounter were recorded using a Global Positioning System (GPS). During this time the presence/absence of immature animals and associated species, water depth (m) and an estimate of group size (± approximate number) were recorded. Only the presence of associated species was recorded, with no attempt made to quantify the number of, or exact nature of each association from *Gemini Galaxsea*. Any subsequent movement of the group was not recorded.

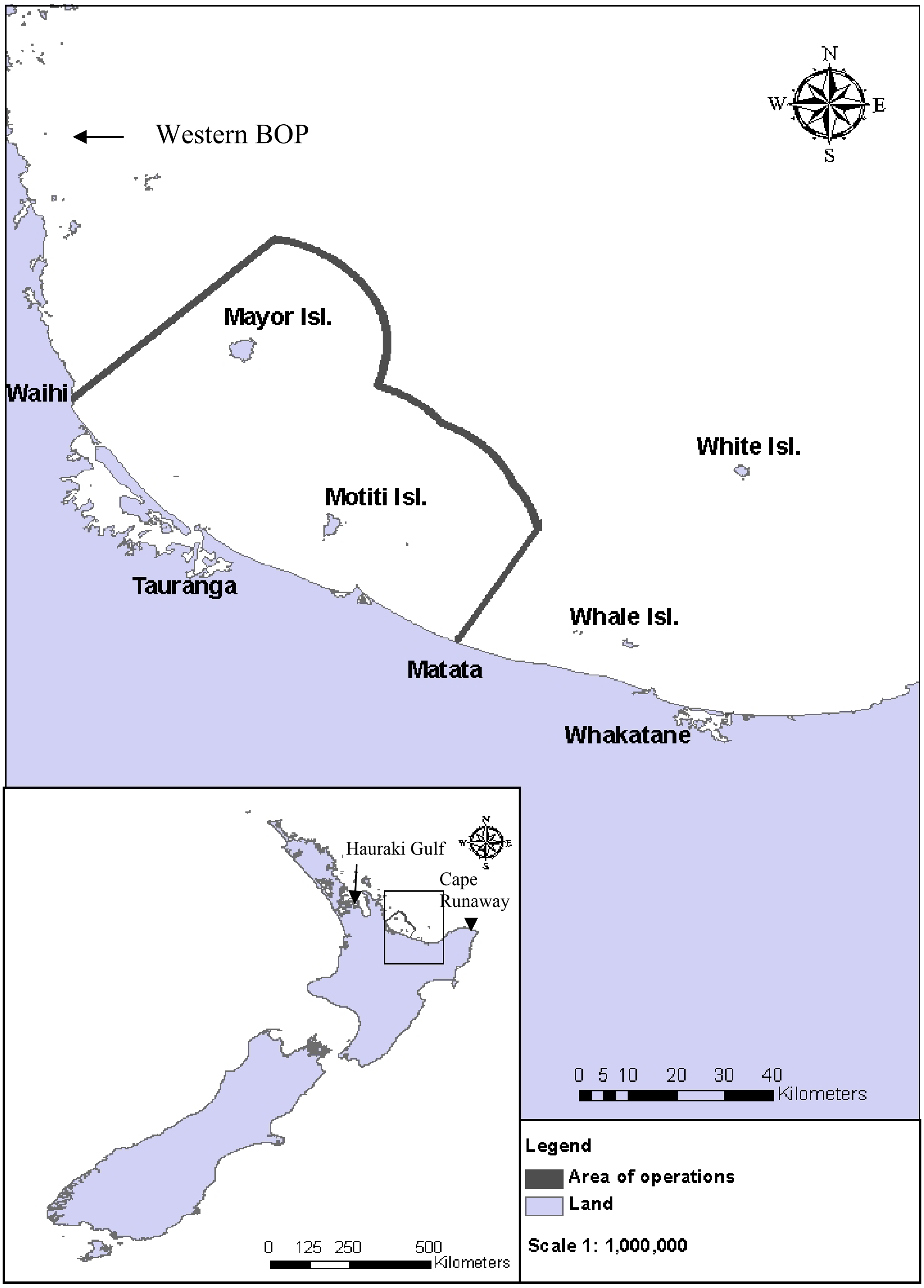

Figure 2.2: Daily operational range of *Gemini Galxsea* in the central Bay of Plenty (BOP), New Zealand.

Figure 2.3: Cetacean-watching vessel, *Gemini Galaxsea,* off the coast of Mount Maunganui, central Bay of Plenty (BOP), New Zealand (Photo: Kim Westerskov).

2.3.3 Data analysis

Common dolphin sightings were analysed in relation to time of day, month, season, field year and water depth as well as the presence/absence of associated species. Group size and composition were also examined in relation to temporal and environmental factors.

As per Martinez *et al.* (2010), the Trip Encounter Rate (TER) was calculated as the total number of sightings per total number of surveys (trips) conducted. Group size categories were adopted from Stockin *et al.* (2008a), in order to perform direct comparisons with previous common dolphin research conducted in the Hauraki Gulf, New Zealand. Group size was categorised at two resolutions: a) fine scale: 1-10, 11-20, 21-30, 31-50, 51-100, 101-200 and 200 + animals; and b) broad scale: ≤ 50 or > 50 animals.

As per Stockin *et al.* (2008a), diel patterns were investigated by assigning each observation to a two-hour time period within the sequence 0800-0959 through to >1600 h. Seasonal analyses were based on the austral seasons as follows: spring (September to November), summer (December to February), autumn (March to May) and winter (June to August). Field years ran from January to December, resulting in 14 consecutive field years from 1998 to 2011.

Depth was provided to 0.1 m accuracy for readings up to 100 m, thereafter (due to a technical issue with the depth sounder) depths beyond 100m were recorded from marine charts using the GPS position and recorded to obtain an approximate (1-2 m accuracy) depth reading. The subsequent water depths were then analysed as raw data.

Group composition was analysed at two resolutions based on the age classes present, as per Stockin *et al.* (2008a). Initially, immature animals were classified as neonates, calves or juveniles. Neonates were defined as small calves with dorsal-ventral foetal folds; calves were approximately less than one half the length of the mother and were consistently observed swimming in the infant position (Fertl, 1994); juveniles were approximately two-thirds the size of an adult. The current dataset was somewhat limited in terms of separating age classes, especially during the earlier years of data collection. As the majority of immature animals were recorded as calves, analyses were primarily performed on a broad scale with adult only *vs* groups with immature animals (neonates, calves and juveniles combined).

Associated species were primarily recorded in order to identify which sea birds may be indicators of common dolphin presence (G. Butler, pers. comm.). However, associated marine mammal species were also recorded. Associated species and species sighted on the same day as common dolphins, but not in direct association were analysed in order to identify which other species may be competing with or predating on common dolphins in the central BOP region.

Data described herein were compared to previous reports on common dolphins from the Hauraki Gulf (Stockin *et al.,* 2008b; Martinez *et al.,* 2010), western Bay of Plenty (Neumann, 2001a) and preliminary (November 2010 to April 2011) results from a tourism impact study currently being conducted in the central Bay of Plenty (Meissner & Stockin, 2011).

In order to avoid pseudo-replication, data were cleaned prior to analyses to remove any potential duplicate sightings and sightings recorded in close succession (within an hour) of each other. The distributions of continuous response variables (i.e. depth) were initially tested for normality and homogeneity using Kolmogorov-Smirnov and Levene's tests. In most cases, data were not normally distributed. Consequently, non-parametric Mann-Whitney U and Kruskal-Wallis tests were applied. Pearson χ^2 tests were used to examine categorical variables (group size and composition). Categorical data were combined and a Fisher's Exact test was performed when data did not meet the conditions for Chi-square analyses (i.e. due to small sample size). All statistical analyses were conducted using SPSS. Finally, ArcGIS (Version 9.2; © ESRI Inc.) was used to create distribution maps depicting seasonality.

2.4 Results

2.4.1 Occurrence

Data were collected between March 1998 and May 2011 during 2364 boat-based surveys on board tourism vessel *Gemini Galaxsea.* Common dolphins were encountered during 54% (n = 1265) of these surveys. Effort was greatest in January, summer and 2002 and lowest in June, winter and 1998 (Figures 2.4 to 2.6). The TER was highest in January, summer and 2011 and lowest in September, spring and 1999 (Figures 2.4 to 2.6). The lower number of trips taken in winter (n = 164) compared to the rest of the year may be attributed to a decrease in tourist numbers during the colder months (G. Butler, pers. com.) and not to a lack of common dolphin sightings, as indicated by the TER for winter which is higher than that for spring

(Figure 2.5). Common dolphin sightings did not vary significantly on a diurnal basis (Pearson χ^2: $\chi^2 = 11.654$, df = 6, $p > 0.05$; Figure 2.7).

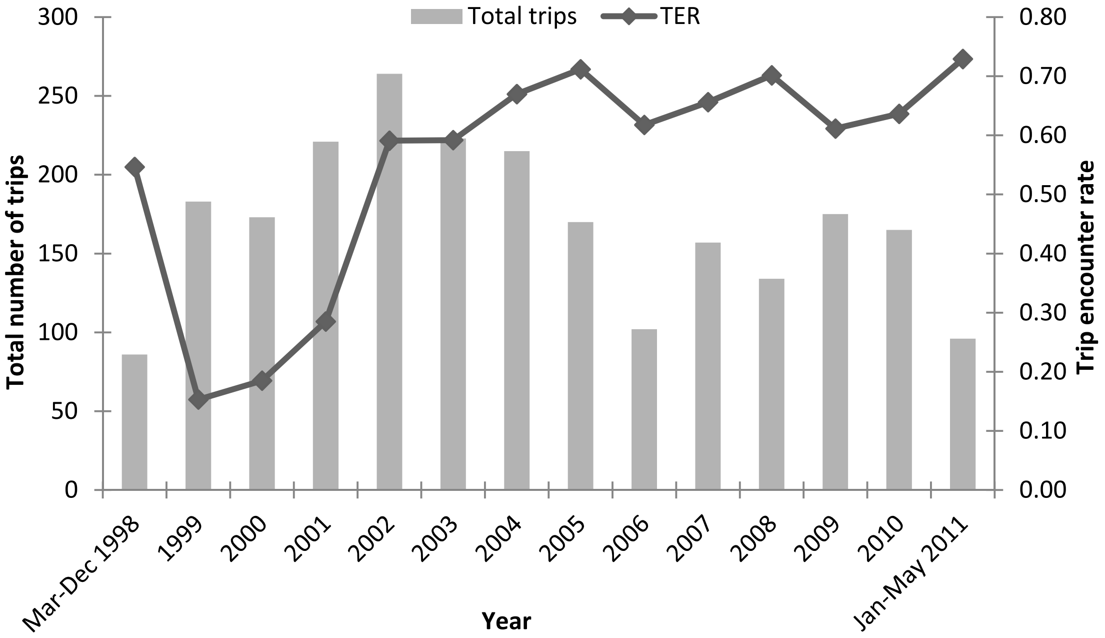

Figure 2.4: Annual Trip Encounter Rate (TER) for common dolphin (*Delphinus* sp.) between March 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand.

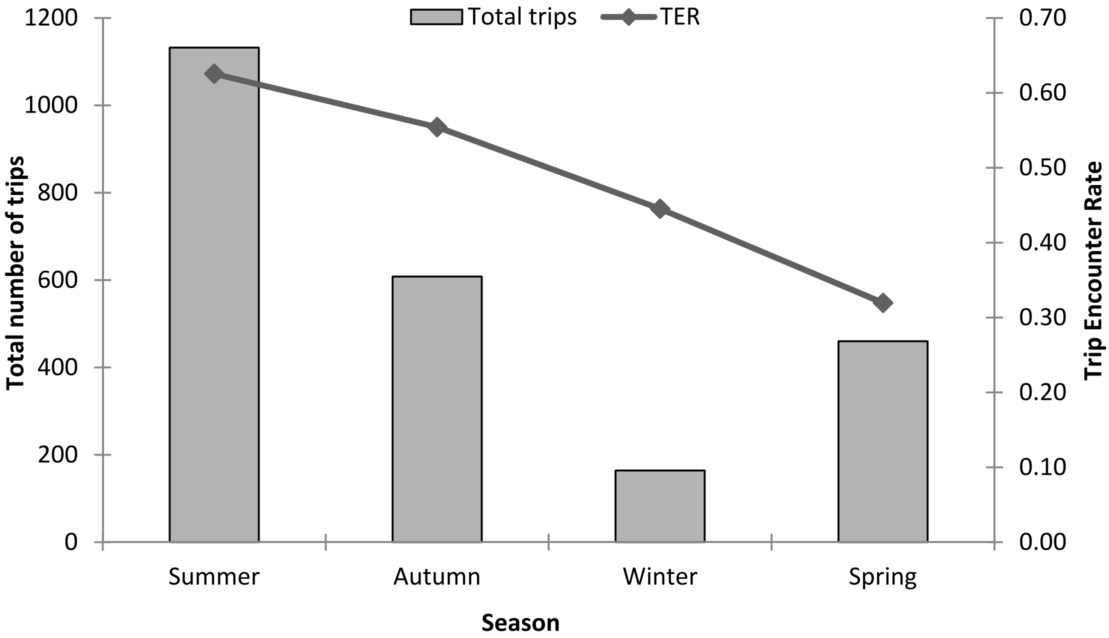

Figure 2.5: Seasonal Trip Encounter Rate (TER) for common dolphin (*Delphinus* sp.) between March 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand.

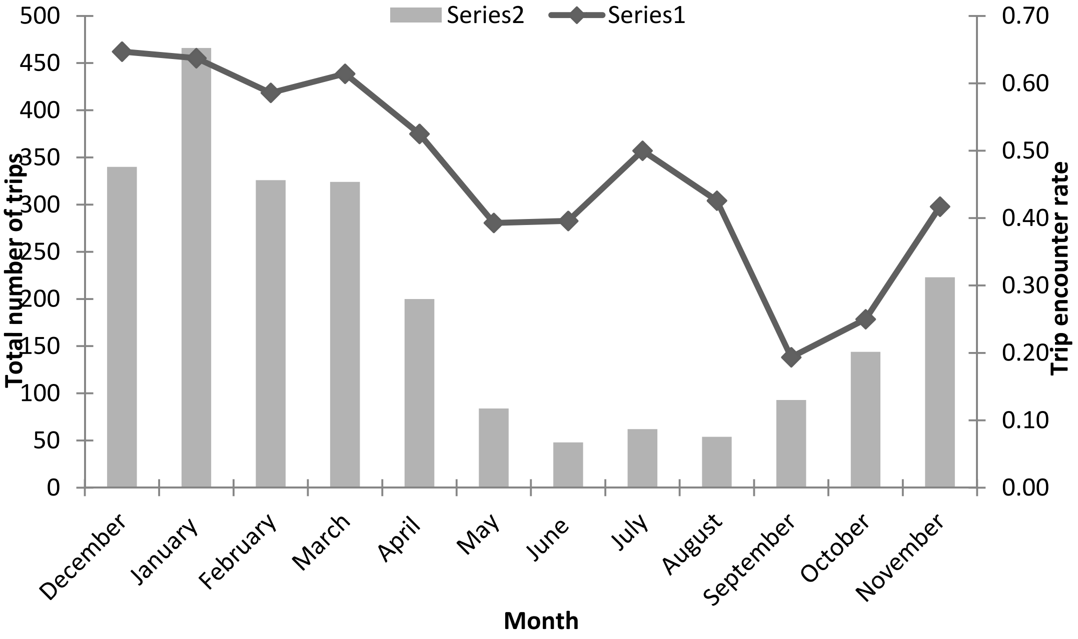

Figure 2.6: Monthly Trip Encounter Rate (TER) for common dolphin (*Delphinus* sp.) between March 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand.

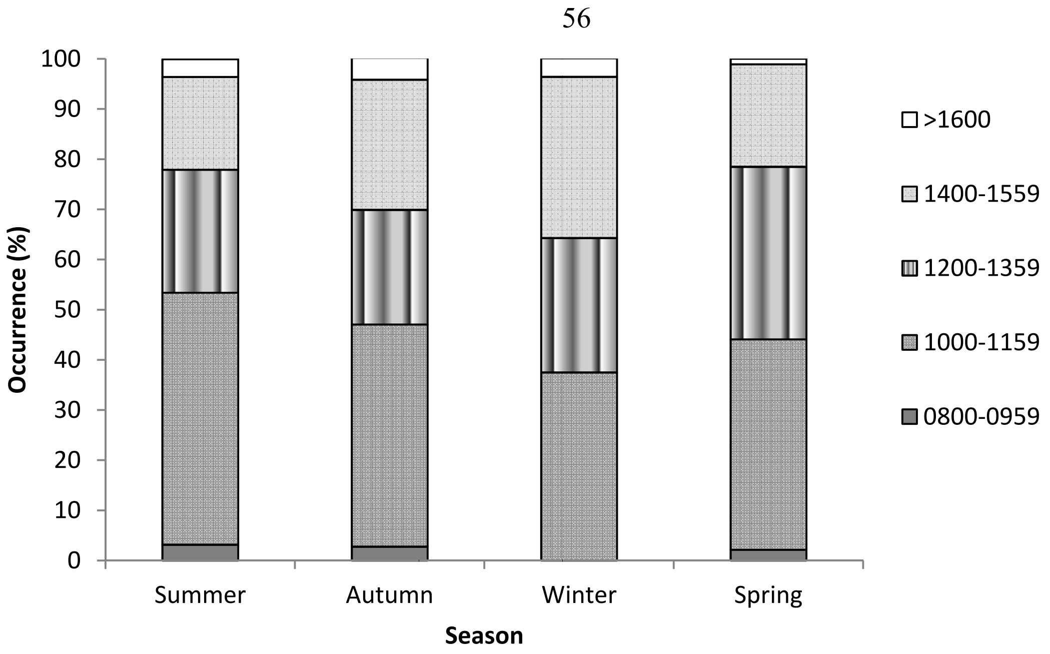

Figure 2.7: Diel occurrence of common dolphin (*Delphinus* sp.) sightings between March 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

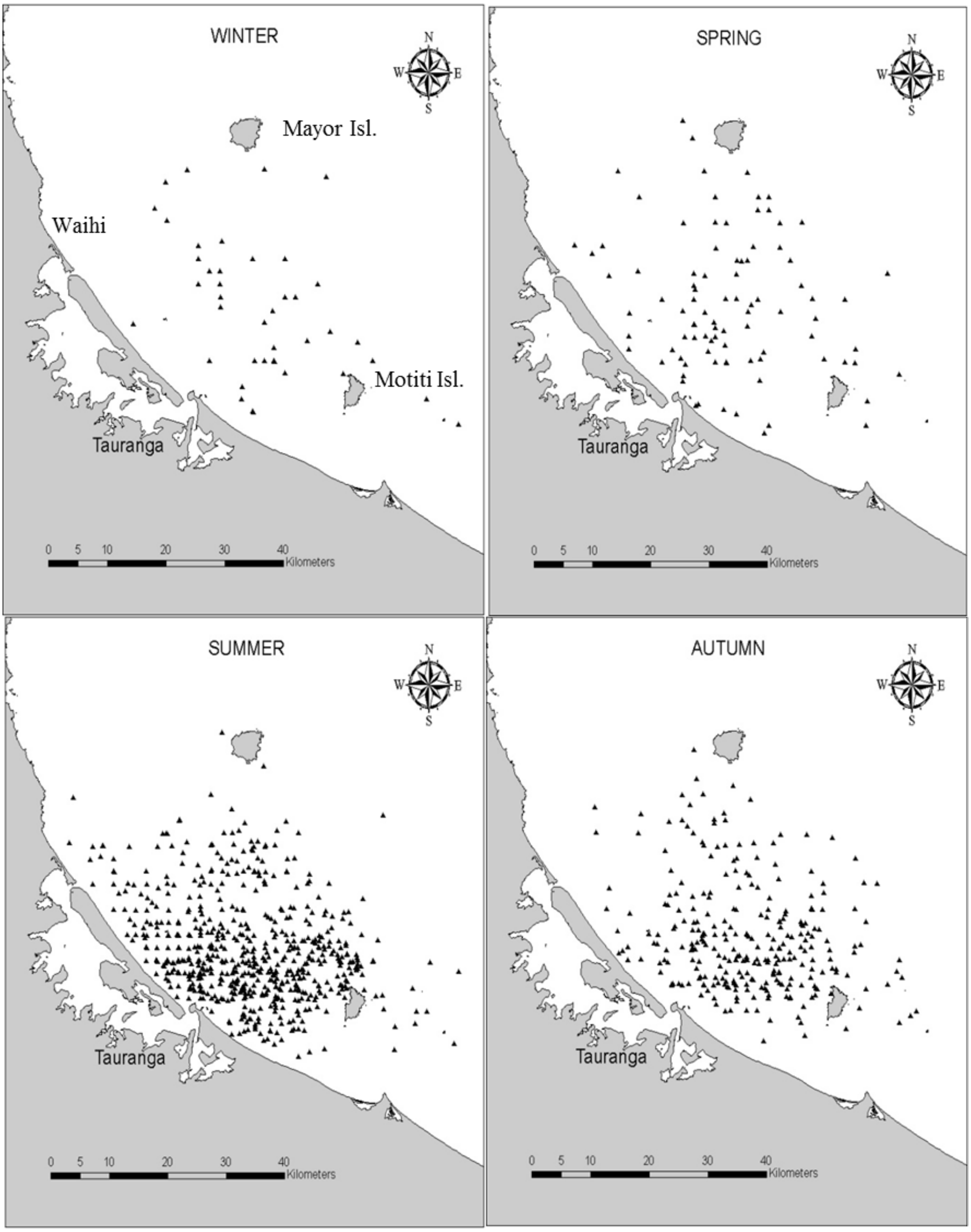

Figure 2.8: Seasonal distribution of common dolphin (*Delphinus* sp.) groups between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand.

Common dolphin sightings primarily occurred in the area between Motiti Island, Mayor Island and Waihi on the mainland (Figure 2.8). Sightings appear to cover the same range throughout all four seasons. However, caution is required in the interpretation of these distributional maps as effort track lines are not available; it is likely that the distribution of common dolphin sightings is directly related to the operational area of the tourism vessel.

2.4.2 Occurrence in relation to depth

Common dolphins were sighted over water depths ranging from 5.0 to 197.0 m (mean = 43.0, SD = 23.2, *n* = 821; Figure 2.9), with the majority of sightings occurring in water depths less than 50 m (Figure 2.9). The median water depth over which dolphins were recorded exhibited significant diel variation (Kruskal-Wallis: *H* = 94.3, df = 4, $p < 0.0001$), with dolphins sighted in the shallowest waters in the morning between 0800 and 0959 (median = 26.0, Interquartile Range (IQR) = 13.0-31.5, *n* = 27) and the deepest waters in the afternoon between 1200 and 1359 h (median = 48.0, IQR = 35.0-60.0, *n* =170; Figure 2.10). The median water depth also varied significantly by month (*H* = 80.6, df = 11, $p < 0.0001$; Figure 2.11) and season (*H* = 51.0, df = 3, $p < 0.0001$), ranging from 49.0 m during the winter months (IQR = 41.0-63.3, *n* = 25) to 36.0 m in summer (IQR = 25.0-47.0, *n* = 518; Figure 2.12).

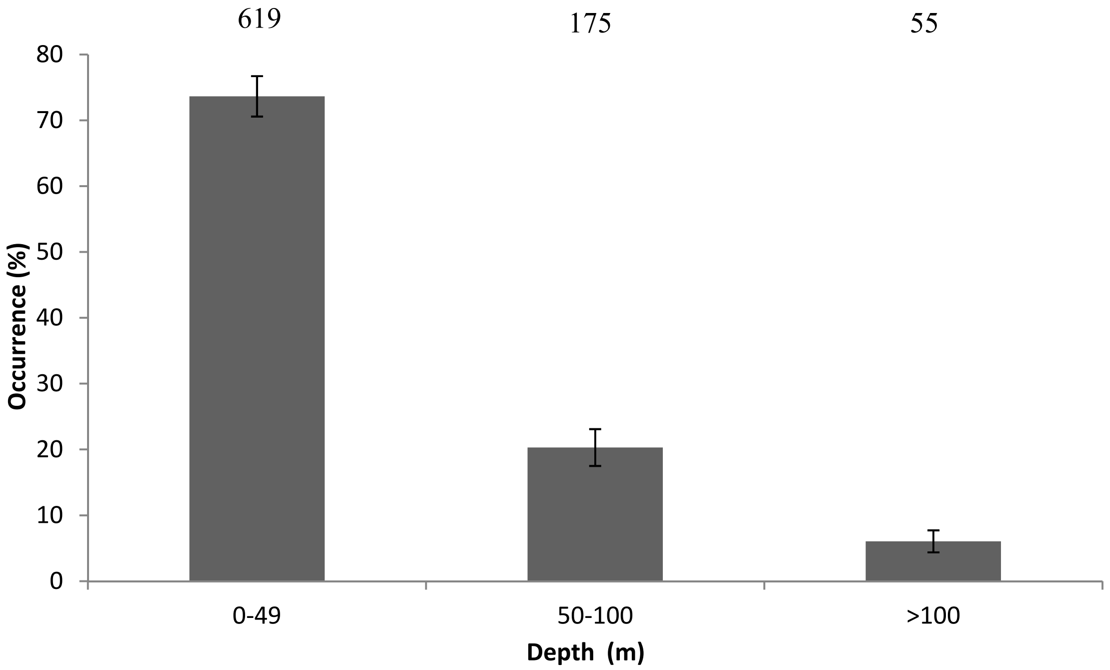

Figure 2.9: Depth of common dolphin (*Delphinus* sp.) sightings (*n* = 849) between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: Bars represent the 95% confidence intervals. Note: numbers above the bars represent the sample number (*n*).

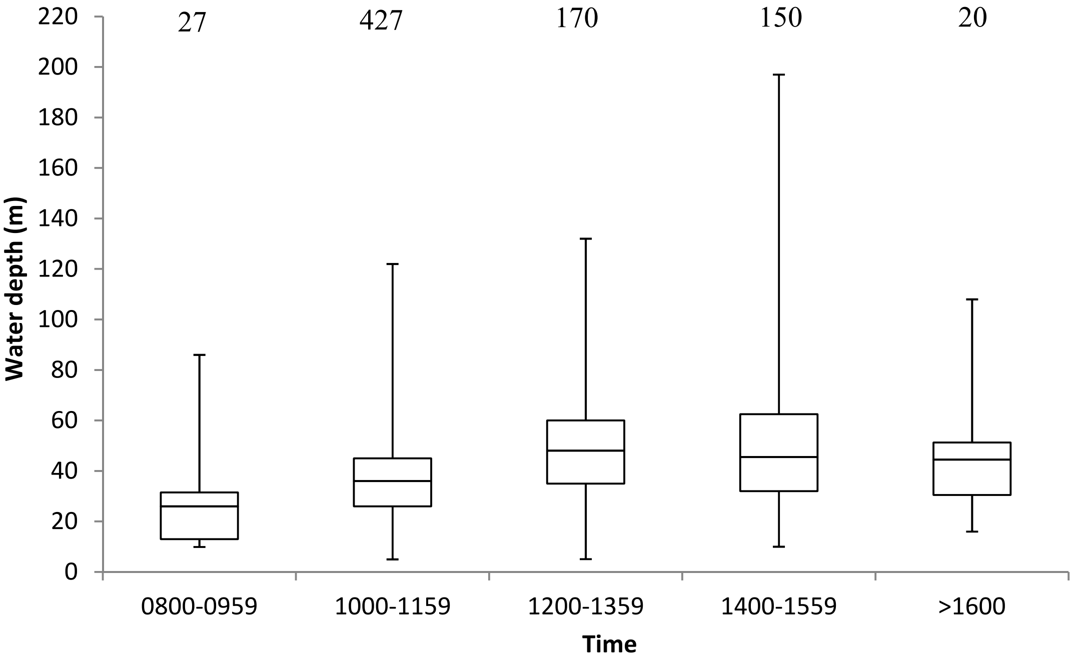

Figure 2.10: Diel water depth for common dolphin (*Delphinus* sp.) sightings between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: Lines represent the median, boxes the 25th and 75th interquartiles and bars the range. Numbers above the boxes represent the sample number (*n*).

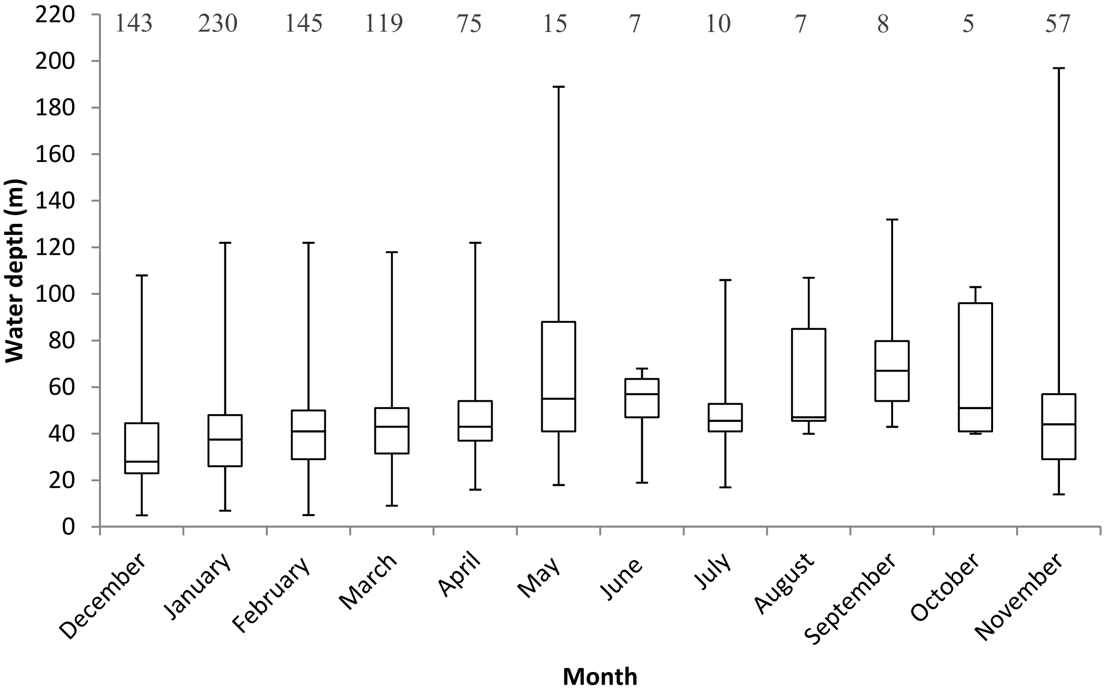

Figure 2.11: Monthly water depth for common dolphin (*Delphinus* sp.) sightings between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: Lines represent the median, boxes the 25th and 75th interquartiles and bars the range. Numbers above boxes represent the sample number (*n*).

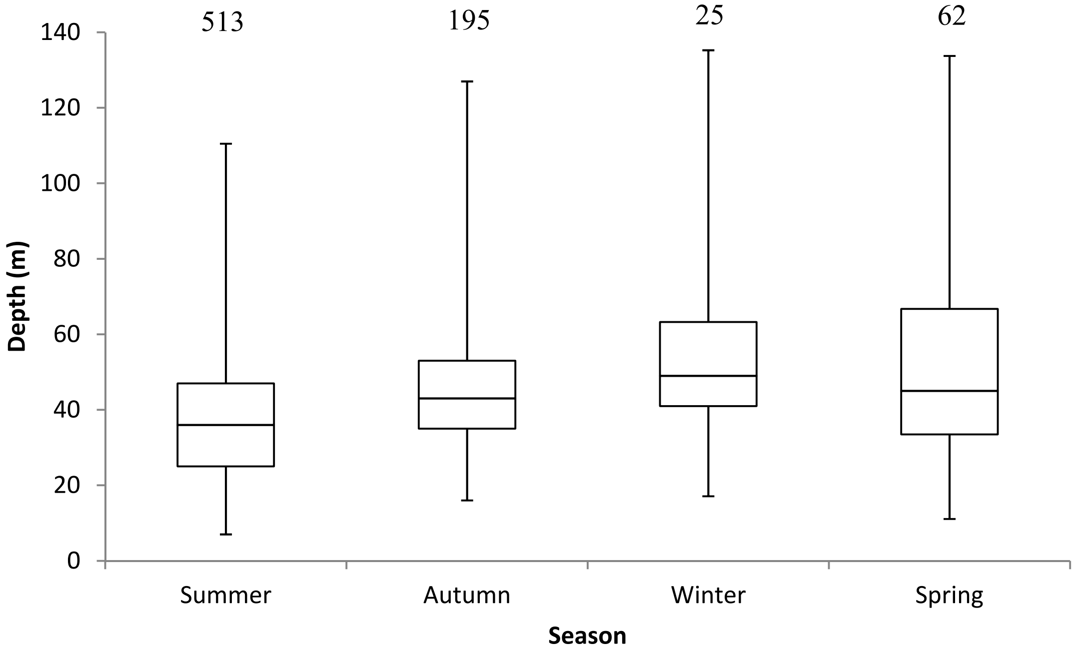

Figure 2.12: Seasonal water depth for common dolphin (*Delphinus* sp.) sightings between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: Lines represent the median, boxes the 25th and 75th interquartiles and bars the range. Numbers above the boxes represent the sample number (*n*).

2.4.3 Group size in relation to abiotic factors

Group sizes ranged from solitary (*n* = 1) to 500+ (*n* = 11) individuals. The most frequently recorded group size involved 51 to 100 animals (21%, *n* = 231), and the least involved one to 10 individuals (12%, *n* = 127; Figure 2.13). Common dolphin sightings were evenly distributed between small and large groups containing less than 50 (49%, *n* = 528) and more than 50 (51%, *n* = 558) individuals, respectively. Groups containing less than 10 individuals were most frequently recorded between 0800 and 0959 h (14%, *n* = 4; Figure 2.14) in October (27%, *n* = 7; Figure 2.15) and during spring (21%, *n* = 25, Figure 2.16). Groups containing 200+ animals were observed most frequently between 1200 and 1359 h (16%, *n* = 39; Figure 2.14), in July (29%, *n* = 7; Figure 2.15) and during spring (25%, *n* = 29; Figure 2.16).

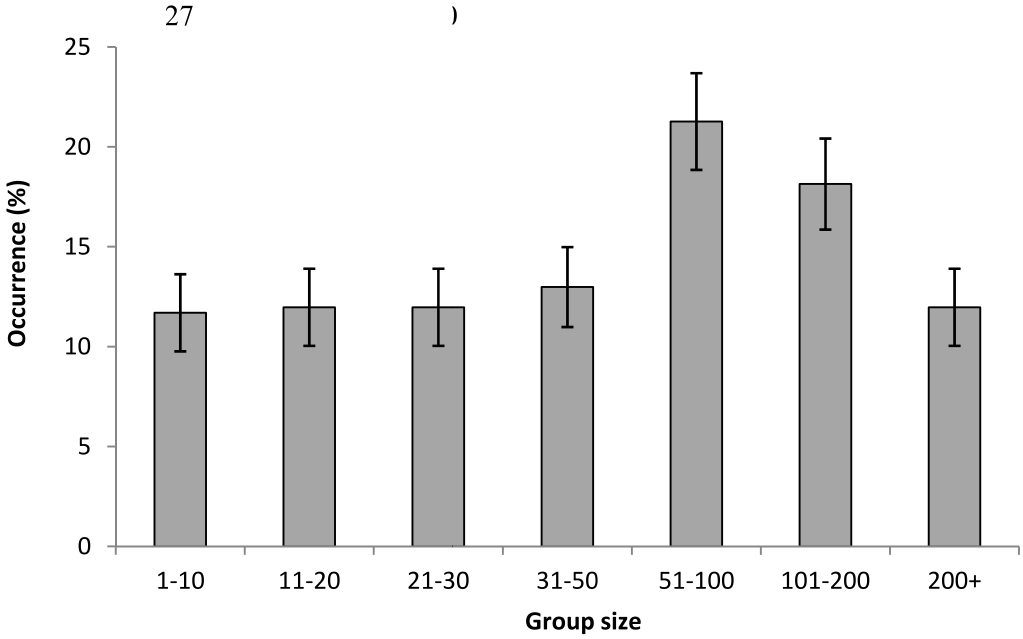

Figure 2.13: Occurrence of common dolphin (*Delphinus* sp.) group size categories observed between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: Bars represent the 95% confidence intervals. Note: numbers above the bars represent the sample number (*n*).

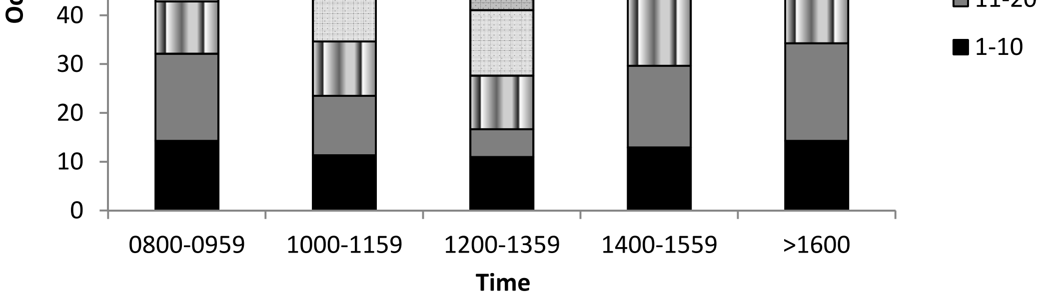

Figure 2.14: Diel occurrence of common dolphin (*Delphinus* sp.) group size observed between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

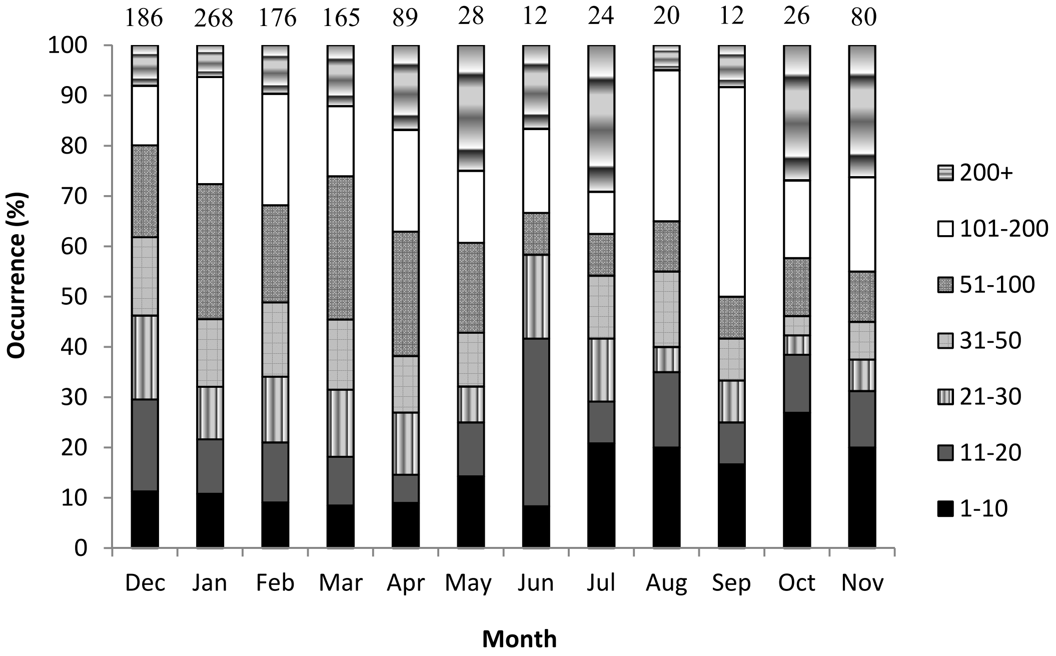

Figure 2.15: Monthly occurrence of common dolphin (*Delphinus* sp.) group size observed between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

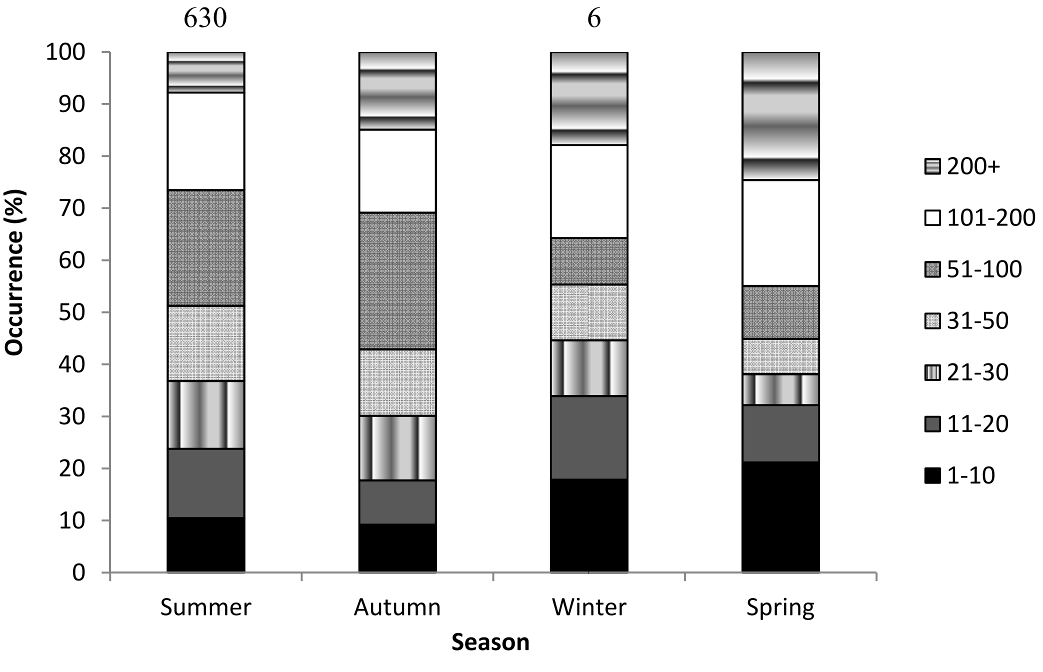

Figure 2.16: Seasonal occurrence of common dolphin (*Delphinus* sp.) group size observed between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

The highest proportion of small groups (≤ 50 animals) occurred between 1400 to 1559 h, in December and during winter (Figures 2.17 to 2.19), whereas, large groups (>50 animals) were most frequent between 1200 to 1359 h, in April and autumn (Figures 2.16 to 2.18). Group size exhibited diel variation (Pearson χ^2: $\chi^2 = 13.982$, df = 4, $p < 0.05$; Figure 2.17), small groups were observed less frequently than expected between 1200 and 1359 h and more frequently between 1400 and 1559 h. The converse applied to large groups. Group size exhibited no seasonal variation ($p > 0.05$) (Figure 2.19) but did vary significantly by month ($\chi^2 = 23.204$, df = 11, $p < 0.05$; Figure 2.18), with large groups observed more frequently than expected in April and less often in December.

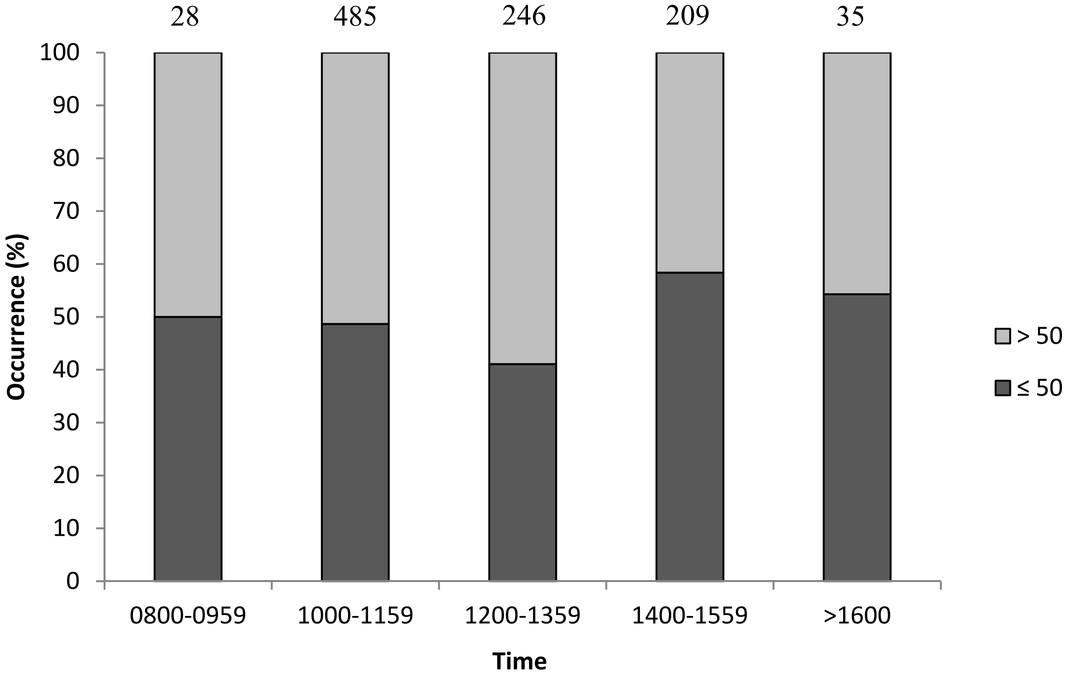

Figure 2.17: Diel occurrence of small and large common dolphin (*Delphinus* sp.) groups observed between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

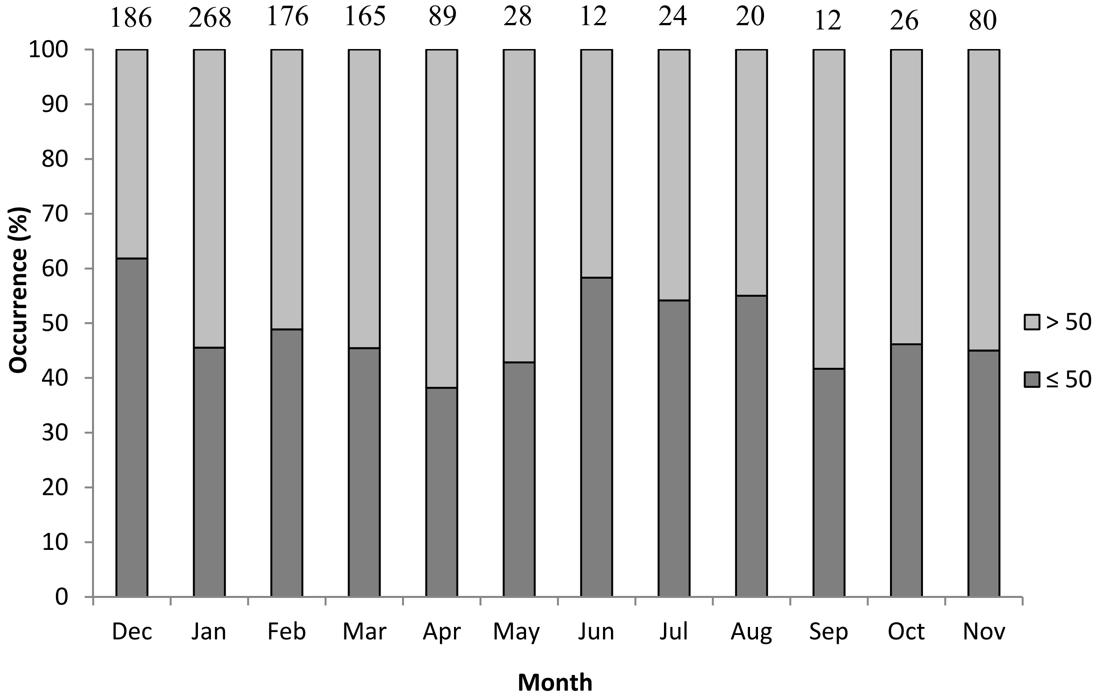

Figure 2.18: Monthly occurrence of small and large common dolphin (*Delphinus* sp.) groups observed between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

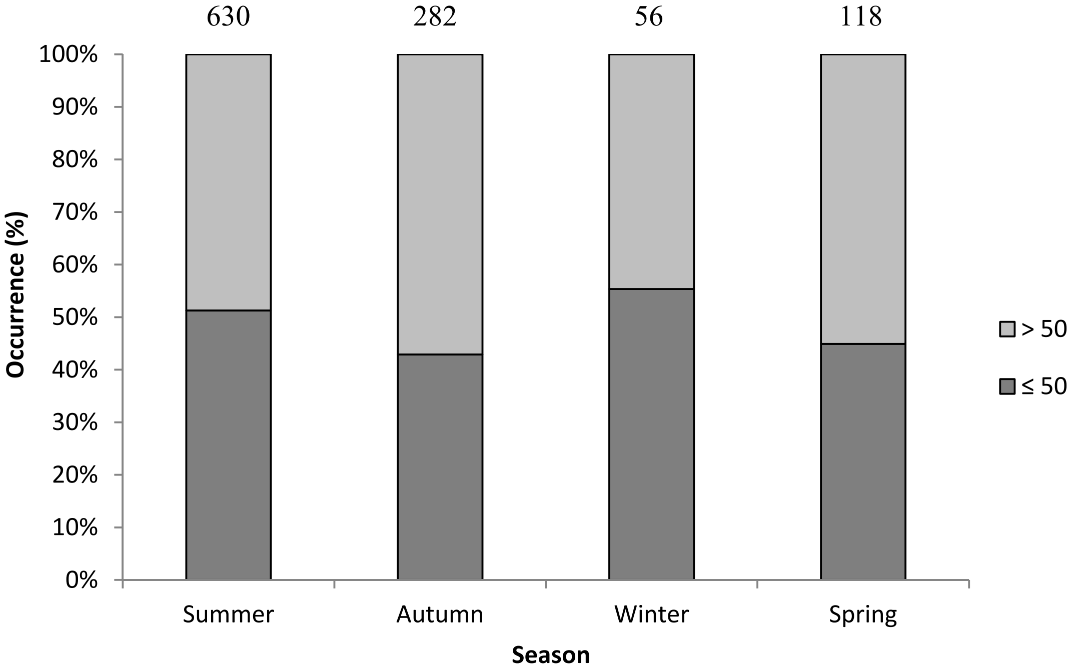

Figure 2.19: Seasonal occurrence of small and large common dolphin (*Delphinus* sp.) groups observed between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

The median water depth at which different groups sizes were observed varied significantly (Kruskal-Wallis: H = 54.379, df = 6, p < 0.0001), with groups containing one to 10 individuals occurring in the shallowest waters (median = 37.0 m, IQR = 27.5-49.0, n = 87) and groups with more than 200 animals occurring in deeper waters (median = 46.0 m, IQR = 39.0-60.5, n = 87; Figure 2.20). This trend was further confirmed in the broad scale group size analyses (Mann-Whitney U: H = 18.028, U = 76,644, df = 1, p <0.0001), with small groups (<50 animals) observed in shallower waters (median = 36.0 m, n = 363) and large groups (>50 animals) found in deeper waters (median = 43.0 m, n = 387).

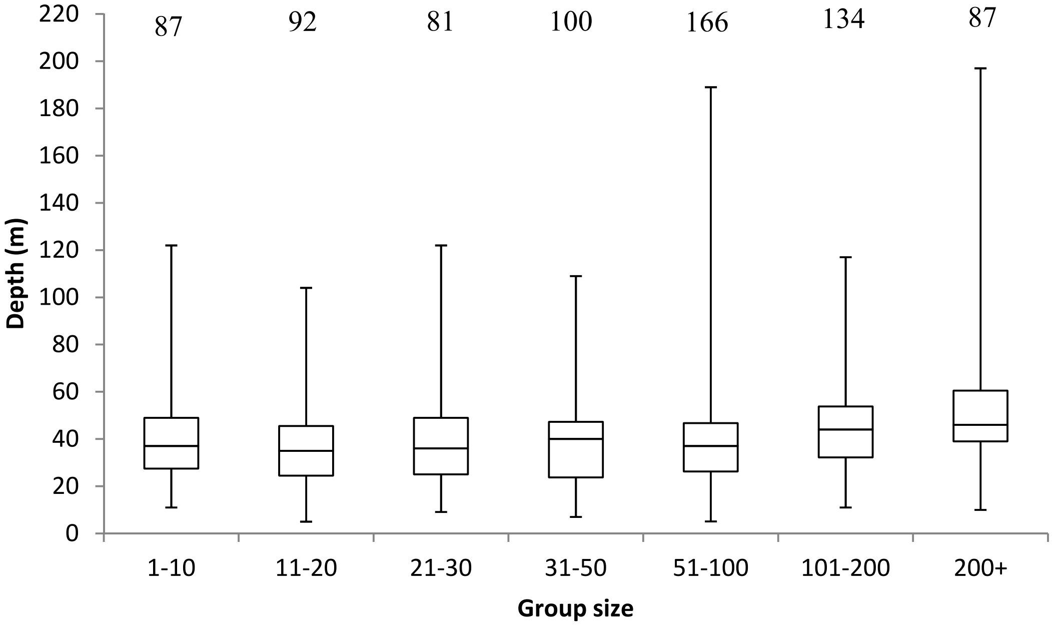

Figure 2.20: Water depth in relation to group size for common dolphin (*Delphinus* sp.) sightings between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: Lines represent the median, boxes the 25th and 75th interquartiles and bars the range. Numbers above the boxes represent the sample number (n).

2.4.4 Group composition in relation to abiotic factors

In the majority of cases immature animals were recorded as calves (82.4%, n = 164), the low proportion of neonates (9%, n = 18) and juveniles (8.5%, n = 17; Table 2.1) recorded may be attributed to the difficulty in separating ages classes in the field. Common dolphin groups with immature animals accounted for 16% (n = 199) of total sightings and were present throughout the year, although neonates were only recorded from late austral spring through to autumn (Table 2.1). The TER for groups with immature animals was highest in December, summer and 2010 to 2011 and lowest in July, winter and 2001 (Figures 2.21 to 2.23).

Table 2.1: Occurrence and seasonality of common dolphin (*Delphinus* sp.) calf categories observed between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand.

Age class	**Austral seasonality**	**Total no. of sightings**	**Occurrence (%)**	**95% confidence interval**
Neonate	Spring, summer and autumn	19	10.0	4.15
Calf	Year round	164	81.5	5.37
Juvenile	Year round	17	8.5	3.86
Total		**201**	**100**	

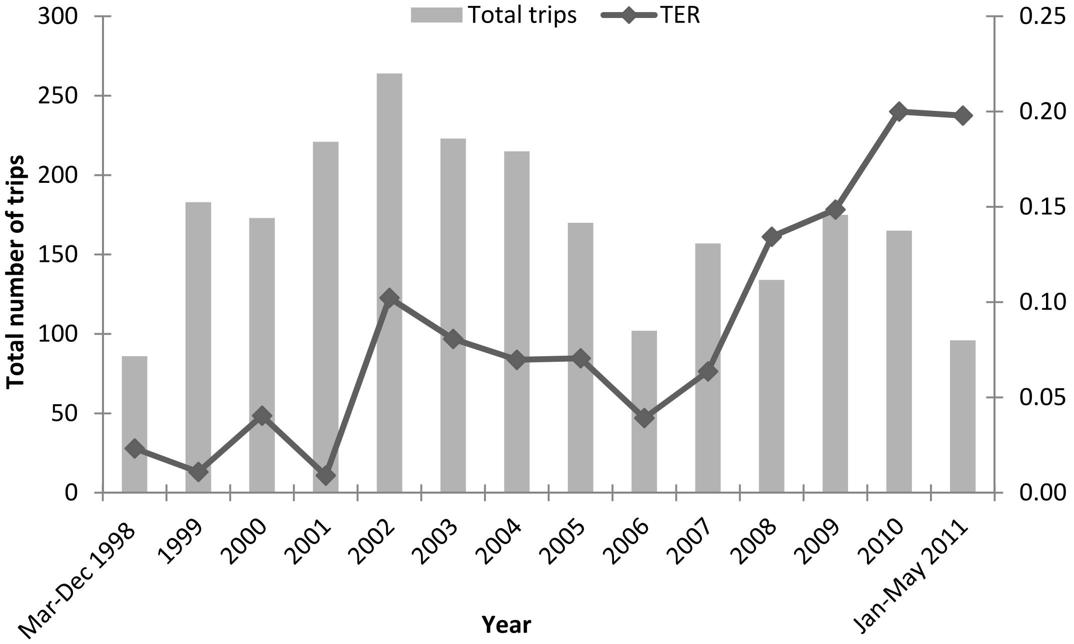

Figure 2.21: Annual Trip Encounter Rate (TER) for groups containing immature common dolphins (*Delphinus* sp.) between March 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand.

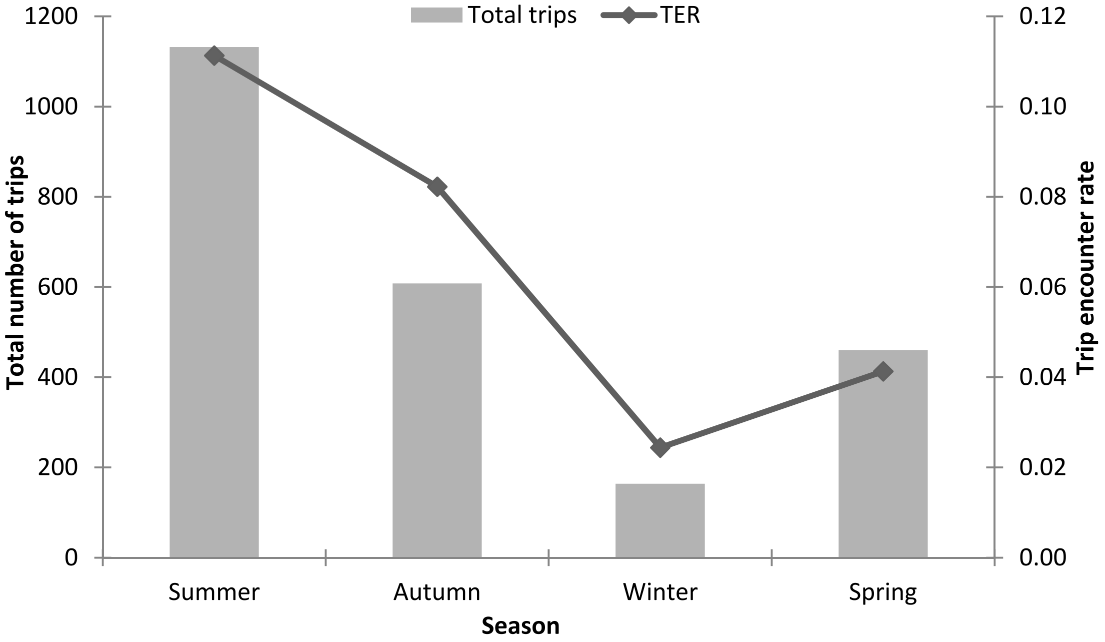

Figure 2.22: Seasonal Trip Encounter Rate (TER) for groups containing immature common dolphins (*Delphinus* sp.) between March 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand.

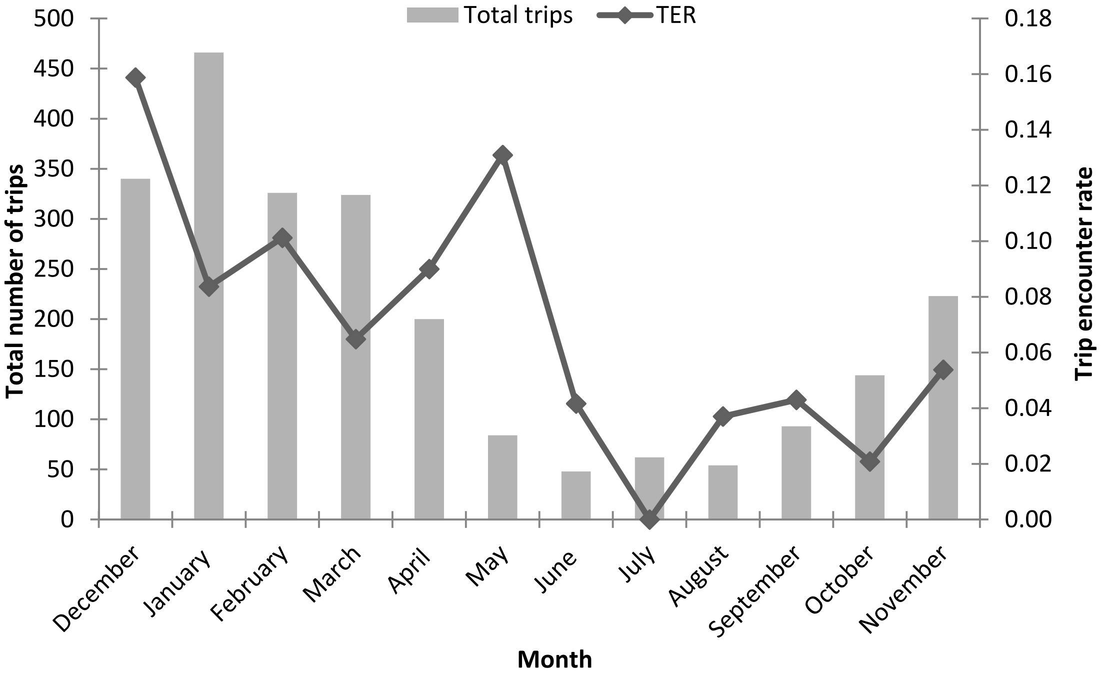

Figure 2.23: Monthly Trip Encounter Rate (TER) for immature common dolphins (*Delphinus* sp.) between March 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand.

Groups containing immature animals accounted for 81.0% of encounters where group size and composition were recorded (n = 232). Immature animals were most frequently (56.4%, n = 106) recorded in large groups containing more than 50 animals (Figure 2.24). The occurrence of mature only *versus* groups with immature animals did not vary significantly according to group size ($\chi^2 = 0.7689$, df = 1, $p > 0.05$).

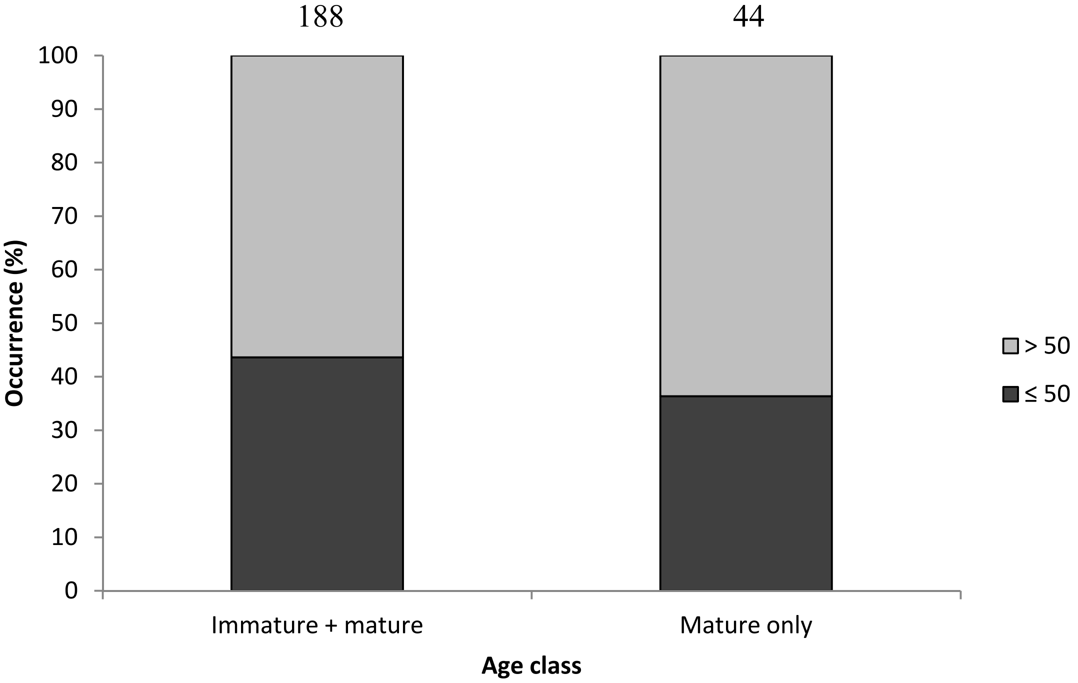

Figure 2.24: Occurrence of common dolphin (*Delphinus* sp.) groups containing immature animals *vs* mature only groups in relation to group size between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (n).

Significant variation was observed in the median water depth between groups with immature animals and mature only groups (Mann-Whitney U: W = 4,660, -3.08, p = 0.0021). Groups containing immature animals were recorded in shallower water (median = 40.0, IQR = 25.0-47.0, n = 147) than mature only groups (median = 45.0, IQR = 34.0-58.0, n = 49; Figure 2.25).

Figure 2.25: Water depth for common dolphin (*Delphinus* sp.) groups containing immature animal's *vs* mature only groups between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: Lines represent the median, boxes the 25th and 75th interquartiles and bars the range. Numbers above the boxes represent the sample number (*n*).

2.4.5 Associated species

Common dolphin groups within the central BOP were reported in association with five cetacean species and 14 avian species (Table 2.2). There were a further five cetacean species which were sighted on the same day as common dolphin groups but not in association (Table 2.2). Common dolphins were primarily associated with petrels (Procellariiformes), Australasian gannets and shearwaters (*Puffinus* sp.), and were rarely sighted in association with other marine mammal species (Table 2.2). However, common dolphins in the central BOP appear to share their habitat with various species of baleen whale (Mysticeti) as well as members of the Delphinidae family including: killer whale, bottlenose dolphin, false killer whale (*Pseudorca crassidens*) and pilot whale (*Globicephala* spp.) (Table 2.2).

Table 2.2: Cetacean and avian species sighted in association with and/or in the vicinity of common dolphins (*Delphinus* sp.) in the central Bay of Plenty (BOP), New Zealand.

Common name	**Scientific name**	**Total no. of sightings**	**Seasonality**
Associated species			
Albatross	*Domedea* sp.	15	Year round
Australasian gannet	*Morus serrator*	379	Year round
Black petrel	*Procellaria parkinsoni*	405	Year round
Blue whale	*Balaenoptera musculus*	1	Spring
Bryde's whale	*B. edeni*	3	Winter
Buller's Shearwater	*Puffinus bulleri*	123	Year round
Cape pigeon	*Daption capense*	5	Winter, Spring
Diving petrel	*Pelecanoides* sp.	132	Year round
Fluttering shearwater	*P. gavia*	86	Year round
Giant petrel	*Macronectes giganteus*	106	Year round
Minke whale	*B. acutorostrata/ bonaerensis*	3	Spring
Mollymawk	*Thalassarche* sp.	13	Year round
New Zealand fur seal	*Arctocephalus forsteri*	1	Winter
Prion	*Pachyptila* sp.	9	Year round
Sei whale	*B. borealis*	1	Spring
Skua	*Catharacta* sp.	11	Year round
Storm petrel	*Fregetta* sp.	17	Year round
Tern	*Sterna* sp.	97	Year round
Species sighted on same day			
Blue whale	*B. musculus*	1	Summer
Bottlenose dolphin	*Tursiops truncatus*	17	Year round
Bryde's whale	*B. edeni*	4	Spring
False killer whale	*Pseudorca crassidens*	1	Summer
Humpback whale	*Megaptera novaeangliae*	3	Spring, Summer
Killer whale	*Orcinus orca*	21	Year round
Minke whale	*B. acutorostrata/ bonaerensis*	1	Spring
Pilot whale	*Globicephala* spp.	1	Summer
Sei whale	*B. borealis*	1	Winter

2.5 Discussion

Common dolphin sightings occurred throughout the year in the central BOP region, which concurs with previous reports from the east coast of the North Island (Neumann, 2001a; Stockin *et al.,* 2008a; Martinez *et al.,* 2010; Gaborit-Haverkort & Stockin, in press). The majority of sightings occurred during the austral summer and autumn, when the largest group sizes were also observed. The most frequently recorded group size involved 51 to 100 individuals, which differs from the Hauraki Gulf where smaller groups of one to 30 animals were most numerous (Stockin *et al.,* 2008a; Martinez *et al.,* 2010). Immature animals were present throughout the year in the central BOP, although neonates were only recorded during the warmer months. This concurs with previous reports from New Zealand waters (Stockin *et al.,* 2008a; Gaborit-Haverkort & Stockin, in press). There are a number of possible reasons for these common dolphin occurrence patterns in the central BOP including: prey availability, competition, predation and reproductive requirements.

2.5.1 Prey availability

Common dolphins are abundant in both neritic (continental shelf, depth < 200 m) and oceanic habitats (> 2000 m depth), which differ in terms of the nature of available prey species (Pusineri *et al.,* 2007). Consequently, common dolphins appear to feed opportunistically, their diet reflecting local prey abundance and availability (Young & Cockroft, 1994). The diet of *D. delphis* has been documented in neritic areas from stomach content analysis of stranded or by-caught animals (*e.g.*, Young & Cockroft, 1994; Meynier, 2004; Santos *et al.,* 2004), with the bulk of the diet consisting of a combination of small pelagic schooling fish. In comparison the diet of *D. delphis* in oceanic areas is less well known. *D. delphis* are thought to target small, mesopelagic fish in the surface layer during dusk and early night (Pusineri *et al.*, 2007). Meynier *et al.* (2008) reported that the most prevalent prey species for common dolphins stranded or bycaught in New Zealand waters included: arrow squid (*Nototodarus* sp.), jack mackerel (*Trachurus* sp.) and anchovy (*Engrauliis australis*).

During the present study, common dolphin sightings primarily occurred in water depths less than 100 m, during the warmer months, when larger aggregations of dolphins were also frequently recorded. When prey are abundant common dolphin populations may stay in large schools that can reach thousands of individuals, however, they often separate into smaller social units of about 30 individuals especially when prey are scattered (Evans, 1994; Bearzi *et al.,* 2003). The presence of large groups in the central BOP could possibly be attributed to increases in anchovy and arrow squid abundance in coastal waters during the warmer months (Ayling & Cox, 1982; MFish, 2011a, 2011b). Sightings during spring were less frequent and primarily consisted of smaller groups (≤ 50 individuals). Neumann (2001a) reported a seasonal offshore-shift in common dolphin distribution during the colder months in the western BOP. This seasonal shift coincides with peak numbers of jack mackerel occurring in offshore waters of the BOP between June and November (MFish, 2011c). Conversely, in the Hauraki Gulf larger aggregations of common dolphins were most frequent during winter due to nutrient upwelling, which typically leads to increased prey availability within the region (Stockin *et al.,* 2008a). Therefore, during the winter months common dolphins from the central BOP may travel to the productive offshore waters of the BOP or to the Hauraki Gulf. This concurs with previous reports using photo-identification catalogues, which indicate that common dolphins move between Whakatane in the eastern BOP and Mercury Bay in the western BOP (200 km distance), as well as between Mercury Bay and the Hauraki Gulf (100 km distance) (Neumann *et al.,* 2002). However, until systematic surveys are completed (Meissner, unpubl. data), common dolphin residency and general movement patterns can only be inferred.

Common dolphins may also exhibit distributional shifts on a diurnal basis. Scott and Cattanach (1998) reported a pattern of increasing group size in the morning and subsequent decline in the late afternoon for *Delphinus* sp. in the eastern Pacific Ocean. It has been suggested that this pattern is linked to diurnal changes in prey distribution. Many small fishes school tightly during the day and disperse at night (Breder, 1959; Major, 1977), and the predators may mirror the patterns of their prey (Scott & Cattanach, 1998). Information on the stomach contents of common dolphins from the Hauraki Gulf supports Scott and Cattanach (1998). Both stranded and bycaught dolphins had fed on a combination of neritic and oceanic prey species, suggesting an inshore/offshore movement of common dolphins on a diurnal basis within the Hauraki Gulf (Meynier *et al.,* 2008). However, it is not known whether all New Zealand *Delphinus* follow the same movement patterns as those from the Hauraki Gulf. In the present study common dolphins were found in shallow water in the morning and deeper waters in the afternoon, which concurs with Neumann (2001a). This diel variation could possibly even be attributed to the daily movement patterns of the tourism vessel, searching in shallow waters in the morning prior to heading out into deeper waters in the afternoon if dolphins had not been encountered (Gaborit-Haverkort, pers. obs.).

2.5.2 Competition

Competitive interactions help determine group size, habitat use and ranging patterns in cetaceans (Heithaus, 2001). Therefore, it is important to determine whether common dolphin diets overlap with other species. Aggregations of common dolphins, yellowfin tuna (*Thunnus albacares*) and seabirds regularly forage together in offshore regions (Au & Perryman, 1985; Au & Pitman, 1986; Reilly, 1990). Sharks have also been observed feeding from the same school of fish as dolphins (Leatherwood, 1977). In New Zealand waters, common dolphins have been observed in association with dusky dolphins (*Lagenorhynchus obscurus*) (Würsig *et al.,* 1997; Markowitz, 2004), Bryde's whales (*Balaenoptera edeni*) (O'Callaghan & Baker, 2002; Neumann & Orams, 2003; Burgess, 2006; Stockin *et al.,* 2009a; Wiseman *et al.,* 2011), sei whales (*Balaenoptera borealis*) and minke whales (*Balaenoptera acutorostrata*) (Neumann & Orams, 2003). In the Bay of Islands, Hauraki Gulf and Mercury Bay areas of the North Island, common dolphins have been also been observed in feeding associations with various avian species, such as Australasian gannets, sooty shearwaters (*Puffinus griseus*), Buller's shearwaters (*P. bulleri*), flesh-footed shearwaters (*P. carneipes*), fluttering shearwaters (*P. garia*), white-fronted terns (*Sterna striata*), and white-faced storm petrels (*Pelagodroma marina*) (Neumann & Orams, 2003; Burgess, 2006; Stockin *et al.,* 2009a).

During the present study, common dolphins were primarily sighted in association with the Australasian gannet as well as various species of petrel and shearwater. There is evidence that common dolphins feed on similar size prey to those preferred by seabirds, especially gannets (Evans, 1982, Machovsky Capuska *et al.,* 2011). Burgess (2006) reported Australasian gannet flocks consisting of over 200 birds occur in the Hauraki Gulf. The author hypothesised that flock size could have an impact on common dolphin foraging success. However, anecdotal information from commercial water users indicate that gannet flock sizes appear to be smaller in the central BOP, often consisting of less than five birds. The effect of associated species presence on common dolphin foraging success cannot be assessed without further data on the flock size and nature of each association.

Common dolphins were rarely sighted in direct association with other marine mammal species in the central BOP. However, they did share their habitat with various species of baleen whale, as well as members of the Delphinidae family, including bottlenose dolphin, false killer whale, pilot whale and killer whale. These findings concur with historic reviews for BOP waters (Gaborit-Haverkort & Stockin, in press). It is possible that common dolphins in the central BOP are competing for food with other delphinids. Stomach content analyses of pilot whales and *Delphinus* sp. in the Mid-Atlantic Bight revealed that the two species were in direct competition for Atlantic mackerel (*Scomber scombrus*) and long-finned squid (*Loligo paelei*) (Overholtz & Waring, 1991). Bottlenose dolphins are opportunistic predators, with a preference for demersal fish (Hanson & Defran, 1993; Blanco *et al.,* 2001; Santos *et al.,* 2001*,* 2007), and are therefore unlikely to compete with common dolphins. They are known, however, to feed on seasonal schools of pelagic squid and fishes (Hobson *et al.,* 1981; Schneider, 1999). False killer whales are less likely to compete with common dolphins as they are known to feed at higher trophic levels, targeting game fish such as yellowfin tuna, mahimahi (*Coryphaena hippurus*) (Baird *et al.,* 2008) and kingfish (*Seriola lalandi lalandi*) (G. Butler, pers. com.). However, stomach content analyses have shown that they also feed on squid (Alonso *et al.,* 1999; Hernández-Garcia, 2002). Finally, it is very unlikely that killer whales are competitors with common dolphins in the central BOP, as New Zealand killer whales primarily forage on stingray (Myliobatidae), sharks (Elasmobranchii), fin-fish and cetaceans (Visser, 1999a; 2005; Visser *et al.,* 2010).

2.5.3 Predation

Killer whales have been observed attacking or harassing over 20 species of cetaceans worldwide, including *Delphinus* sp. (Jefferson *et al.,* 1991). In New Zealand waters, killer whales have been recorded predating on common dolphins (Visser, 1999b; Gaborit-Haverkort & Stockin, in press; G. Butler, pers. comm.). In the present study, killer whales were occasionally (1.6%, n = 21) sighted on the same day as common dolphin groups, sometimes within 5 nm of each other (Gaborit-Haverkort, pers. obs.). This indicates that although common dolphins have been predated upon by killer whales in the area (G. Butler, pers. comm.), they may not always perceive killer whales as a direct threat. There were also occasions when common dolphins appeared to be absent from the central BOP for days at a time, which coincided with killer whale sightings in the area (Gaborit-Haverkort, pers. obs.).

Visser (2000a) identified three sub-populations of New Zealand killer whales (North Island only, South Island only and North + South Island sub-populations), each with different diets. The North + South Island sub-population appear to be generalist or opportunistic foragers (feeding on stingrays, sharks, fin-fish and cetaceans), whereas, the North Island sub-population has not been recorded feeding on cetaceans and the South Island sub-populations has been observed feeding exclusively on cetaceans (Visser, 2000a). It is possible that common dolphins may be able to distinguish between different sub-populations of New Zealand killer whales, and thus attempt to avoid the North + South Island sub-population when they pass through BOP waters. In the eastern North Pacific, dialect differences between two killer whale sub-populations allow them to be distinguished from each other (Ford & Fisher, 1982; Barrett-Lennard *et al.,* 1996). Sound may, therefore, be very important in mediating interactions between killer whales and other cetaceans (Jefferson *et al.,* 1991). Whether the perceived absence of common dolphin groups were indeed linked to the presence of predatory North + South Island killer whales or whether there was other motivating factors requires further investigation.

Several species of shark are known to be relatively frequent predators of dolphins and porpoises including: white (*Carcharodon carcharius*), bull (*Carcharhinus leucas*), tiger (*Galeocerdo cuvier*), bluntnose sixgill (*Hexanchus griseus*) and broadnose sevengill sharks (*Notorynchus cepidianus*) (Long & Jones, 1996; Heithaus, 2001). Oceanic whitetip (*Carcharhinus longimanus*) and shortfin mako sharks (*Isurus oxyrinchus*) are also occasional predators (Heithaus, 2001). All of these species occur within New Zealand waters (Cailliet *et al.*, 2004; Compagno, 2005; Cook & Compagno, 2005; Fergusson *et al.,* 2005; Simpfendorfer, 2005; Baum *et al.,* 2006) except for bull sharks (Simpfendorfer & Burgess, 2005). Dolphins have been known to show species-specific reactions to sharks and seem to be able to distinguish between predatory species and those that pose no threat (Heithaus, 2001). Such reactions were observed during the present study; common dolphin groups usually ignored hammerhead sharks but would flee when mako sharks were observed (Gaborit-Haverkort, pers. obs.).

Predation risk may also influence common dolphin group size. There are numerous examples of group formation successfully reducing predation in the terrestrial environment (e.g. Clutton-Brock *et al.,* 1999; Hebblewhite & Pletscher, 2002), and predation has been suggested as an important determinant of group size in some odontocetes (e.g. Norris & Dohl, 1980; Wells *et al.,* 1980; Wells *et al.,* 1987). In the present study, smaller common dolphin groups were most often observed in shallow water, with sightings in deeper water involving larger groups. In deep water, the only defence against predation is to form large groups, and pelagic dolphins consistently form much larger groups than their coastal counterparts (Saayman *et al.,* 1972).

2.5.4 Reproductive requirements

In temperate regions of the world seasonal peaks in common dolphin births have been reported by numerous sources (Tomilin, 1957; Collet, 1981; Perrin & Reilly, 1984; Bräger & Schneider, 1998; Neumann, 2001b; López *et al.,* 2002; Sabin *et al.,* 2002; Murphy, 2004; Westgate & Read, 2007; Stockin *et al.,* 2008a). The primary reasons for this seasonal variability are thought to involve prey availability, energy demands and sea surface temperature (SST) (Whitehead & Mann, 2000). Conversely, in tropical regions, neonate calves have been reported year round (Danil & Chivers, 2007), which may be attributed to relatively constant SSTs in the tropics.

There is evidence that common dolphins in New Zealand waters move inshore during the main reproductive season (Bräger & Schneider, 1998; Neumann, 2001a; Stockin *et al.,* 2008a). In the Hauraki Gulf, groups containing neonates were typically found during austral summer and in shallow waters representing areas close to shore (Schaffar-Delaney, 2004; Stockin *et al.,* 2008a). Reports on *Delphinus* populations in the western and central BOP also concur (Neumann 2001a; Gaborit-Haverkort & Stockin, in press, respectively). Similar results were reported for dusky dolphins on the east coast of the South Island of New Zealand, where vulnerable mothers with calves tend to stay in shallow water to avoid predation (Markowitz, 2004). Results from the present study concur, with groups containing immature animals occurring in shallower water (ca 40 m) than mature only groups (ca 50 m). Groups with immature animals were recorded throughout the year, although neonates were only reported from late spring through to early autumn, which supports the concept of reproductive seasonality in this population. However, assumptions cannot be made without group composition data from offshore areas for comparison. Additionally, it is not known whether seasonal inshore movements are attributed to reproductive requirements or seasonal changes in prey availability (section 2.5.1), both factors are likely to play a role in common dolphin distribution.

The presence of neonates may also influence group size. In the northern Adriatic Sea bottlenose dolphin groups with calves were the largest (Bearzi *et al.,* 1997). This concurs with reports from the Hauraki Gulf, where common dolphin groups with immature animals tended to be significantly larger than adult only groups (Schaffar-Delaney, 2004; Stockin *et al.,* 2008a). In the present study, immature animals were primarily recorded in large groups with more than 50 animals. It seems likely that larger groups may provide a protected environment within which early postnatal development and learning may occur (Wells *et al.,* 1987), especially in the more exposed waters of the central BOP.

2.6 Conclusion

The central BOP appears to constitute an important area for common dolphins especially during the warmer months when large aggregations of dolphins with calves are present within 12 nm of shore. It is therefore crucial that common dolphins inhabiting these waters are effectively managed.

Chapter Three: Behaviour in the presence of the tour vessel

Figure 3.1: New Zealand common dolphins (*Delphinus* sp.) travelling (Photo: Sarah Dwyer).

3.1 Abstract

Herein, a preliminary insight into common dolphin (*Delphinus* sp.) behaviour in the presence of the tour vessel (*Gemini Galaxsea*) in the central Bay of Plenty (BOP) is provided. The influence of abiotic parameters (e.g. depth, season), group dynamics (e.g. group size and composition) and associated species on common dolphin behaviour is assessed. Behavioural data were collected from 162 independent dolphin groups during boat-based surveys conducted between April 1998 and May 2011. Overall, forage, social and travel accounted for the majority of recorded behavioural states, while mill and rest were less frequent. Common dolphin behaviour was influenced by water depth, with foraging dolphins encountered in the deepest waters. Behaviour varied significantly according to group size, with foraging occurring more often than expected in large groups and resting, socialising and milling occurring more often in smaller groups. The presence of immature animals also had a significant influence on common dolphin behaviour, with foraging occurring more often than expected in groups containing immature animals. The presence of associated species varied according to behaviour, with the majority of foraging groups occurring in the presence of Australasian gannets (*Morus serrator*). Seasonal and diurnal peaks in behaviour were not evident. Social behaviours primarily occurred during summer when large nursery groups were also reported in the central BOP, which supports the hypothesis that the region may potentially be of importance for nursery groups. While the presented data do not reflect a true activity budget, owing to bias in the way behavioural data were collected from the tour boat, they do offer first insights into how dolphins behave around this platform.

3.2 Introduction

In order to effectively manage a population, there needs to be an understanding of how the population utilises its environment (e.g. Gostomski, 1998). Research has shown that cetacean behaviour may be influenced by a number of factors including water depth (e.g. Cañadas *et al.,* 2002), time of day (e.g. Neumann, 2001c; Baird *et al.,* 2002; Stafford *et al.,* 2005; Degrati *et al.,* 2008), season (e.g. Bräger, 1993; Stockin *et al.,* 2009a), bottom topography (e.g. MacLeod & Zuur, 2005), tidal flow (e.g. Acevedo, 1991; Hanson & Defran, 1993; Gregory & Rowden, 2001), group size (e.g. Stockin *et al.,* 2009a) and the presence of vessels (e.g. Corkeron, 1995; Erbe, 2002; Leitenberger, 2001; Lusseau, 2003; Constantine *et al.*, 2004; Bejder *et al.*, 2006a,b; Neumann & Orams, 2006; Williams *et al.,* 2006; Dans *et al.,* 2008; Stockin *et al.,* 2008b; Visser *et al.,* 2010; Martinez *et al.,* 2011). Behavioural responses of cetaceans to vessel traffic vary within and between species, ranging from attraction through to avoidance responses (e.g. Constantine *et al.,* 2004; Williams *et al.,* 2006; Stockin *et al.,* 2008b; Martinez *et al.,* 2011), resulting in possible long-term alterations to activity budgets and potential displacement from habitat (e.g. Bejder *et al.,* 2006b).

Despite common dolphins (*Delphinus* sp.) being one of the most widely distributed cetaceans globally, information on their behaviour is limited to a few studies (e.g. Gallo Reynoso, 1991; Constantine & Baker, 1997; Neumann, 2001c; Neumann *et al.,* 2002; Bruno *et al.,* 2004; Bearzi, 2003, 2005; Burgess, 2006; Stockin *et al.,* 2008b*,* 2009a). Common dolphins (*Delphinus* sp.) are highly gregarious, with groups generally composed of dozens to hundreds of individuals (e.g. Neumann, 2001a,b; Bearzi *et al.,* 2003; Jefferson *et al.,* 2007; Stockin *et al.,* 2008b; Gaborit-Haverkort & Stockin, in press). Common dolphins exhibit a fluid fission-fusion social structure (Bruno *et al.,* 2004), with some evidence for segregation in age and sex classes (Neumann *et al.,* 2002; Perrin 2009). However, there is evidence that kinship relationships are unlikely to be of importance (Viricel *et al.,* 2008). It has been suggested that this flexibility may enable the animals to adapt to environmental shifts and fluctuating prey availability (Bruno *et al.,* 2004). There is a general lack of activity budgets available for common dolphins worldwide (Neumann, 2001c; Stockin *et al.,* 2008b*,* 2009a), although some data describing behaviour in relation to tour vessels is available (Constantine & Baker, 1997; Neumann & Orams, 2005, 2006; Meissner & Stockin, 2011). Generally, available data indicate that common dolphin behaviour varies between regions. It is therefore important from a management perspective, that common dolphin behaviour (with and without the presence of tour boats) is assessed on a regional basis, especially for those populations exposed to tourism pressure. Common dolphins are currently the focus of eight commercial tours operating within the Bay of Plenty (BOP) Conservancy (Gaborit-Haverkort & Stockin, in press). As such, a specific study is currently underway to assess the effects of such activity on *Delphinus* behaviour within BOP waters (Meissner & Stockin, 2011).

The following chapter provides a preliminary insight into common dolphin behaviour in the central BOP, as determined from a platform of opportunity (PoO). The influence of environmental parameters (e.g. depth, season), group dynamics (group size and composition) and associated species on common dolphin behaviour is assessed in order to give insight to habitat use in the presence of tour boats.

3.3 Methods

3.3.1 Study site

The BOP (Figure 2.2, Chapter 2) is situated on the east coast of the North Island of New Zealand, extending from Waihi east to Lottin Point near Cape Runaway (latitude 37°25’ to 37°33’ S; longitude 175°55’ to 178°10’ E). The BOP provides foraging habitat for common dolphins, with peaks in the abundance of prey species such as anchovy (*Engraulis australis*) and arrow squid (*Nototodarus* sp.) in coastal waters during warmer months (Ayling & Cox, 1982; MFish, 2011a, 2011b), and jack mackerel (*Trachurus* sp.) in offshore waters of the BOP during between June and November (MFish, 2011c). Other common dolphin prey species such as kahawai (*Arripis trutta*), yellow-eyed mullet (*Aldrichetta forsteri*), flying fish (*Cypselurus lineatus*), parore (*Girella tricuspidate*), and garfish, (*Hyporamphus ihi*) also occur within the region (Neumann & Orams, 2003).

3.3.2 Data collection

Observations were conducted between April 1998 and May 2011 from *Gemini Galaxsea* (Figure 2.3, Chapter 2). Data were collected as detailed in chapter two (section 2.3.2). Behaviour was classified into five widely accepted categories (Table 3.1) as per Stockin *et al.* (2008b, 2009a). Typically, dolphin behaviour is assessed using the predominant behavioural state (Mann, 2000), in which more than 50% of the animals are involved is recorded (e.g. Neumann, 2001c; Stockin *et al.,* 2009a; Meissner & Stockin, 2011). However, the recording of behavioural states was not a standardised procedure on board *Gemini Galaxsea*. Consequently, behaviour was often noted once dolphins had already engaged with the boat (e.g. commenced bow riding), however, bow riding itself was not classified as a behavioural state. There is evidence, which suggests that common dolphins alter their behaviour in the presence of boats (Stockin *et al.,* 2008b). Therefore, the behavioural data examined in this chapter do not accurately represent a true activity budget for common dolphins in the central BOP *per se*. However, it does offer first insights into the behaviour of common dolphins in this region when interacting with tour boats, and thus can be compared to behavioural data in the presence of tour boats from the Hauraki Gulf (Stockin *et al.,* 2008b) and Bay of Islands (Constantine & Baker, 1997) as well as preliminary results (November 2010 to March 2011) from a tourism impact study currently underway in the BOP (Meissner & Stockin, 2011).

Table 3.1: Definitions of behavioural states of common dolphin (*Delphinus* sp.) groups adapted from the Hauraki Gulf, New Zealand (Sourced from: Stockin *et al.,* 2008b, 2009a).

State	Definition
Travel	Dolphins engaged in persistent, directional movement making noticeable headway along a specific compass bearing. Group spacing varied and individuals swam with short, relatively constant dive intervals.
Rest	Dolphins observed in a tight group (<1 body length between individuals), engaged in slow manoeuvres (slower than the idle speed of the observing boat) with little evidence of forwards propulsion. Surfacing appeared slow and were generally more predictable than those observed in other behavioural states.
Mill	Dolphins exhibited non-directional movement, frequent changes in bearing prevented animals from making headway in any specific direction. No net movement. Individuals surfaced facing various directions.
Forage	Dolphins involved in any effort to pursue, capture and/or consume prey, as defined by observations of fish chasing, co-ordinated deep diving and rapid circle swimming. Prey frequently observed at the surface during the foraging activity of the dolphins.
Social	Dolphins observed in diverse interaction events such as chasing, copulating and/or engaged in any other physical contact with other dolphins (excluding mother-calf pairs). Aerial behaviours such as breaching frequently observed.

3.3.3 Data analysis

The behaviour of common dolphins in the central BOP, New Zealand, was investigated in the presence of a tour vessel, *Gemini Galaxsea*. The effects of diel, season, depth, group size and composition on dolphin behaviour were assessed. Additionally, the behaviour of common dolphins in the presence of associated species was examined.

As per chapter two (section 2.3.3), season, month, time of day and depth were considered explanatory variables. Group size categories were determined as ≤ 50 or > 50 animals, as per

Stockin *et al.* (2008a), in order to facilitate direct comparisons with previous studies conducted in the Hauraki Gulf, New Zealand.

Group composition was analysed based on the age classes present as per Stockin *et al.* (2008a). Initially, immature animals were classified as neonates, calves or juveniles. Neonates were defined as small calves with dorso-ventral foetal folds; calves were approximately less than one half the length of the mother and were consistently observed swimming in the infant position beside an adult (Fertl, 1994); juveniles were approximately two-thirds the size of an adult and frequently observed swimming in association with an adult animal, although not in the infant position, suggesting they were weaned (Mann, 2000). Mature and immature categories were selected herein for data analysis given that the current dataset was somewhat limited in terms of separating age classes (immature animals were primarily recorded as calves). Finally, common dolphin behaviour was examined in relation to the presence/absence of associated species.

The percentages given herein relate to the proportion of sightings for which behaviour was recorded. In order to avoid pseudo-replication, data were cleaned prior to analyses to remove any duplicate sightings (e.g. sightings of a subgroup recorded in close succession, within an hour of an earlier encounter). The distributions of continuous response variables (i.e. depth) were initially tested for normality and homogeneity using Kolmogorov-Smirnov and Levene's tests. In most cases, data were not normally distributed. Consequently, non-parametric Mann-Whitney U and Kruskal-Wallis tests were applied. Pearson χ^2 tests were used to examine categorical variables (behaviour, group size and composition). Categorical data were combined and a Fisher's Exact test was performed when data did not meet the conditions for Chi-square analyses (i.e. due to small sample size). All statistical analyses were conducted using SPSS. Finally, ArcGIS (Version 9.2; © ESRI Inc.) was used to create distribution maps depicting the location of observed behaviours.

3.4 Results

3.4.1 Activity budget in the presence of *Gemini Galaxsea*

Data were collected between April 1998 and May 2011 on board tourism vessel *Gemini Galaxsea.* A total of 162 independent behavioural observations were recorded. Data described herein was recorded in the presence (within 100 m) of the observation platform. Overall, forage (49.4%, *n* = 76), social (29.9%, *n* = 46) and travel (11.7%, *n* = 18) accounted for the majority of recorded behavioural states, while mill (5.8%, *n* = 9) and rest (3.2%, *n* = 5) were less frequent (Figure 3.2). Foraging in the presence of boat(s) occurred more often in the central BOP than in the Bay of Islands or Hauraki Gulf (Figure 3.2). Travelling was least frequent in the central BOP (12.0%) when compared to the Hauraki Gulf (34.7%) and Bay of Islands (16.7%) (Figure 3.2). Resting occurred at a similar level throughout the regions assessed (2.4 to 5.4%) (Figure 3.2). Social behaviours in the central BOP (30.0%) were recordered more often than in the Hauraki Gulf (10.4%) and Bay of Islands (9.5%) (Figure 3.2). Milling was least frequent in the central BOP (6.0%), and most frequent in the Hauraki Gulf (27.9%) (Figure 3.2). Bowriding (although not actually a state but behavioural event) was only recorded in the Bay of Islands and accounted for 42.9% of the activity budget in the presence of the observation platform.

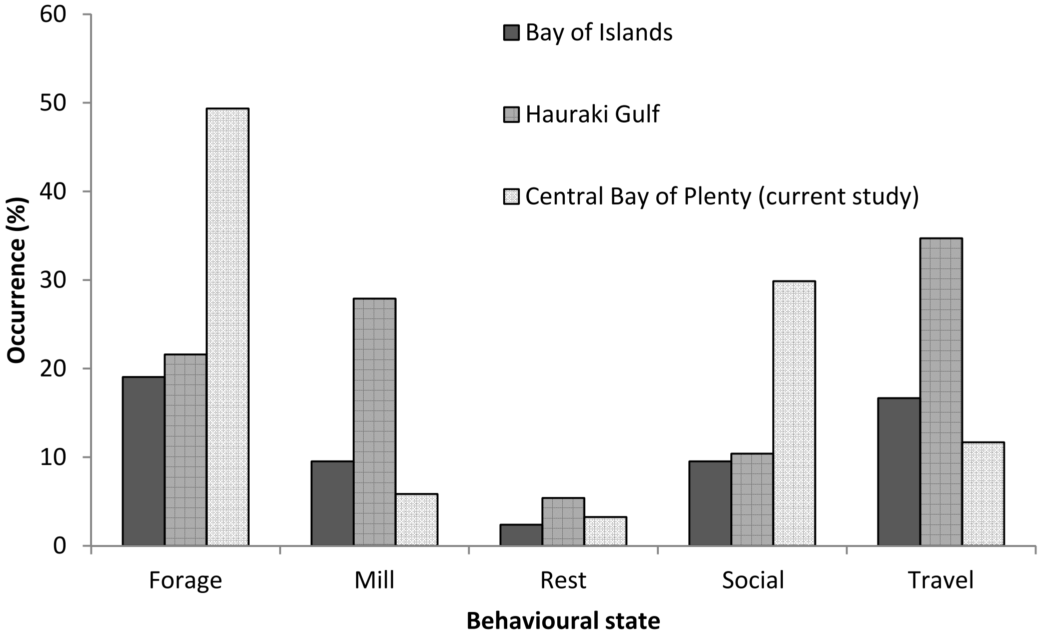

Figure 3.2: Common dolphin (*Delphinus* sp.) activity budget in the presence of *Gemini Galaxsea* in the central Bay of Plenty (BOP), New Zealand, between April 1998 and May 2011 (current study, *n* = 162), compared to behaviour (in the presence of tour vessels) from the Bay of Islands (*n* = 42: Constantine & Baker, 1997) and Hauraki Gulf (*n* = 448: Stockin *et al.,* 2008b).

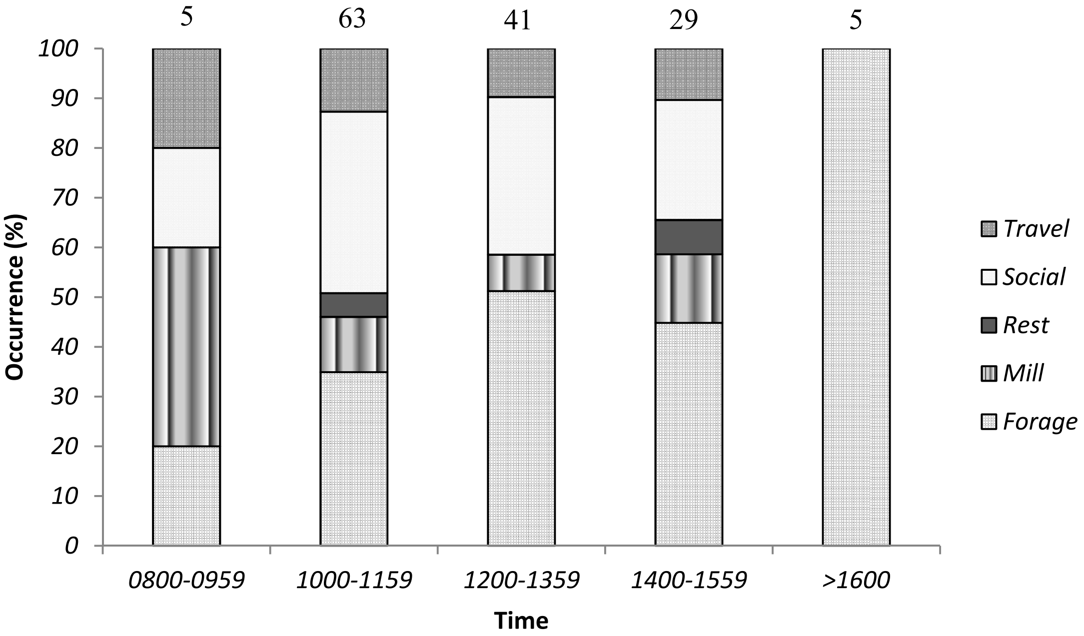

Figure 3.3: Diel occurrence of common dolphin (*Delphinus* sp.) behaviours between April 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

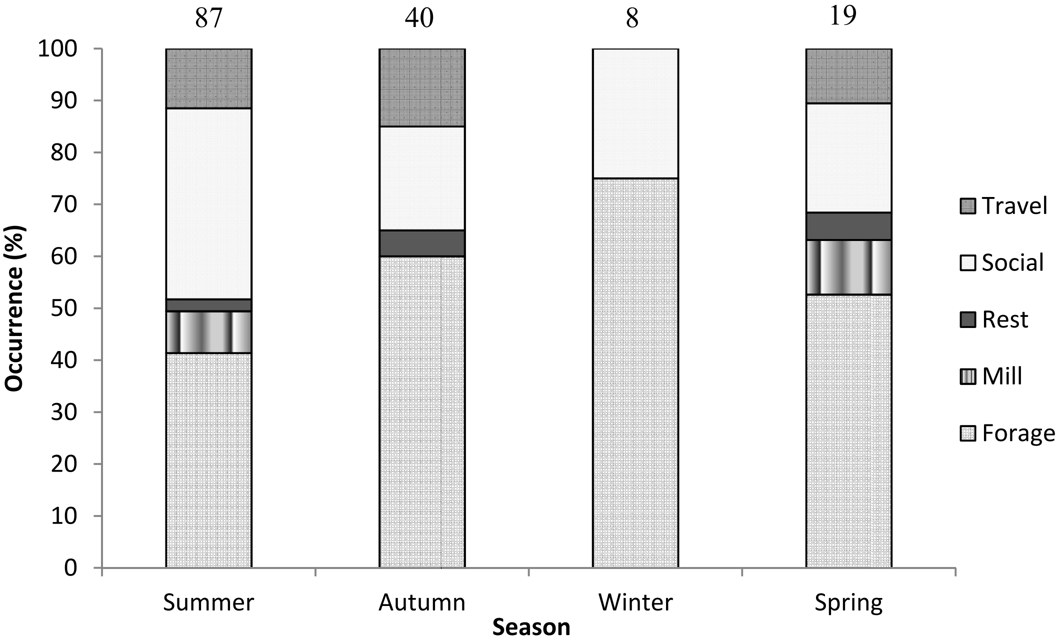

Figure 3.4: Seasonal occurrence of common dolphin (*Delphinus* sp.) behaviours between April 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

While milling and travelling were most prevalent in the morning, foraging increased into the afternoon in the central BOP (Figure 3.3), no significant diurnal difference was detected in activity budget (Pearson χ^2: $\chi^2 = 4.840$, df = 3, $p = 0.184$). Seasonally, foraging was most frequent during autumn and least frequent in summer. Conversely, socialising was most frequent during summer and least in autumn (Figure 3.4). However, these seasonal variations were also not found to be significant (Pearson χ^2: $\chi^2 = 1.953$, df = 3, $p = 0.582$). Travel, rest and milling behaviours were not evident during winter. Common dolphin behavioural states appeared to be evenly distributed throughout the central BOP, although, travelling was most centralised and milling was observed more on the eastern side of the study area (Figure 3.5). However, caution is required in the interpretation of these distributional maps as the vessel track lines were not available in order to correct for effort. As such, it is likely that the distribution of common dolphin behaviours is directly related to the operational area of the tourism vessel.

3.4.2 Behaviour in relation to depth

Common dolphin behaviour was recorded over water depths ranging from 10.0 to 122.0 m (mean = 47.7, SD = 24.2, $n = 96$; Figure 3.6). The difference between the median water depth at which different behaviours were observed was not significant (Kruskal-Wallis: $H = 7.515$, df = 3, $p = 0.072$).

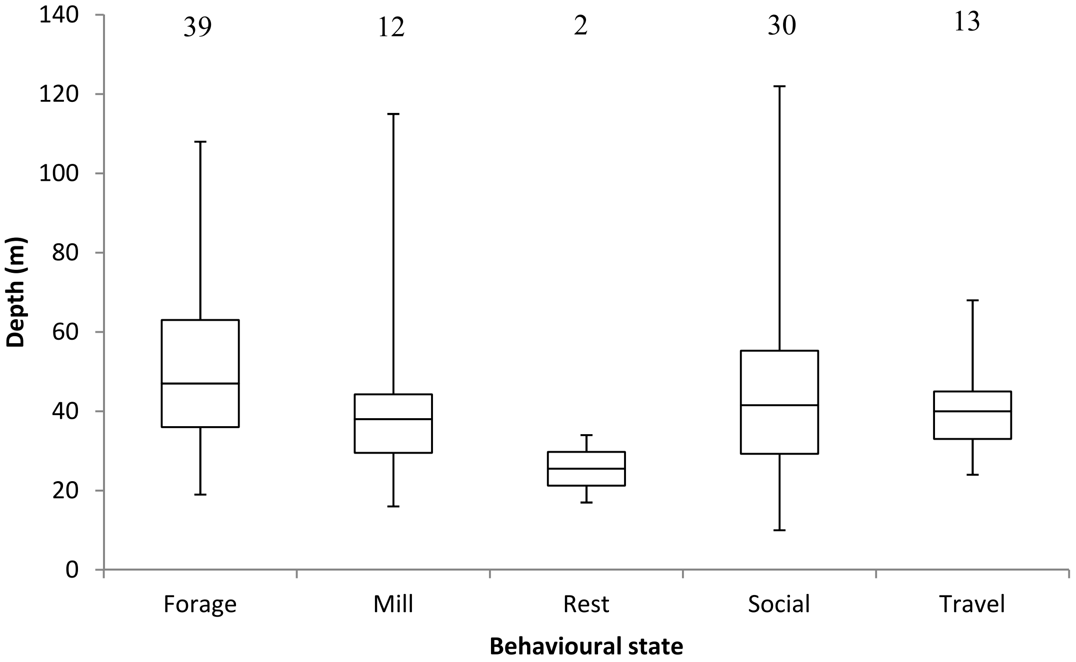

Figure 3.6: Behaviour in relation to water depth (m) for common dolphin (*Delphinus* sp.) groups between April 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: Lines represent the median, boxes the 25th and 75th interquartiles and bars the range. Numbers above the boxes represent the sample number (*n*).

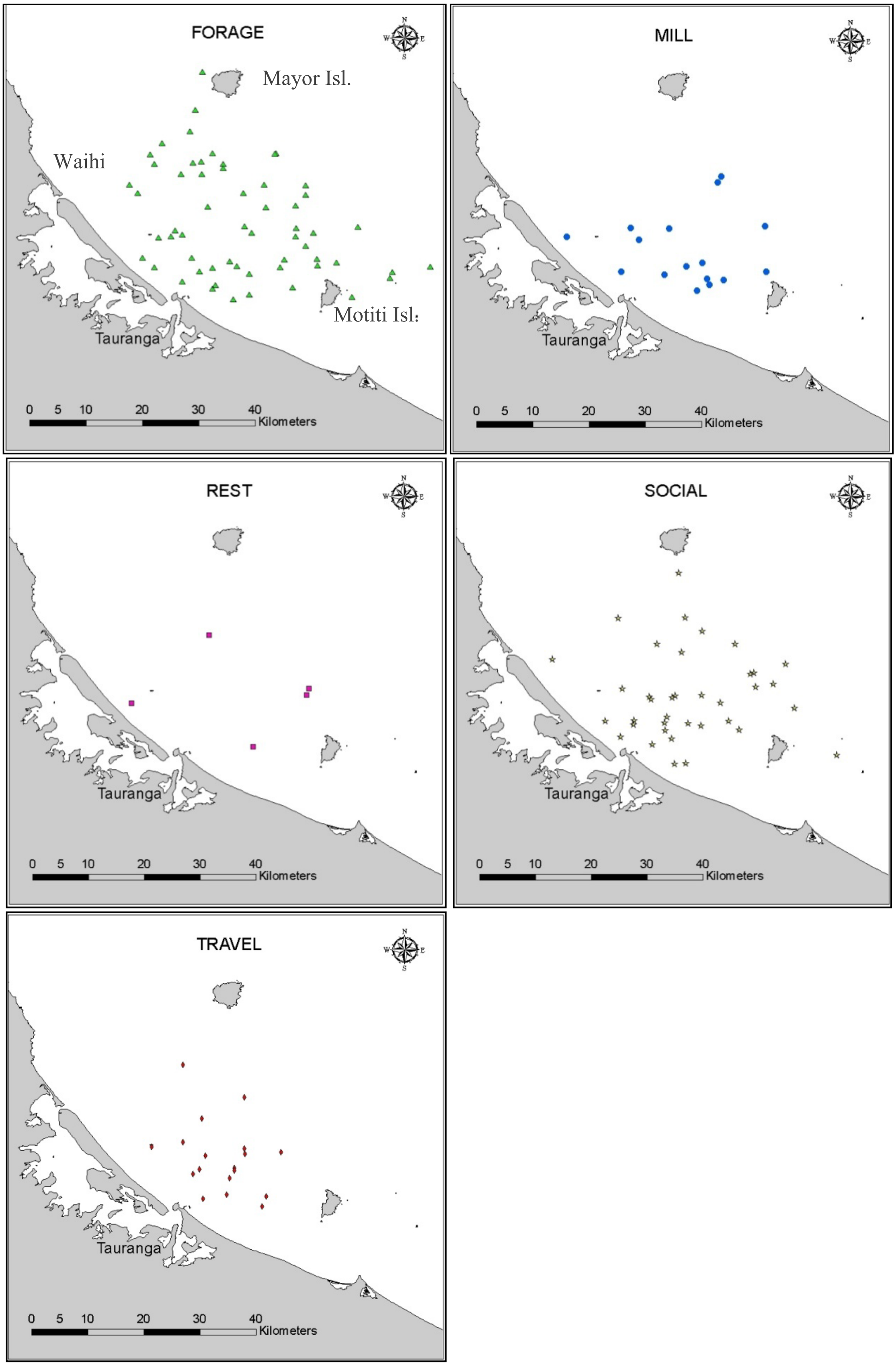

Figure 3.5: Distribution of common dolphin (*Delphinus* sp.) behaviours between April 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand. Note: not corrected for search effort

3.4.3 Behaviour in relation to group size

Behaviour was recorded for common dolphin groups involving between two (n = 1) and 500+ (n = 4) individuals. Behaviour varied significantly according to group size (Pearson χ^2: χ^2 = 13.041, df = 3, p = 0.005), with foraging occurring more often than expected in large (> 50 animals) groups while resting, socialising and milling more often in smaller (≤ 50 animals) groups (Figure 3.7).

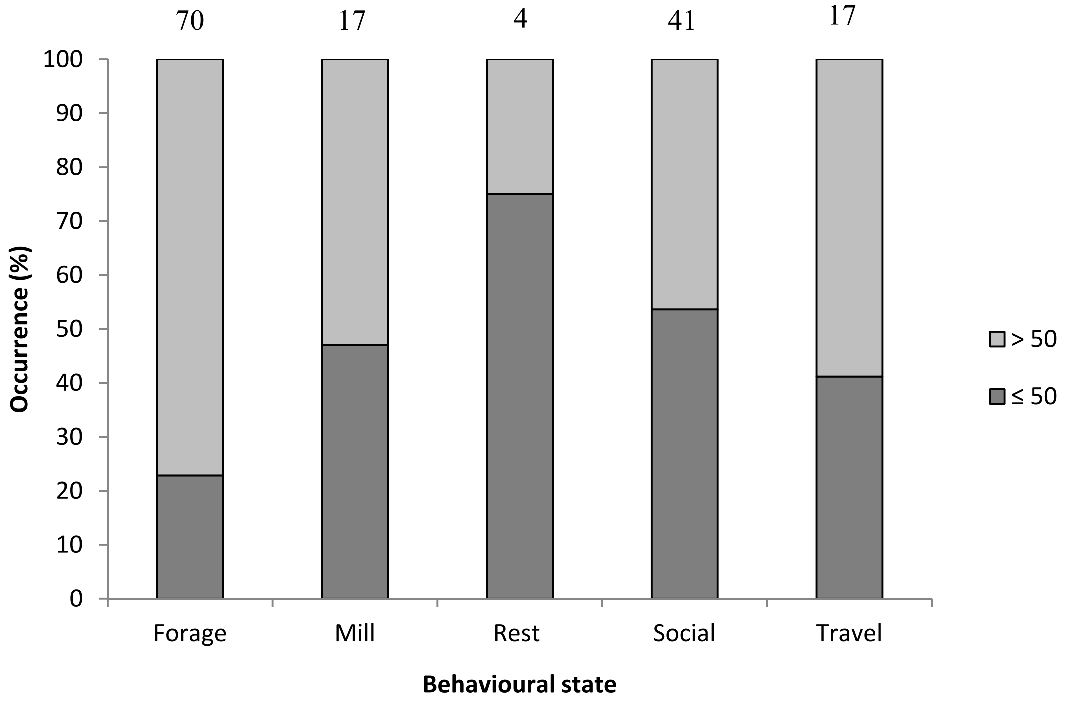

Figure 3.7: Behaviour of small (≤ 50 individuals) *vs* large (> 50 individuals) common dolphin (*Delphinus* sp.) groups between April 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

3.4.4 Behaviour in relation to group composition

Group composition was recorded during 46.9% of behavioural observations (n = 162). Foraging and travelling behaviours were most frequent in groups containing immature animals, whereas, mature groups were more likely to be engaged in milling, resting or social behaviours (Figure 3.8). The presence of immature animals had a significant influence on common dolphin behaviour (Pearson χ^2: χ^2 = 10.891, df = 1, p = 0.001), with foraging occurring more often than expected in groups containing immature animals.

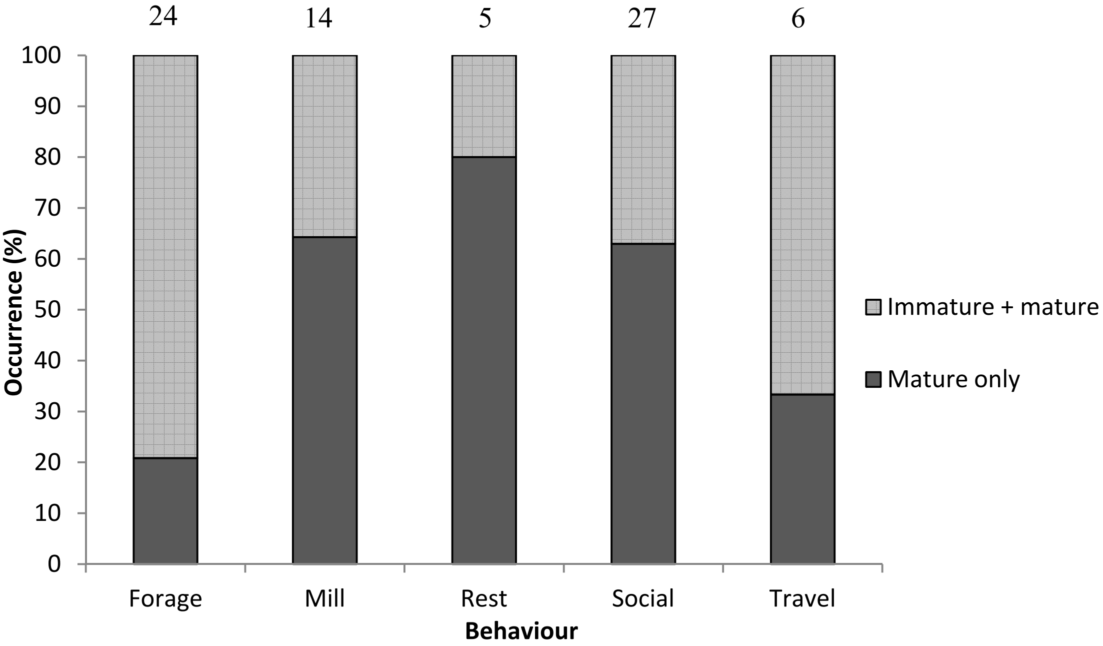

Figure 3.8: Behaviour of common dolphin (*Delphinus* sp.) groups with immature animals *versus* mature only groups between April 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

3.4.5 Behaviour in relation to associated species

The presence of associated species was recorded during 55.6% (n = 90) of behavioural encounters. Common dolphins were observed in association with 13 avian species, in addition to two Bryde's whales (*Balaenoptera edeni*) and a single unidentified whale (*Balaenoptera* sp.) (Table 3.2). Typically, associated species were observed during active behaviours such as foraging (60.0%, n = 76), socialising (21.1%, n = 19) and travelling (11.1%, n = 10) and were less frequent while dolphins were resting (1.1%, n = 1) or milling (6.7%, n = 6) (Figure 3.9). Common dolphin behaviour had a significant influence on the presence of associated species (Pearson χ^2: χ^2 = 13.999, df = 1, p = 0.003), with 71.1% (n = 54) of foraging activity occurring in the presence of associated species (Figure 3.9). Common dolphins were primarily observed in association with the Australasian gannet (29.9%, n = 69) and black petrel (*Procellaria parkinsoni*) (29.7%, n = 67; Table 3.2). Consequently, the presence/absence of these two species only is considered herein. During Australasian gannet associations, foraging vs. non-foraging behaviours varied significantly (Pearson χ^2: χ^2 = 21.695, df = 1, $p < 0.0001$), with 61.8% (n = 47) of foraging occurring in the presence of gannets. Foraging vs. non-foraging behaviours did not vary significantly during black petrel associations (Pearson χ^2: χ^2 = 2.132, df = 1, p = 0.144).

Table 3.2: Occurrence of species associated with common dolphins (*Delphinus* sp.) between April 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand.

Associated species		**Total number of sightings**	**Occurrence (%)**
Common name	**Scientific name**		
Albatross	*Domedea* sp.	1	0.4
Australasian gannet	*Morus serrator*	69	29.9
Black petrel	*Procellaria parkinsoni*	67	29.0
Bryde's whale	*Balaenoptera edeni*	2	0.9
Buller's shearwater	*Puffinus bulleri*	12	5.2
Cape petrel	*Daption* sp.	2	0.9
Diving petrel	*Pelecanoides* sp.	23	10.0
Fluttering shearwater	*Puffinus gavia*	17	7.4
Giant petrel	*Macronectes giganteus*	3	1.3
Mollymawk	*Thalassarche* sp.	3	1.3
Prion	*Pachyptila* sp.	2	0.9
Skua	*Catharacta* sp.	1	0.4
Storm petrel	*Fregetta* sp.	15	6.5
Tern	*Sterna* sp.	13	5.6
Unidentified baleen Whale		1	0.4
Total		**231**	**100**

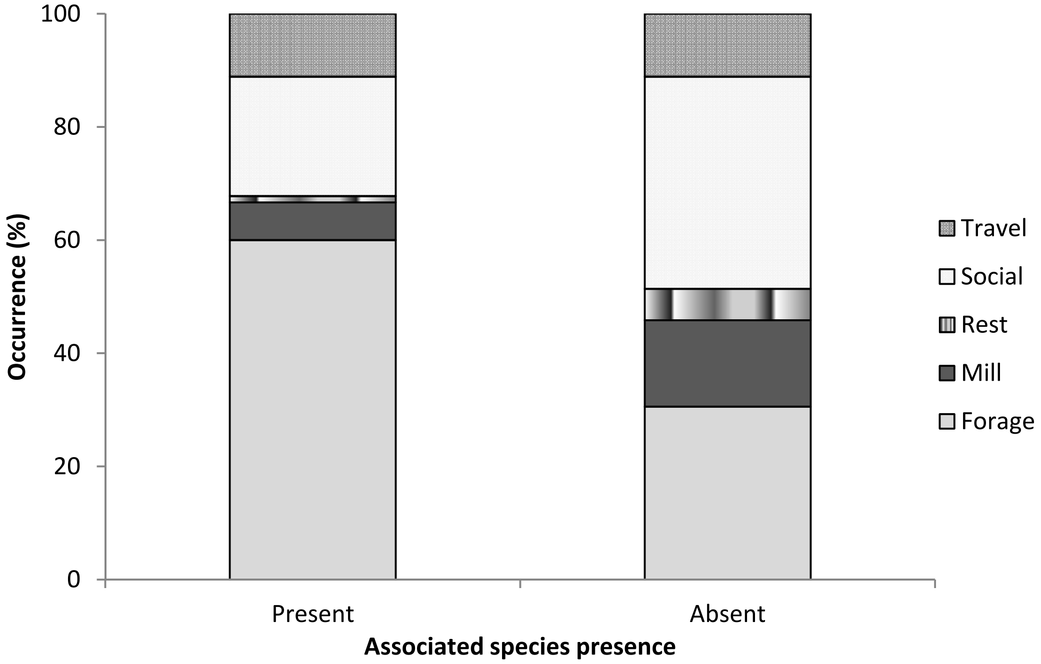

Figure 3.9: Common dolphin (*Delphinus* sp.) behaviour in the presence/absence of associated species between April 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

3.5 Discussion

In the central BOP, New Zealand, common dolphin behaviour in the presence of the observation platform was primarily influenced by water depth, group size and the presence of Australasian gannets; whereas, time of day, seasonality and group composition did not appear to influence their behaviour for this region. Potential reasons for these variations in behaviour are discussed herein.

3.5.1 Foraging

It is widely accepted that the most important factor influencing an animal's activity budget is food availability (e.g. Shane *et al.,* 1986; Hanya, 2004; Stelle *et al.,* 2008). Foraging was frequently recorded (49.0%) in the presence of the tour boat in the central BOP. This highlights the importance of managing the way in which tour boats interact with the dolphins. Foraging (in the presence of the tour boat) was more frequently recorded in the central BOP than in the Bay of Islands (Constantine & Baker, 1997) or the Hauraki Gulf (Stockin *et al.,* 2008b), where common dolphins spent 19.1% and 21.6% of their time feeding in the presence of tour boat(s), respectively. There are a number of possible explanations for this difference. Firstly, foraging could potentially occur more frequently within the central BOP than in other regions. The BOP provides a year round foraging habitat for common dolphins, with peaks in the abundance of prey species such as anchovy (*Engraulis australis*) and arrow squid (*Nototodarus* sp.) in coastal waters during warmer months (Ayling & Cox, 1982; MFish, 2011a, b), and jack mackerel (*Trachurus* sp.) in offshore waters of the BOP between June and November (MFish, 2011c). Other known common dolphin prey species such as kahawai (*Arripis trutta*), yellow-eyed mullet (*Aldrichetta forsteri*), flying fish (*Cypselurus lineatus*), parore (*Girella tricuspidate*), and garfish, (*Hyporamphus ihi*) also occur within the region (Neumann & Orams, 2003). However, it is likely that foraging in the central BOP occurs at a similar level to the western BOP, where the activity budget in the absence of any boats indicates that common dolphins only spent 17.0% of their time foraging (Neumann, 2001c). This is further supported by preliminary results from a behavioural study underway in the central BOP, which indicates that foraging accounts for approx 13% of the initial activity budget (Meissner & Stockin, 2011).

Secondly, the observation platform utilised during the present study (*Gemini Galaxsea,* a 60 ft ketch sailboat powered by a four stroke 120 hp diesel engine) may not alter common dolphin foraging behaviours as much as tourism platforms that were used in the Bay of Islands (two catamarans, 39 and 66 ft long with diesel powered jet and propeller driven engines) and Hauraki Gulf (a 66 ft catamaran powered by twin 350 hp diesel engines). In the Bay of Islands, common dolphins were most likely to be foraging (40.0%) prior to the approach of the tourism vessel, once the boat was within 100 m of the dolphins, feeding was most likely to change to bowriding (47.0%) (Constantine & Baker, 1997). In the Hauraki Gulf the time spent foraging also decreased in the presence of the tour boat, *Dolphin Explorer*; dolphins exhibited a preference to shift their behaviour to socialising or milling and took significantly longer to return to foraging in the presence of the tour boat (Stockin *et al.,* 2008b). Behavioural responses to boat presence may vary according to the type and number of vessels, nature of approach and length of interaction, cetacean species, age class and gender (e.g. Constantine & Baker, 1997; Constantine, 2001; Lusseau, 2003; Richter *et al.,* 2006; Stockin *et al.,* 2008b; Martinez, 2010). These differences highlight the need to assess the impacts of cetacean-watching tourism activities on a case by case basis. However, without pre-approach (control) data from *Gemini Galaxsea,* the differences in behavioural transitions between observation platforms can only be inferred.

Foraging is likely over-represented in the current activity budget due to the conspicuous surfacing behaviour of foraging dolphins and the presence of key indicator species, such as Australasian gannets, making them easier to locate. As stated above, foraging was more prevalent in the absence of tour boats within the Hauraki Gulf (Stockin *et al.,* 2008b). Without an independent research platform, it is not possible to discern the level of bias in the behavioural data collected on board *Gemini Galaxsea*.

Diurnal peaks in foraging were not evident during the present study, this corresponds with previous reports from the western BOP (Neumann, 2001c) and Hauraki Gulf (Stockin *et al.,* 2009a). However, Neumann (2001c) reported a higher proportion of early morning feeding, which concurs with preliminary results from the central BOP (Meissner & Stockin, 2011). It is likely that night-time foraging activities also occur, as foraging on the deep-scattering layer at night has been reported in a number of common dolphin populations worldwide (e.g. Young & Cockcroft, 1994; Scott & Cattanach, 1998; Goold, 2000). Neumann (2001b) hypothesised that a peak in foraging may occur around dusk, once the deep-scattering layer rises close to the surface. This theory is supported by the stomach contents of common dolphins in New Zealand waters (Meynier *et al.,* 2008), which show oceanic species associated with the deep-scattering layer in their diet, particularly arrow squid (*Nototodarus* sp.).

Seasonally, however, no significant variation was detected. Foraging was most prevalent during autumn, when larger group sizes were also observed. This coincides with seasonal increases in common dolphin prey species such as anchovy and arrow squid in BOP coastal waters (Ayling & Cox, 1982; MFish, 2011a, b). In contrast, foraging was significantly more frequent during winter and spring in the Hauraki Gulf (Stockin *et al.,* 2009a), when nutrient upwelling leads to increased prey availability within the region (Stockin *et al.,* 2008a). Neumann (2001b) hypothesised that the lower proportion of time spent foraging in the western BOP may be attributed to prey being patchier than in the confined waters of the Hauraki Gulf, thus necessitating increased travel to locate food. This may also be applicable to the central BOP. However, common dolphin habitat use can only be inferred pending the collection of effort-related control and impact (in the presence of boats) data via surveys currently underway in the region (Meissner, unpubl. data).

3.5.2 Travelling

Travelling in the presence of the tour boat was least frequent in the central BOP (12.0%) when compared to the Hauraki Gulf (34.7%) and was more closely related to results from the Bay of Islands (16.7%). Preliminary control data from the western and central BOP suggest that travelling is more frequent in the absence of tour boat(s) (54.8%: Neumann, 2001c; 68.5%: Meissner & Stockin, 2011, respectively). This indicates that common dolphin groups may have transitioned from travelling to a different behaviour at the onset of encounters with *Gemini Galaxsea*. The increased amount of time spent travelling in the BOP may be attributed to prey being sparsely distributed, as suggested by Neumann (2001c), thus necessitating increased travel to locate food. The search for mating opportunities or special environments to give birth may also influence cetacean travel (e.g. Waples *et al.,* 1998; Clapham, 1996). However, these behaviours were not evident for common dolphins during the present study.

3.5.3 Socialising

The amount of time committed to socialising probably depends on how easily other more immediate requirements (e.g. food) can be satisfied. During the present study, social behaviours (e.g. belly-to-belly contact) primarily occurred during summer when large nursery groups were also reported in the central BOP, supporting the concept of reproductive seasonality in the population (Gaborit-Haverkort & Stockin, in press). Social behaviours in the presence of the tour boat were more frequent (30.0%) during the present study than in the Bay of Islands (9.5%) and Hauraki Gulf (10.4%) (Constantine & Baker, 1997; Stockin *et al.,* 2008b). There is evidence suggesting that common dolphins often alter their behaviour to milling or socialising in the presence of boats (Stockin *et al.,* 2008b), which would account for the higher perceived proportion of socialising in the presence of *Gemini Galaxsea*. Especially when compared to preliminary results from the central BOP, which indicate that socialising is infrequent (1.9%) in the absence of boat(s) (Meissner & Stockin, 2011).

Socialising may also be over-represented during the present study due to the way in which behaviour was recorded on board *Gemini Galaxsea,* conspicuous behaviours associated with socialising (e.g. breaching, back slapping and spy-hopping) were more likely to be recorded than less obvious activity states such as resting or milling. Additionally, any number of sub-groups within the vicinity may be attracted to the vessel, and thus would be more likely to socialise with each other. Pending results from an independent platform in the central BOP (Meissner, unpubl. data), the importance of the region for breeding and/or nursing groups and the influence of tour boats on common dolphin behaviour can only be inferred.

3.5.4 Milling

Milling accounted for 6.0% of the current activity budget, which differs from the Hauraki Gulf, where milling occured in the presence of boats 27.9% of the time (Stockin *et al.,* 2008b). These results are more consistent with surveys conducted in the Bay of Islands, where milling accounted for 9.5% of the activity budget in the presence of the tour boat (Constantine & Baker, 1997). However, preliminary control data from the western and central BOP indicate milling as the second most frequent activity in the absence of boats (20.5%: Neumann, 2001c; 14.8%: Meissner & Stockin, 2011, respectively). Therefore, it is likely that milling dolphins may have altered their behaviour to socialising in the presence of *Gemini Galaxsea.*

The non-directional movement associated with milling may also indicate an early stage of foraging, when dolphins are searching for potential prey (Neumann, 2001c). If this is accurate, then the low proportion of milling reported here may indicate that dolphin prey species are concentrated within the central BOP thus necessitating less travel to locate food. However, it is more likely attributed to the recording of behavioural states not being a standardised process onboard *Gemini Galaxsea.* Therefore, less conspicuous activities such as milling and resting may be under-represented.

3.5.5 Resting

In the central BOP, 3.0% of the activity budget in the presence of the tourism platform was attributed to rest. This concurs with results from the Bay of Islands and Hauraki Gulf, where common dolphins spent 2.4 to 5.4% of their time resting in the presence of boat(s), respectively (Constantine & Baker, 1997; Stockin *et al.,* 2008b). Control data from the Bay of Islands and Hauraki Gulf indicate that resting is more frequent in the absence of boat(s) (9.0 to 7.7%, respectively) (Constantine & Baker, 1997; Stockin *et al.,* 2008b). It is possible that the approach of the tourism vessel could have triggered a change in behaviour, however, according to tourism impact studies conducted in the Bay of Islands (Constantine & Baker, 1997) and Hauraki Gulf (Stockin *et al.,* 2008b), rest was the behavioural state least likely to change in the presence of the tourism vessel. Control data from the western and central BOP (preliminary result) indicate that resting occurs even less frequently (0.4 to 1.9%, respectively) than reported herein (Neumann, 2001c; Meissner & Stockin, 2011). The low proportion of resting dolphins may be an under-representation, due to the inconspicuous surfacing behaviour of resting dolphins making them difficult to find (e.g. Neumann, 2001c).

Overall, resting dolphins occurred in the shallowest waters (median = 25.5 m) during this study. This is consistent with previous reports from the Hauraki Gulf (Stockin *et al.,* 2009a), and may be attributed to dolphins preferring shallow waters to gain better protection from predators (e.g. Visser, 1999b; Markowitz, 2004).

3.5.6 Group size and composition

Common dolphin behaviour varied significantly according to group size, with foraging occurring more often than expected in large (> 50 animals) groups, while resting, socialising and milling occurring more often in smaller (≤ 50 animals) groups. These findings concur with those from the Hauraki Gulf (Stockin *et al.*, 2009a). This increase in foraging activity with group size may occur because of the fission-fusion nature of common dolphin societies

(Neumann, 2001c), as groups merge to form larger aggregations for the purpose of foraging (Neumann & Orams, 2003; Burgess, 2006; De la Brosse, 2010).

The presence of immature animals had a significant influence on common dolphin behaviour, with foraging occurring more often than expected in groups containing immature animals. This differs from the Hauraki Gulf, where groups containing immature animals were recorded resting, milling and socialising more than mature groups (Stockin *et al.,* 2009a). This discrepancy may be attributed to the recording of group composition and behaviour not being a standardised process on board *Gemini Galaxsea.* Pending effort based systematic surveys, the way in which common dolphin groups with immature animals utilise central BOP waters can only be inferred.

3.5.7 Associated species

Common dolphins in the central BOP were observed in association with 13 avian species, as well as Bryde's whales and a single unidentified whale. Common dolphin behaviour had a significant influence on associated species occurrence, with 71.1% of foraging groups occurring in the presence of associated species. This indicates that associated species may be attracted to common dolphin groups engaged in foraging activities. During feeding, common dolphins appear to work cooperatively to herd large schools of bait fish into tight aggregations, where other species such as birds and whales may take advantage of this food source (Neumann & Orams, 2003; Burgess, 2006; De la Brosse, 2010). This is further supported by the low presence of associated species while dolphins were engaged in less active behavioural states such as resting (1.1%) and milling (6.7%). Common dolphins were primarily observed in association with the Australasian gannet (29.9%) and black petrel (29.7%). During Australasian gannet associations, foraging vs. non-foraging behaviours varied significantly, with 61.8% of foraging occurring in the presence of gannets. These results reflect those of Stockin *et al.* (2009) in the Hauraki Gulf. Conversely, foraging vs. non-foraging behaviours did not vary significantly during black petrel associations. This may be attributed to black petrels being primarily nocturnal feeders, preying on bioluminescent squid from the deep-scattering layer (Imber, 1976). However, studies on the foraging relationships between oceanic dolphins and black petrels in the Eastern Tropical Pacific indicate that this species primarily feeds during the day by diving under the surface scavenging for scraps of prey dismembered by dolphin species such as false killer

(*Pseudorca crassidens*) and pilot whales (*Globicephala* spp.) and are rarely associated with common dolphins (Pitman & Ballance, 1992). Further research is required in order to gain a full understanding of black petrel/common dolphin associations observed within BOP waters.

During the present study only the presence/absence of associated species was recorded, the number of species present and the exact nature of these associations were not recorded. Burgess (2006) identified a number of ways in which avian and other cetacean species may interact with common dolphin groups. Australasian gannets may, for example, be seen following, circling above, diving or resting on the water in the presence of common dolphin groups. Pending further results, the importance of common dolphin associations within the central BOP can only be inferred.

3.5 Conclusion

While the presented data do not represent an activity budget owing to bias in way behavioural data were collected from the tour boat, they do offer first insights into how dolphins behave around this tour boat. Foraging and socialising frequently occurred in the presence of the observation platform (*Gemini Galaxsea*), which supports the hypothesis that the central BOP is utilised by common dolphins for feeding and potential breeding purposes. Behavioural responses to boat presence may vary according to the type and number of vessels, nature of approach and length of interaction, cetacean species, age class and gender. These differences highlight the need to assess the impacts of cetacean-watching activities on a case by case basis within the region.

Chapter Four: Cetacean occurrence in the central Bay of Plenty

Figure 4.1: Killer whale (*Orcinus orca*) sighted in the central Bay of Plenty (BOP), New Zealand (Photo: Beverly Rendall).

4.1 Abstract

Herein, the occurrence and group dynamics (e.g. group size and composition) of other cetacean species observed from the Platform of Opportunity (PoO), *Gemini Galaxsea* in the central Bay of Plenty (BOP) are assessed in relation to temporal trends, water depth and associated species. Sightings data were collected between March 1998 and May 2011 during 2364 boat-based surveys on board tourism vessel *Gemini Galaxsea.* Eleven cetacean species (6 Mysticeti and 5 Delphinidae, including *Delphinus* sp.) were identified as utilising central BOP waters. Cetacean sightings primarily occurred in the area between Karewa Island, Mayor Island (Tuhua) and Motiti Island in the central BOP. The majority of delphinid sightings occurred in spring and principally involved bottlenose dolphin, *Tursiops truncatus* (50.5%) and killer whale, *Orcinus orca* (42.9%). Pilot, *Globicephala* spp. (3.8%) and false killer whale, *Pseudorca crassidens* (2.9%) sightings were less frequent. Group sizes ranged from solitary to 200+ individuals. Calf presence was recorded for bottlenose dolphins during summer and autumn and killer whales during spring and autumn. Pilot and false killer whale calves were not recorded during the study period. The majority of baleen whale sightings occurred during winter and spring and involved minke, *Balaenoptera acutorostrata/bonaerensis* (44.3%), blue, *B. musculus* (19.0%) and Bryde's whale, *B. edeni* (16.5%). Humpback, *Megaptera novaeangliae* (10.1%), sei, *B. borealis* (8.9%) and southern right whale, *Eubalaena australis* (1.3%) sightings were less frequent. Group sizes ranged from solitary to four individuals, with results highly skewed towards solitary animals (79%). Cow-calf pairs were observed during spring for all baleen whales except sei and humpback. Cetaceans were primarily observed in association with the Australasian gannet (*Morus serrator*) as well as various species of petrel (Procellariiformes) and shearwater (*Puffinus* sp.). Bottlenose dolphins and false killer whales were sighted together in mixed species groups (*n* = 3). Bryde's whales were also sighted in association with common dolphins (*n* = 3).

4.2 Introduction

New Zealand has earned a reputation for the sizeable number of marine mammals which live or migrate through its waters, including 41 species of cetacean (Suisted & Neale, 2004). New Zealand's Bay of Plenty (BOP) (Figure 2.2, Chapter 2) provides habitat for a wide range of cetacean species (Clement, 2009; Gaborit-Haverkort & Stockin, in press). Following an extensive historic review of marine mammal occurrence within the East Coast Bay of Plenty (ECBOP) Conservancy (Gaborit-Haverkort & Stockin, in press), 26 cetacea (19 Odontoceti and 7 Mysticeti) were identified as utilising these waters. In order to compare and contrast their occurrence and use of these waters compared with the focal species (*Delphinus* sp), data relating to other cetacea recorded from the same Platfrom of Opportunity (PoO), tour vessel *Gemini Galaxsea*, during the same study period, are examined. Herein, the occurrence and distribution of other cetacea sighted within the central BOP, New Zealand are examined in relation to group dynamics, environmental parameters and the presence of associated species. Cetacean occurrence and residency patterns are discussed in context to that for *Delphinus*.

4.3 Methods

4.3.1 Study site

The BOP (Figure 2.2, Chapter 2) is situated on the east coast of the North Island of New Zealand extending from Waihi east to Lottin Point near Cape Runaway (latitude 37°25' to 37°33' S; longitude 175°55' to 178°10' E). Water depths in the BOP can exceed 1000 m (within Tauranga and White Island trenches); however, within the operational area covered during this study (Figure 2.2, Chapter 2) the water depth does not exceed 600 m. The continental shelf (max depth 100 m) extends out up to 20 miles off shore in the central BOP, providing shallow waters for nursing and breeding purposes. The BOP provides habitat for a wide range of cetacean species (Clement, 2009; Gaborit-Haverkort & Stockin, in press). BOP waters are positioned within an important southern migratory corridor, which leads from rich feeding grounds in the south to tropical breeding/calving grounds in the north (Clapham & Mead, 1999). Inshore (12 nm limit) areas also offer sheltered productive waters for resident cetaceans, while more exposed offshore waters provide habitat for deep-water species (Gaborit-Haverkort & Stockin, in press).

4.3.2 Data collection

Cetacean observations were conducted from a PoO, the cetacean-watching vessel *Gemini Galaxsea* (a 60 ft ketch sailboat; Figure 2.3, Chapter 2). Tours departed daily at 0830 h, from Tauranga Harbour (37°40’ S, 176°10’ E) between the northern permit limits and Motiti Island (rarely venturing further east) (Figure 2.2, Chapter 2). The survey speed varied between 5 to 8 kts and the direction taken differed daily depending on prevailing sea conditions.

Observations were conducted by experienced observers by naked eye and with binoculars (Steiner Commander 7x50). Dolphins and whales were detected using sighting cues such as splashing and/or silhouettes of porpoising animals, water disturbance, sightings of dorsal fins and the presence of key indicator species (mainly the Australasian gannet, *Morus serrator*) (Stockin *et al.,* 2008a).

Once within 400m of any cetacean species, the vessel would slow down to approach speed (< 5 kts). The start time and location for the encounter were then recorded using a Global Positioning System (GPS). The species, presence/absence of immature animals and associated species, depth (0.1 m accuracy) and group size were subsequently recorded.

4.3.3 Data analysis

As per Martinez *et al.* (2010), the Trip Encounter Rate (TER) was calculated as the total number of sightings per total number of surveys (trips) conducted. Group size categories for bottlenose dolphins (*Tursiops truncatus*), baleen whales (Mysticeti) and killer whales (*Orcinus* orca) were adopted from Martinez *et al.* (2010) in order to perform direct comparisons with previous research conducted in the Hauraki Gulf, New Zealand. False killer whale (*Pseudorca crassidens*) and pilot whale (*Globicephala* spp.) group size categories were assigned according to best fit. Group size was classified into the following species-specific categories:

- Bottlenose dolphins: 1-10, 11-20, 21-30, 31-50, 41-50 and 50+ individuals
- False killer whale: 1-50, 50-100 and 100+ individuals
- Pilot whales: 1-50, 50-100 and l00+ individuals
- Killer whales: 1-5, 6-10 and 11+ individuals
- Baleen whales: based on the number of individual whales (no pooling)

Group composition was analysed in terms of the presence of immature animals. Seasonal analyses were based on the austral seasons as follows: spring (September to November), summer (December to February), autumn (March to May) and winter (June to August).

The depth gauge used on board *Gemini Galaxsea* provided water depth (0.1 m accuracy) readings up to 100 m. There after, due to a technical issue with the depth sounder, depths exceeding 100 m were estimated from marine charts using GPS positions (1-2 m accuracy). The subsequent water depths were then analysed as raw data.

In order to avoid pseudo-replication, data were filtered prior to analyses to remove any duplicate records (e.g. those sightings in close succession, within an hour of each other). The distributions of continuous response variables (depth) were initially tested for normality using Kolmogorov-Smirnov tests. In most cases, data were not normally distributed so non-parametric Kruskal-Wallis tests were applied. Pearsons χ^2 tests were used to examine categorical variables (group size and composition). A Fisher's Exact test was performed when categorical data did not meet the conditions for Chi-square analyses. All statistical analyses were conducted using SPSS. ArcGIS (Version 9.2; © ESRI Inc.) was used to create distribution maps.

4.4 Results

4.4.1 Cetacean occurrence

Data were collected between March 1998 and May 2011 during 2364 boat-based surveys on board *Gemini Galaxsea.* Eleven cetacean species (6 Mysticeti and 5 Delphinidae) were identified in central BOP waters. The majority of cetacean sightings involved bottlenose dolphins (28.8%, *n* = 53), killer whales (24.5%, *n* = 45) and minke whales (*Balaenoptera acutorostrata/bonaerensis*) (19.0%, *n* = 35). The least frequently recorded species included southern right (*Eubalaena australis*) (0.5%, *n* = 1), false killer (1.6%, *n* = 3) and pilot whales (2.2%, *n* = 4) (Table 4.1).

Table 4.1: Cetacean sightings for the central Bay of Plenty (BOP), New Zealand, between March 1998 and May 2011.

Common name	**Scientific name**	**Total No. of sightings per species**	**Occurrence (%)**	**TER**
Blue whale	*Balaenoptera musculus*	15	8.2	0.006
Bottlenose dolphin	*Tursiops truncatus*	53	28.8	0.022
Bryde's whale	*B. edeni*	13	7.1	0.005
False killer whale	*Pseudorca crassidens*	3	1.6	0.001
Humpback whale	*Megaptera novaeangliae*	8	4.3	0.003
Killer whale	*Orcinus orca*	45	24.5	0.019
Minke whale	*B. acutorostrata/ bonaerensis*	35	19.0	0.015
Pilot whale	*Globicephala* spp.	4	2.2	0.002
Sei whale	*B. borealis*	7	3.8	0.003
Southern right whale	*Eubalaena australis*	1	0.5	0.000
Unidentified baleen whale		9	4.9	0.004
Unidentified beaked whale		2	1.1	0.001
Unidentified dolphin		1	0.5	0.000
Unidentified whale		52	28.3	0.022

4.4.2 Odontoceti (toothed whales, dolphins and porpoises)

All toothed whales identified during this study were members of the Delphinidae family (delphinids). Delphinid sightings (n = 105) occurred throughout the central BOP. However, only bottlenose dolphins and killer whales were sighted within Tauranga Harbour (37°39’ S, 176°10’ E, Figure 4.2). The majority of sightings involved bottlenose dolphin (50.5%, n = 53) and killer whale (42.9%, n = 45); pilot (3.8%, n = 4) and false killer whale (2.9%, n = 3) sightings were less frequent (Table 4.1, Figure 4.2).

Bottlenose dolphins, killer, pilot and false killer whales were observed in association with seven avian species in the central BOP, primarily Australasian gannets and black petrels (*Procellaria* sp.) (Table 4.2). Bottlenose dolphins and false killer whales were also sighted in mixed-species groups on three occasions during the study period (Table 4.2).

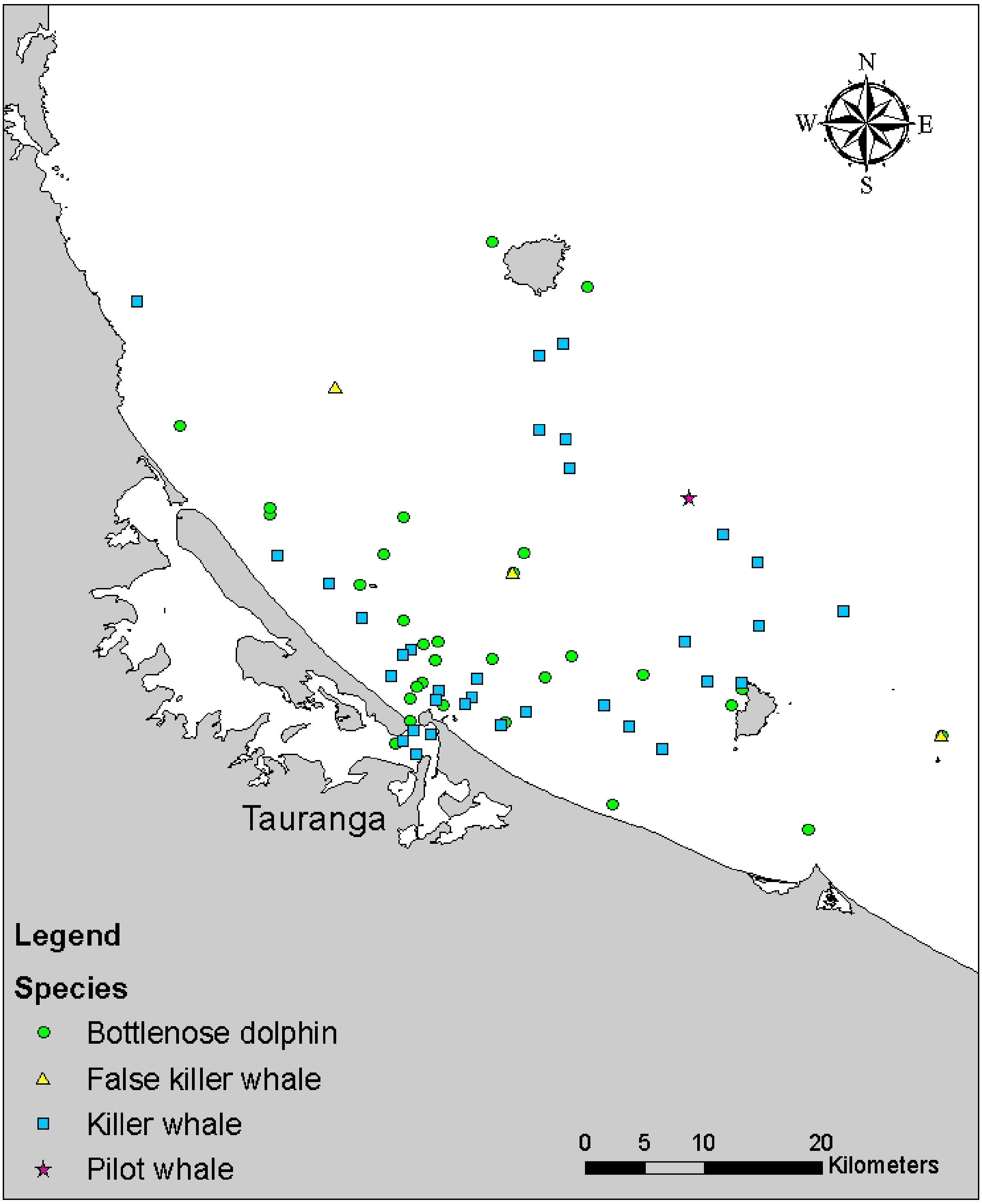

Figure 4.2: Delphinid (Delphinidae) distribution between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand.

Table 4.2: Species observed in association with bottlenose dolphin (BD), false killer whale (FKW), killer whale (KW) and pilot whale (PW) between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand.

Associated species		**Number of associations = % (n)**			
Common name	**Scientific name**	**BD**	**FKW**	**KW**	**PW**
Australasian gannet	*Morus serrator*	23.3 (7)	30.0 (3)	15.4 (4)	
Black petrel	*Procellaria* sp.	23.3 (7)	30.0 (3)	38.5 (10)	50.0 (1)
Bottlenose dolphin	*Tursiops truncatus*		30.0 (3)		
Buller's shearwater	*Puffinus bulleri*	3.3 (1)		11.5 (3)	
Diving petrel	*Pelecanoides* sp.	10.0 (3)		11.5 (3)	50.0 (1)
False killer whale	*Pseudorca crassidens*	10.0 (3)			
Fluttering shearwater	*Puffinus gavia*	10.0 (3)	10.0 (1)	7.7 (2)	
Storm petrel	*Fregetta* sp.	6.7 (2)		11.5 (3)	
Tern	*Sterna* sp.	13.3 (4)		3.8 (1)	
Total		**100 (30)**	**100 (10)**	**100 (29)**	**100 (2)**

4.4.2.1 Bottlenose dolphin (*Tursiops truncatus*)

Bottlenose dolphins were encountered during 2.2% (n = 53) of total trips (n = 2364) (Table 4.1). Bottlenose dolphins were present throughout the year, although TER varied by season, peaking during winter (Figure 4.3). Bottlenose dolphins were sighted in association with false killer whales (10.0%, n = 3) as well as Australasian gannets (23.3%, n = 7) and various species of petrel (40.0%, n = 12), shearwater (*Puffinus* sp.; 13.3%, n = 4) and tern (*Sterna* sp.; 13.3%, n = 4; Table 4.2).

Bottlenose dolphins were sighted over water depths ranging from 3.8 to 109.0 m (mean = 25.1, SD = 18.6, n = 42). The majority of sightings occurred in water depths less than 50.0 m (97.6%, n = 41), except for one encounter at 109.0 m, involving a large group (100+ individuals) in association with false killer whales. Bottlenose dolphins were sighted in shallower water in winter (median = 18.0, IQR = 9.0-33.0, n = 6) and deeper water during autumn (median = 24.0, IQR = 19.3-31.8, n = 10; Figure 4.4). However, no significant seasonal variation in water depth was found ($H = 1.169$, df = 3, $p > 0.05$).

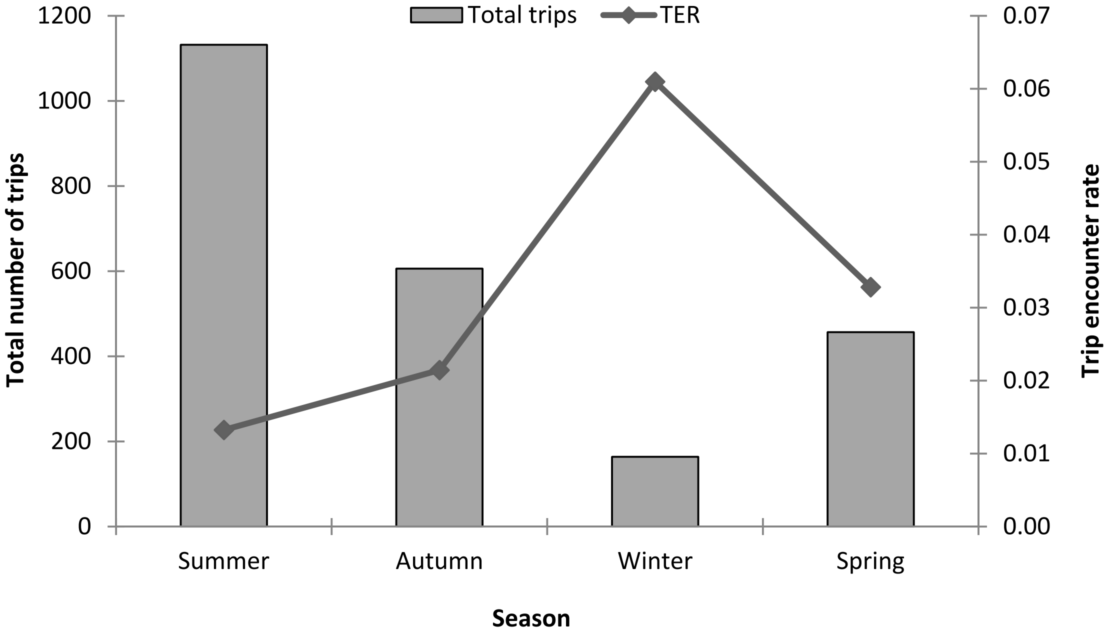

Figure 4.3: Seasonal Trip Encounter Rate (TER) for bottlenose dolphins (*Tursiops truncatus*) between March 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand.

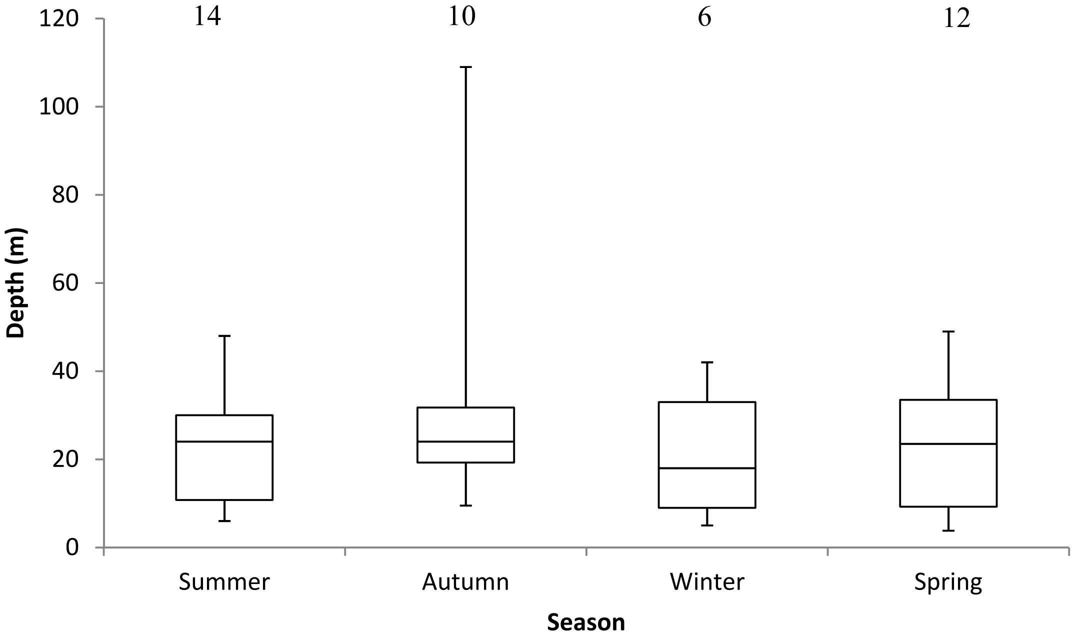

Figure 4.4: Seasonal water depth for bottlenose dolphin (*Tursiops truncatus*) sightings between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: Lines represent the median, boxes the 25th and 75th interquartiles and bars the range. Numbers above the boxess represent the sample number (*n*).

Group size was recorded during 62.3% (*n* = 33) of bottlenose dolphin encounters, ranging from two (*n* = 4) to 50+ (*n* = 2) individuals. Larger groups (> 50 individuals) were sighted in association with false killer whales (*Pseudorca crassidens*). The most and least frequently recorded group size involved 11 to 20 animals (39%, *n* = 13) and 31 to 50 individuals (0%, *n* = 0; Figure 4.5), respectively. No seasonal variation in group size was detected ($\chi^2 = 0.0885$, df = 1, $p > 0.05$). In the central BOP, calves were recorded during 9% (*n* = 5) of bottlenose dolphin encounters, primarily in summer and autumn.

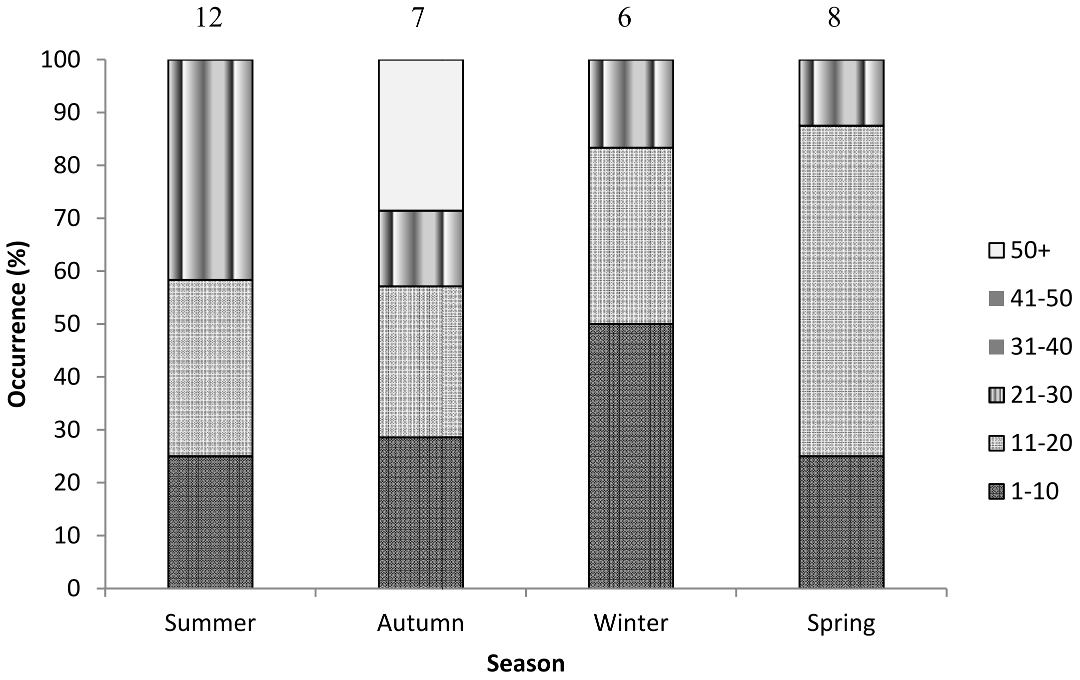

Figure 4.5: Seasonal occurrence of bottlenose dolphin (*Tursiops truncatus*) group sizes observed between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

4.4.2.2 False killer whale (*Pseudorca crassidens*)

False killer whales were encountered on three occasions during the study period (Table 4.1), each time in association with bottlenose dolphins. TER varied by season and was highest in autumn, with no sightings confirmed during winter or spring. Encounters occurred in water depths ranging from 45.0 to 109.0 m (mean = 67.0, SD = 43.8, *n* = 3). Group sizes ranged from 45 (*n* = 1) to 100+ (*n* = 2) individuals. False killer whales were sighted in association with bottlenose dolphins (30.0%, *n* = 3), as well as Australasian gannets (30.0%, *n* = 3), black petrels (30.0%, *n* = 3) and fluttering shearwaters (*P. gavia*; 10.0%, *n* = 1; Table 4.2). No false killer whale calves were recorded during the study period.

4.4.2.3 Killer whale (*Orcinus orca*)

Killer whales were encountered on 45 occasions (Table 4.1). TER varied by season and was highest in spring and lowest in summer and winter (Figure 4.6). Killer whales in the central BOP were sighted in association with various species of petrel (55.2%, *n* = 16), shearwaters (17.0%, *n* = 5), Australasian gannets (13.8%, *n* = 4) and terns (3.5%, *n* = 1; Table 4.2). Killer whales were sighted over water depths ranging from 3.8 to 115.0 m (mean = 39.2, SD = 34.5, *n* = 36). Seasonally, the median water depth in which killer whales were observed ranged from 58.0 m in winter (IQR = 39.5-76.5, *n* = 2) to 23.0 m in autumn (IQR = 17.3-25.0, *n* = 10; Figure 4.7), although these differences were not found to be significant ($H = 0.882$, df = 3, $p > 0.05$).

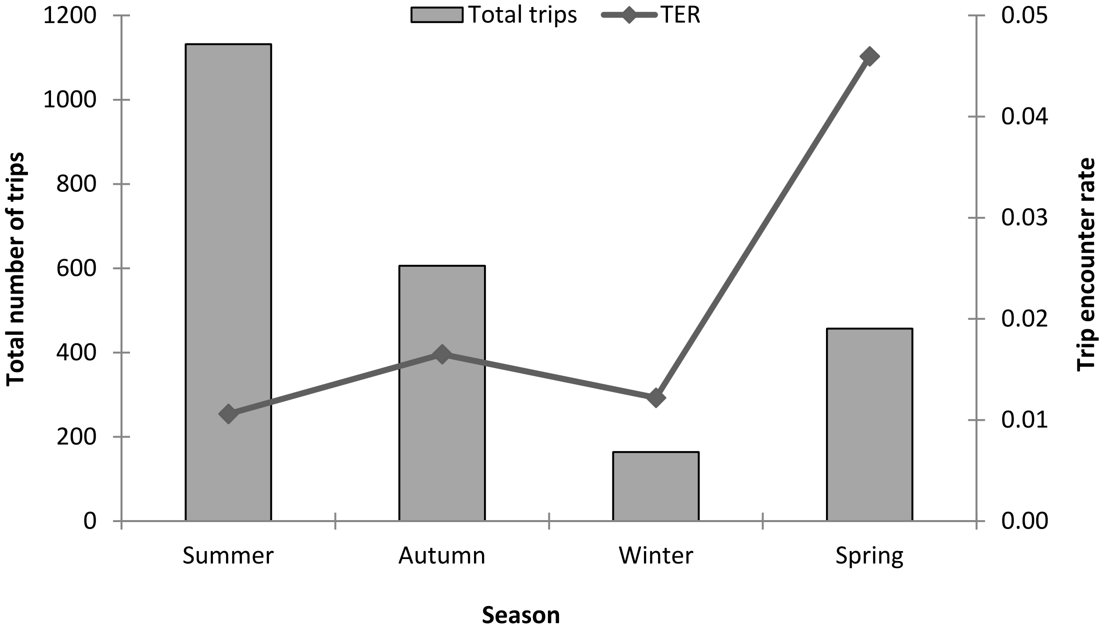

Figure 4.6: Seasonal Trip Encounter Rate (TER) for killer whale (*Orcinus orca*) between March 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand.

Group size was assessed during 77.8% (*n* = 35) of killer whale encounters, with group size ranging from one (*n* = 1) to 30+ (*n* = 1) individuals. The most and least frequently recorded group size involved six to 10 animals (51%, *n* = 18), and one to five individuals (23%, *n* = 8; Figure 4.8), respectively. However, no overall seasonal variation in group size was detected ($\chi^2 = 2.3066$, df = 2, $p > 0.05$). Calves were sighted during 33.3% (*n* = 15) of killer whale observations, primarily in spring and autumn.

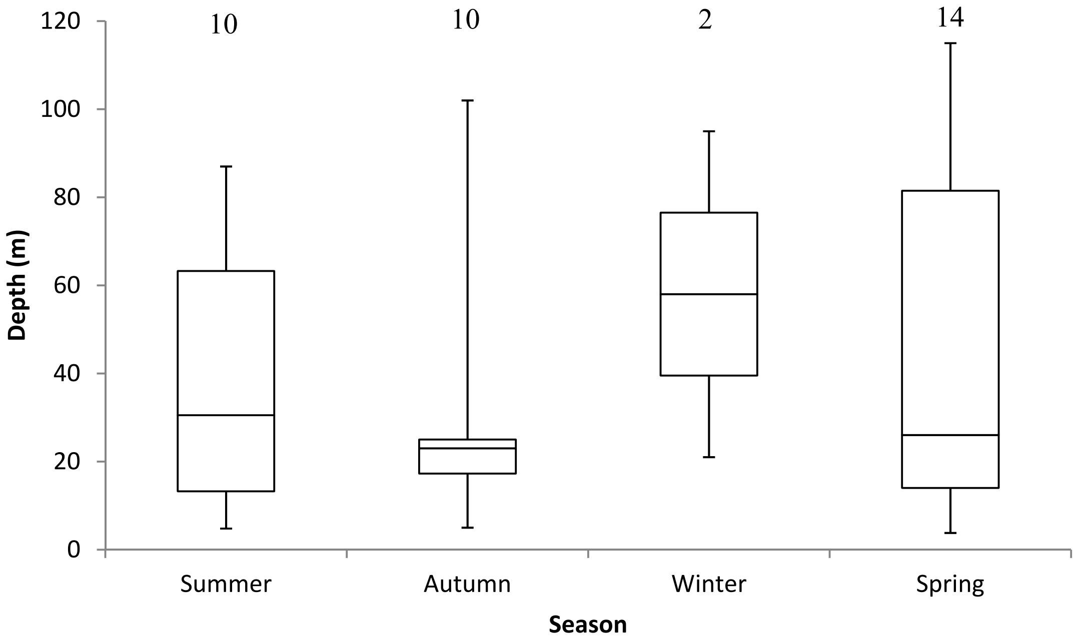

Figure 4.7: Seasonal water depth for killer whale (*Orcinus orca*) sightings between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: Lines represent the median, boxes the 25th and 75th interquartiles and bars the range.
Numbers above the boxes represent the sample number (*n*).

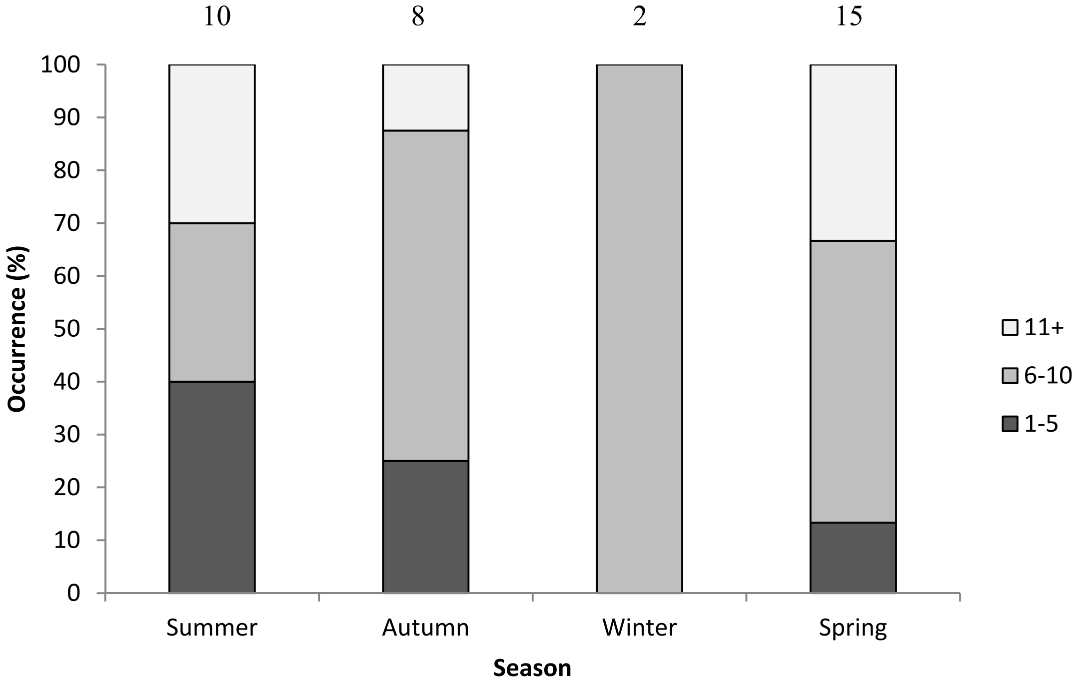

Figure 4.8: Seasonal occurrence of killer whale (*Orcinus orca*) group sizes observed between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: numbers above the bars represent the sample number (*n*).

4.4.2.4 Pilot whale (*Globicephala* spp.)

Pilot whales were encountered on four independent occasions (Table 4.1). TER varied by season and was highest in spring and summer; pilot whales were not sighted during autumn or winter. The depth of sightings was only recorded during summer (52.0 m) and spring (83.0 m). Group size was assessed on two occasions, both involving groups of 30 to 50 animals. No pilot whale calves were recorded during the study period, which is most likely attributed to the small sample size. Pilot whales were only ever sighted in association with black petrels (50.0%, *n* = 1) or diving petrels (*Pelecanoides* sp.; 50.0%, *n* = 1; Table 4.2).

4.4.3 Mysticeti (baleen whales)

Baleen whales were encountered during 3.0% (*n* = 79) of total trips (*n* = 2364). Baleen whales were primarily encountered in the area between Karewa Island, Mayor Island (Tuhua) and Motiti Island (Figure 4.9). The majority of baleen whale sightings involved minke (44.3%, *n* = 35), blue (*Balaenoptera musculus*) (19.0%, *n* = 15) and Bryde's whales (*B. edeni*) (16.5%, *n* = 13). Humpback (*Megaptera novaeangliae*) (10.1%, *n* = 8), sei (*B. borealis*) (8.9%, *n* = 7) and southern right whale (1.3%, *n* = 1) sightings were less frequent (Table 4.1, Figure 4.9).

Baleen whales were observed in association with common dolphins (*n* = 3) and nine avian species within the central BOP, primarily the Australasian gannet, as well as various species of petrel (including giant petrel, *Macronectes giganteus*), shearwater, prion (*Pachyptila* sp.) and tern (Table 4.3).

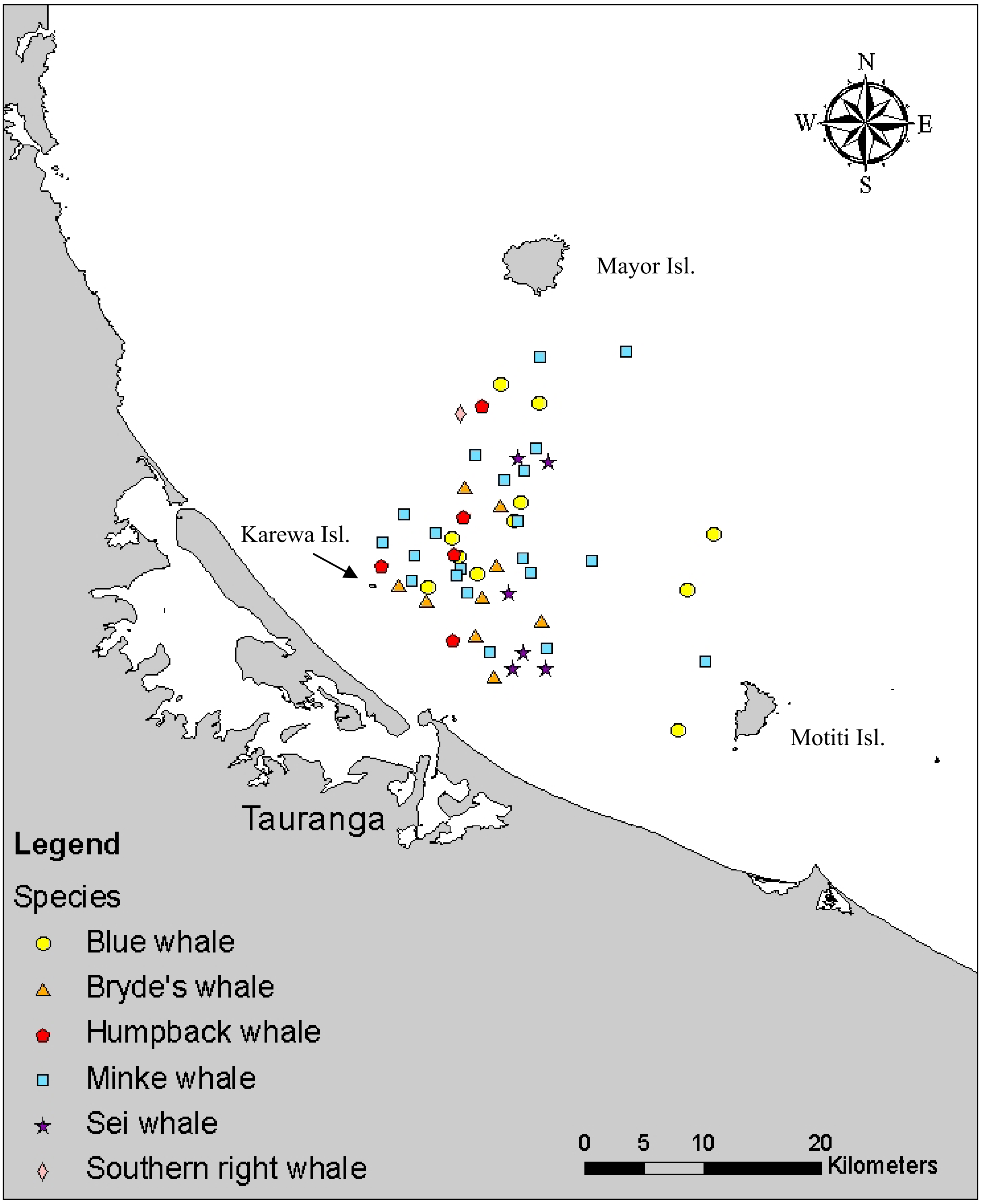

Figure 4.9: Baleen whale (Mysticeti) sightings between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand.

Table 4.3: Species observed in association with blue (BLW), Bryde's (BRW), humpback (HW), minke (MW), sei (SW) between March 1998 and May 2011 in the central Bay of Plenty (BOP), New Zealand. Note: southern right whales were not sighted in association with any other species.

Associated species		**Number of associations = % (n)**				
Common name	**Scientific name**	**BLW**	**BRW**	**HW**	**MW**	**SW**
Australasian gannet	*Morus serrator*	28.6 (4)	18.8 (3)	40.0 (2)	25.7 (9)	18.2 (2)
Black petrel	*Procellaria* sp.	28.6 (4)	12.5 (2)	0	31.2 (11)	9.1 (1)
Buller's shearwater	*Puffinus bulleri*	0	0	0	5.7 (2)	18.2 (2)
Common dolphin	*Delphinus* sp.	0	18.8 (3)	0	0	0
Diving petrel	*Pelecanoides* sp.	28.6 (4)	25.0 (4)	20.0 (1)	25.7 (9)	18.2 (2)
Fluttering shearwater	*Puffinus gavia*	7.1 (1)	6.3 (1)	20.0 (1)	0	0
Giant petrel	*Macronectes giganteus*	0	6.3 (1)	20.0 (1)	2.9 (1)	9.1 (1)
Prion	*Pachyptila* sp.	0	6.3 (1)	0	0	0
Storm petrel	*Fregetta* sp.	7.1 (1)	0	0	8.6 (3)	27.3 (3)
Tern	*Sterna* sp.	0	6.3 (1)	0	0	0
Total		**100 (14)**	**100 (16)**	**100 (5)**	**100 (35)**	**100 (11)**

4.4.3.1 Blue whale (*Balaenoptera musculus*)

Blue whales were encountered on 15 occasions during the study period (Table 4.1). Blue whales were sighted over water depths ranging from 24.0 to 110.0 m (mean = 60.0, SD = 30.9, n = 13), primarily during spring (92.3%, n = 12). Blue whales were not sighted during autumn or winter (Figure 4.10). Group size ranged from solitary to four individuals (mean = 1.6, SD = 1.06, n = 15), with results highly skewed towards singletons (66.7%, n = 10). One cow-calf pair was observed in spring 2010. Blue whales were primarily observed in association with Australasian gannets (28.6%, n = 4), black petrels (28.6%, n = 4) and diving petrels (28.6%, n = 4; Table 4.3).

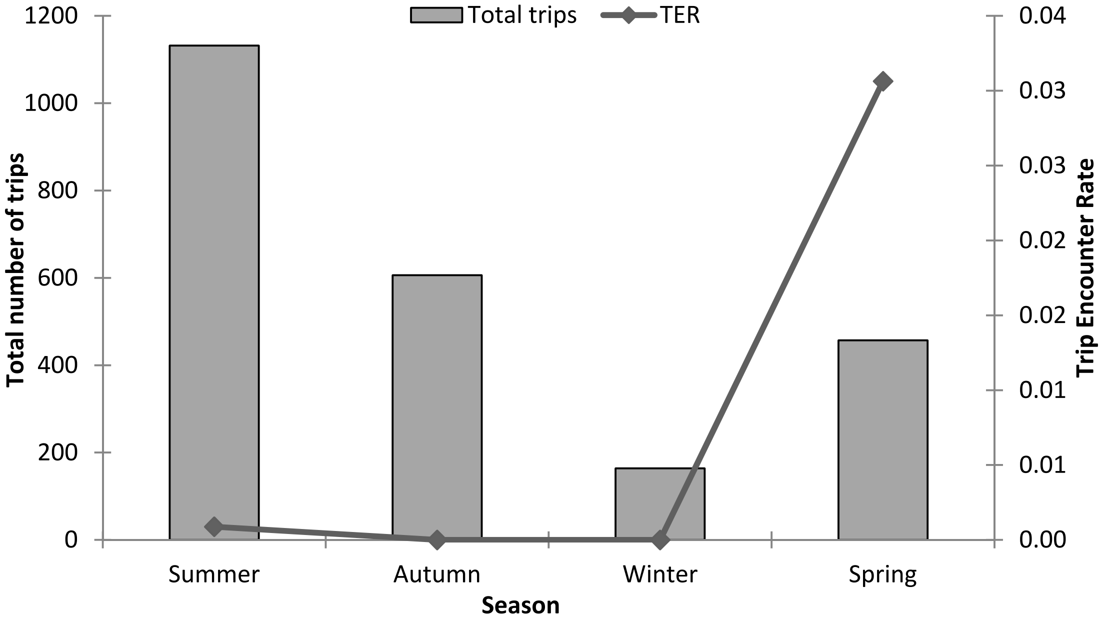

Figure 4.10: Seasonal Trip Encounter Rate (TER) for blue whales (*Balaenoptera musculus*) between March 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand.

4.4.3.2 Bryde's whale (*Balaenoptera edeni*)

Bryde's whales were encountered on 13 occasions between March 1998 and May 2011 (Table 4.1). TER varied by season and was highest in winter and spring; Bryde's whales were not encountered during summer or autumn (Figure 4.11). Bryde's whales were sighted over water depths ranging from 30.0 to 56.0 m (mean = 44.1, SD = 8.8, *n* = 10). Seasonally, sightings occurred in slightly deeper water during winter (median = 49.5, IQR = 47.8-51.3, *n* = 2) and shallower water in spring (median = 43.5, IQR = 34.8-48.5, *n* = 8). Group size ranged from solitary to two individuals (mean = 1.1, SD = 0.28, *n* = 13), with results highly skewed towards singletons (92.3%, *n* = 12). One cow-calf pair was observed in spring 2002. Bryde's whales were observed in association with common dolphins (18.8%, *n* = 3), as well as seven avian species including Australasian gannets (18.8%, *n* = 3) and giant petrels (6.3%, *n* = 1; Table 4.3).

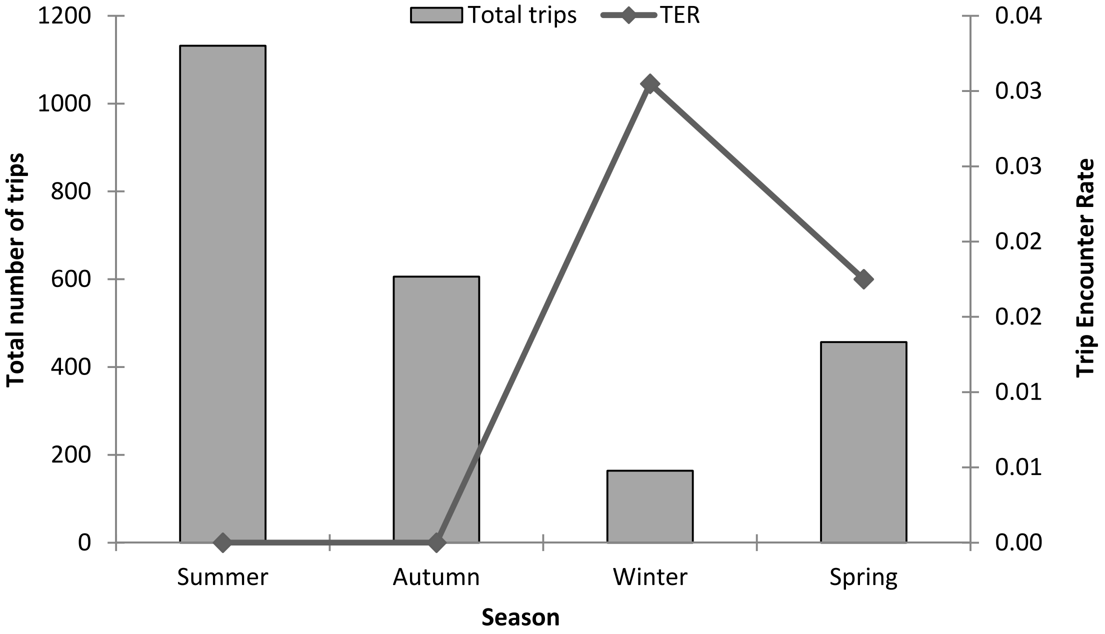

Figure 4.11: Seasonal Trip Encounter Rate (TER) for Bryde's whales (*Balaenoptera edeni*) between March 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand.

4.4.3.3 Humpback whale (*Megaptera novaeangliae*)

Humpback whales were encountered on eight occasions during the study period (Table 4.1), primarily during winter and spring. They were not encountered in autumn. Humpback whales were sighted over water depths ranging from 30.0 to 68.0 m (mean = 31.9, SD = 25.1, *n* = 5). Only singleton humpback whales were recorded during the study period (*n* = 8). Calf presence was never recorded. Humpback whales were observed in association with Australasian gannets (40.0%, *n* = 2), diving petrels (20.0%, *n* = 1), fluttering shearwaters (20.0%, *n* = 1) and giant petrels (20.0%, *n* = 1; Table 4.3).

4.4.3.4 Minke whale (*Balaenoptera acutorostrata/bonaerensis*)

Minke whales were encountered on 35 occasions during the study period (Table 4.1). TER varied by season and was highest during spring; minke whales were not encountered during summer or autumn (Figure 4.12). Water depth for minke whale sightings was only available for spring, and ranged from 10.0 to 153.0 m (mean = 49.8, SD = 28.5, *n* = 28). Group size ranged from solitary to three individuals (mean = 1.3, SD = 0.68, *n* = 34), with results highly skewed towards singletons (82.4%, *n* = 28). Cow-calf pairs were observed on three occasions during spring. Minke whales were observed in association with six avian species including: black petrel (31.2%, *n* = 11), Australasian gannet (25.7%, *n* = 9), diving petrel (25.7%, *n* = 9), and giant petrel (2.9%, *n* = 1; Table 4.3).

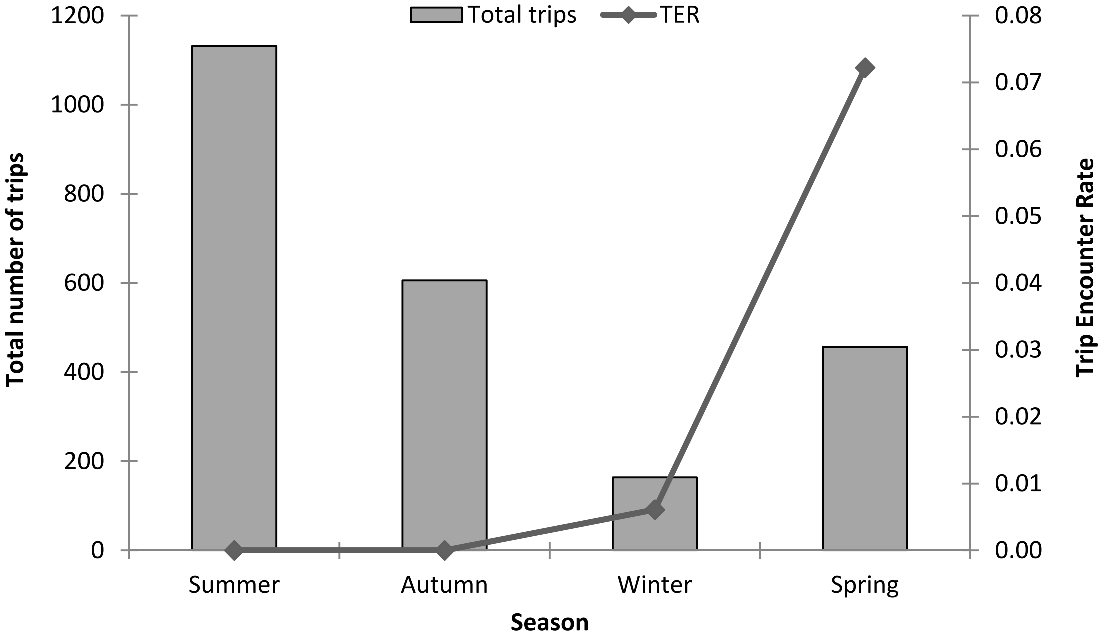

Figure 4.12: Seasonal Trip Encounter Rate (TER) for minke whales (*Balaenoptera acutorostrata/bonaerensis*) between March 1998 and May 2011, in the central Bay of Plenty (BOP), New Zealand.

4.4.3.5 Sei whale (*Balaenoptera borealis*)

Sei whales were encountered on seven occasions during the study period (Table 4.1), primarily during winter and spring. They were not encountered during summer or autumn. Sei whales were sighted over water depths ranging from 20.0 to 64.0 m (mean = 44.1, SD = 14.6, *n* = 7). Sightings occurred in shallower water in winter (mean = 33.7, SD = 11.9, *n* = 3) and deeper water during spring (mean = 52.0, SD = 11.9, *n* = 4). Group size ranged from solitary to two individuals (mean = 1.3, SD = 0.49, *n* = 7), with results skewed towards singletons (57.1%, *n* = 4). No sei whale calves were recorded during the study period. Sei whales were observed in association with six avian species including: Australasian gannet (18.2%, *n* = 2), diving petrel (18.2%, *n* = 2) and giant petrel (9.1%, *n* = 1; Table 4.3).

4.4.3.6 Southern right whale (*Eubalaena australis*)

The only sighting of a southern right whale over the 14 year period involved a cow-calf pair in spring 1998. Southern right whales were not observed in association with other cetacean or avian species during the present study (Table 4.3).

4.5 Discussion

Eleven cetacean species (6 Mysticeti and 5 Odontoceti) were reported in central BOP waters. This differs from historic records, which identified 26 different cetacean species (7 Mysticeti and 19 Odontoceti) which live in or migrate through the waters of the ECBOP Conservancy (Gaborit-Haverkort & Stockin, in press). This difference may be attributed to the time span covered by the historic review (dating back to early 1800s) and as such could reflect an actual change in species composition within the region. However, it is more likely a reflection of the size of the current dataset, which is based on observations from a single platform, whereas, the historic review included data from the Department of Conservation as well as interviews with commercial and recreational water users and results from an extensive review of museum archives. The historic review also encompassed stranding records, which may be more likely to include inconspicuous species than sightings data alone.

No confirmed beaked whale (Ziphiidae family) sightings occurred during the present study, despite historic evidence from the ECBOP Conservancy indicating that at least eight of the eleven species of beaked whales found in New Zealand frequently strand within the region, especially Gray's beaked whales (*Mesoplodon grayi*, *n* = 53) (Clement, 2009; Gaborit-Haverkort & Stockin, in press). During the present study there were a number of sightings involving beaked whales, which were unable to be identified to a species level. This is likely attributable to the long dive times and unobtrusive surfacing behaviour exhibited by beaked whales (Tyack *et al*., 2006).

Sperm whale (*Physeter macrocephalus*) sightings were also conspicuously absent from the central BOP during the present study. This concurs with historic evidence from the ECBOP Conservancy, which indicates that the majority of sperm whale sightings occur in deeper waters off the east coast near Gisborne, as well as near White Island Trench in the eastern BOP (Clement, 2009; Gaborit-Haverkort & Stockin, in press). This is likely attributed to the diet of sperm whales being focussed on squid (Teuthida) found in deep water (Smith & Whitehead, 2000).

Fin whale sightings were not present within the current dataset, despite historic evidence suggesting that fin whales occur more frequently than sei whales within BOP waters (Gaborit-Haverkort & Stockin, in press). This may reflect a change in habitat use by fin whales. However, it is more likely attributed to the difficulty in distinguishing between rorqual whales (Balaenopterids) at sea, especially between sei and fin whales given that they share similar pigmentation patterns (Jefferson *et al.,* 2007).

4.5.1 Odontoceti

Delphinidae were encountered throughout the year within the central BOP, primarily in spring. The majority of delphinid sightings (excluding *Delphinus* sp.) involved bottlenose dolphins (50.5%) and killer whales (42.9%). Pilot (3.8%) and false killer whales (2.9%) were less frequent. Delphinids occurred throughout the operational range of the tourism vessel, over water depths ranging from 3.8 to 115.0 m. Historic evidence suggests that bottlenose dolphin, false killer and pilot whale sightings occur more frequently further east around White Island (Whakaari) (Gaborit-Haverkort & Stockin, in press). This may be attributed to increased prey availability due to nutrient upwelling in the area around White Island Trench (*ca* 1000 m+ deep) in the eastern BOP (Ridgeway & Greig, 1986).

4.5.1.1 Bottlenose dolphin

Bottlenose dolphins are widely distributed in temperate and tropical oceans (Kenney, 1990). Around New Zealand, three genetically distinct populations are recognized: Northland, Marlborough Sounds and Fiordland (Tezanos-Pinto, 2009). The Northland population is highly mobile and is known to range between the Bay of Islands in the north and Gisborne in the south east (Constantine, 2002; Tezanos-Pinto, 2009). Bottlenose dolphins observed in central BOP waters most likely form part of this far ranging population, as demonstrated in the Hauraki Gulf (Berghan *et al.,* 2008). This species is listed by the IUCN as of *least concern* (Hammond *et al.,* 2008). In New Zealand waters its status has recently been elevated to *nationally endangered* (Baker *et al.,* 2010), based on the small regional and total abundance (*ca* 900-1000 mature individuals), and an apparent local decline in the Northland and Fiordland populations (Baker *et al.,* 2010).

Bottlenose dolphins were encountered throughout the year in the central BOP, which concurs with historic evidence from the region (Gaborit-Haverkort & Stockin, in press). Calves were recorded during 9% of bottlenose dolphin encounters, primarily in summer and autumn. However, group size did not vary on a seasonal basis, which is consistent with previous reports from the Hauraki Gulf (Martinez *et al.,* 2010). Conversely, in the Bay of Islands calves were observed in 32 to 63% of bottlenose dolphin groups (Constantine, 2002) and significant variation in group size was also detected across the four seasons with the largest groups present during spring and summer (Constantine & Baker, 1997; Tezanos-Pinto, 2009). Similar results were also reported for the Marlbourough Sounds population (Merriman *et al.,* 2009). This may be attributed to *Tursiops* occurring more frequently in the Bay of Islands, which likely represent a potential breeding/nursing area, whereas, they appear to be at best 'seasonal residents' within the BOP (Gaborit-Haverkort & Stockin, in press). Bottlenose dolphin groups observed without calves in the central BOP may represent "bachelor" groups (e.g. Wells *et al.,* 1980) possibly in search of mates (e.g. Wells *et al.,* 1980; Wiszniewski *et al.,* 2012). There is, however, no evidence of such groups occurring in New Zealand waters and further research is required in order to ascertain the level of habitat use by bottlenose dolphins in the central BOP.

The majority of bottlenose dolphin sightings in the central BOP involved groups comprising less than 30 animals and occurred in water less than 50 m deep, occasionally within Tauranga Harbour. These groups likely represent part of the Northland population taking advantage of foraging opportunities within the coastal waters of the BOP. Bottlenose dolphins have been observed predating on numerous species known to occur in harbours and bays, including: flounder (*Rhombosolea* spp.), yellow-eyed mullet (*Aldrichetta forsteri*)*,* kahawai (*Arripis trutta*)*,* parore (*Girella tricuspidata*) and piper (*Hyporhampbus ihi*) (Constantine & Baker, 1997). Larger groups (> 50 animals) were primarily sighted in deeper water (< 50 m) in association with false killer whales. Bottlenose dolphins are also known to occur in mixed species groups with pilot whales (e.g. Kenney, 1990; Scott & Chivers, 1990; Gaborit-Haverkort & Stockin, in press; Zaeschmar *et al.,* in press). Cetaceans forming mixed species groups have been observed in a number of marine habitats (Frantzis & Herzing, 2002; Herzing *et al.,* 2003; Quérouil *et al.,* 2008; Zaeschmar *et al.,* in press). Mixed species groups may be formed for a number of reasons ranging from anti-predator to foraging advantages (Stensland *et al.,* 2003). Historic reports from the BOP Conservancy suggest that larger bottlenose dolphin groups (often associated with either pilot or false killer whales) may represent an offshore (oceanic) form of *Tursiops* (Gaborit-Haverkort & Stockin, in press), since many mixed species associations reported elsewhere in New Zealand involve the offshore ecotype (Zaeschmar *et al.,* in press). This is further supported by historic evidence, which indicates that large bottlenose dolphin groups occur further offshore (> 20 nm) in the BOP (Clement, 2009), outside the operational limits of the observation platform in this study.

A number of studies on bottlenose dolphins have reported an increase in group size with water depth (e.g. Norris & Dohl, 1980; Wells *et al.,* 1980). These variations may be related to foraging techniques and protection from predation (e.g. Norris & Dohl, 1980; Wells *et al.,* 1980). Shallow, inshore waters often provide relatively predictable, evenly distributed food resources, whereas, in more open waters, schooling fish become the predominant resource available to the dolphins (e.g. Norris & Dohl, 1980; Wells *et al.,* 1980). Larger groups of dolphins increase the probability of locating these patchy but rich food sources and provide the numbers of individuals necessary to cooperatively locate and herd prey (e.g. Norris & Dohl, 1980; Wells *et al.,* 1980). In the same way, larger groups in open waters serve some of the same functions as the inshore physical habitat in terms of protection from predation (e.g. Norris & Dohl, 1980; Wells *et al.,* 1980).

Bottlenose dolphins in the central BOP were also sighted in association with Australasian gannets and various species of petrel, shearwater and tern. This differs from the Bay of Islands, where bottlenose dolphins were rarely sighted in association with avian species (Constantine & Baker, 1997). This could possibly be attributed to there being more bird life in the central BOP. Alternatively, the foraging strategy utilised by bottlenose dolphins may differ between regions. Bottlenose dolphins are considered opportunistic predators, with a preference for demersal fish (Hanson & Defran, 1993; Blanco *et al.,* 2001; Santos *et al.,* 2001, 2007). However, they are also known to feed on seasonal schools of pelagic squid and fishes (Hobson *et al.,* 1981; Schneider, 1999). It is possible that bottlenose dolphins visit the central BOP to take advantage of seasonal increases in the abundance of jack mackerel (*Trachurus* spp.) and arrow squid (*Nototodarus* spp.) (MFish, 2011b, c), which would also attract seabirds such as Australasian gannets. However, pending research on the foraging strategies utilised by bottlenose dolphins in the central BOP, such associations can only be inferred.

4.5.1.2 False killer whale

False killer whales are found in all tropical and warm temperate oceans of the world (Stacey *et al*., 1994; Odell & McClune, 1999; Baird *et al.,* 2008), and occasionally venture into cold temperate waters (Baird *et al.,* 1989). Although they are typically characterized as a pelagic species, they do approach close to shore and utilize shallow waters around oceanic islands (Odell & McClune, 1999; Gannier, 2002). False killer whales are listed as *data deficient* by the IUCN, due to a lack of global abundance data (Taylor *et al.,* 2008). Within New Zealand waters, false killer whales are listed as *not threatened* (Baker *et al.,* 2010). However, there is vast paucity in our knowledge of the New Zealand population, with basic data required for management (e.g. abundance, life history) still absent for this population. Given the high re-sighting rate observed in some regions (Zaeschmar, unpubl. data), New Zealand false killer whales could be less abundant than previously assumed.

Early records of false killer whales in New Zealand waters suggest that they were frequently sighted within the central BOP (Gaskin, 1967). However, this species was only encountered on three occasions during the study period. Historic evidence suggests that false killer whales appear more frequently (up to four times per annum) outside the current study area, in the eastern BOP between Whakatane and White Island, where sightings occur throughout the year but appear to be more typical during the warmer months (Gaborit-Haverkort & Stockin, in press). This may be attributed to an increase in false killer whale prey species such as yellowfin tuna (*Thunnus albacares*) (Baird *et al.,* 2008) and kingfish (*Seriola lalandi lalandi*) (G. Butler, pers. com.) in the eastern BOP due the higher productivity around White Island Trench (*ca* 1000 m+ deep).

During the present study, false killer whales occurred in groups ranging from 45 to 100+ animals in water depths ranging from 45.0 to 109.0 m. This differs from historic reports, which suggest that the most typical group size in the eastern BOP involved 10 to 30 animals (Gaborit-Haverkort & Stockin, in press). Calf presence was not recorded during the present study; this differs from historical reviews which indicate that calves were present during summer and autumn in the BOP (Clement, 2009; Gaborit-Haverkort & Stockin, in press). This discrepancy is likely attributed to a small sample size (n = 3) and the recording of calf presence not being a standardised process on board *Gemini Galaxsea.* This is further confirmed by a recent sighting (January, 2012) of false killer whales within the central BOP that included at least two cow-calf pairs (Gaborit-Haverkort, pers. obs.). All false killer whale groups sighted during this study were in mixed species groups with bottlenose dolphins. This is consistent with previous reports from the Hauraki Gulf where false killer whales and bottlenose dolphins have been observed exhibiting cooperative foraging techniques (Zaeschmar *et al.,* in press). False killer whales were also sighted in association with Australasian gannets, black petrels and fluttering shearwaters within the region. This may be indicative of a foraging relationship. Flesh footed shearwaters (*Puffinus carneipes*) and black petrels have been shown to feed by diving under the surface scavenging for scraps of prey dismembered by false killer whales within the Hauraki Gulf and Eastern Tropical Pacific (Pitman & Ballance, 1992; Zaeschmar *et al.,* in press). Further research is required in order to gain a full understanding of such associations within BOP waters.

4.5.1.3 Killer whale

At least three sub-populations of killer whale (*ca* 119 individuals) exist within New Zealand waters: a regional North Island population, a regional South Island population, and a population that travels back and forth between the two islands (Visser, 2000). The east coast of the North Island appears to be an important region for both the North Island and the north-south subpopulations (Visser, 2000). Killer whales are listed globally as *data deficient,* due to taxonomic uncertainty (Taylor *et al.,* 2008). Under the New Zealand Threat Classification System, the species is listed as *nationally critical* due to low abundance (Baker *et al.,* 2010).

Killer whales occurred throughout the year within the central BOP, most frequently during spring. These results concur with previous reports from the Hauraki Gulf (Martinez *et al.,* 2010) and the ECBOP Conservancy (Clement, 2009; Gaborit-Haverkort & Stockin, in press). Historic evidence suggests that this species may be ‘seasonally resident’ within the region (Gaborit-Haverkort & Stockin, in press). However, regular continued sightings of what appear to be many different individuals more likely reflects the transient nature of the New Zealand killer whale population, rather than any form of site fidelity *per se* (Gaborit-Haverkort & Stockin, in press).

Seasonally, the median water depth in which killer whales were observed ranged from 58.0 m in winter to 23.0 m in autumn. These results differ from the Hauraki Gulf, where killer whales were sighted in deeper water in autumn (median = 29.8 m) and shallower water during spring (median = 18.9 m) (Martinez *et al.,* 2010). This difference is likely attributed to differences in topography between the central BOP and the shallow enclosed waters of the Hauraki Gulf. During the present study the species has been sighted up to 18 nm from shore, usually in the vicinity of sea mounts or reefs (Gaborit-Haverkort, pers. obs.). New Zealand killer whales forage on sharks (Elasmobranchii) and fin-fish (Visser, 1999a, 2005), known to visit and congregate around sea mounts due to enhanced productivity (Morato & Pauly, 2004). In the study herein, killer whales were also sighted within the confines of Tauranga Harbour, where they were observed foraging on stingray (Myliobatidae) (Visser, 1999a;

Gaborit-Haverkort, pers. obs.). This is consistent with historic evidence, suggesting that BOP waters represent feeding opportunities for *Orcinus* (Gaborit-Haverkort & Stockin, in press.).

Killer whales group sizes ranged from one to 30+ individuals. The most frequently recorded group size involved six to 10 animals (51%). Calves were primarily sighted during spring and autumn. This concurs with historic evidence from the BOP, where killer whale groups were generally small (< 10 animals), likely family groups with at least one bull, cows, juveniles and/or calves present (Gaborit-Haverkort & Stockin, in press). This is also consistent with previous research conducted on the species inhabiting New Zealand waters, where they tend to travel in groups of less than 12 individuals, usually (83%) with at least one calf and/or juvenile (Visser, 2000). The author further reported that some New Zealand killer whales are known to form strong associations and may stay together for a number of years. Furthermore, these animals were more likely to share food with each other than those individuals seen to move between groups (Visser, 2000) which indicates that they are most likely related (e.g. Bigg *et al.,* 1987; Ford *et al.,* 1994; Ford & Ellis, 1999). However, without identifying photographs (fin-ids) from the killer whales sighted during this study, it is not possible to ascertain whether these individuals had been previously sighted in association.

Killer whales in the central BOP were sighted in association with Australasian gannets as well as various species of petrel, shearwater and tern. These birds are likely deliberately associating with killer whales due to the foraging advantages. There are numerous records of sea birds following hunting groups of killer whales in order to scavenge on left over scraps of food (Condy *et al.,* 1978; Griffiths, 1982; Enticott, 1986; Ridoux, 1987).

4.5.1.4 Pilot whale

Long-finned pilot whales (*Globicephala melas*) are the more prevalent of the two species in New Zealand based on stranding records (Gaborit-Haverkort & Stockin, in press). Due to taxonomic ambiguity with species identification, especially with at sea observations, both species are generically referred to as pilot whales in the present study. Despite this taxonomic uncertainty, the New Zealand Threat Classification System lists short-finned pilot whales (*G. macrorhychus*) as *migrant* and the long-finned as *not threatened* (Baker *et al.,* 2010). However, there is no baseline data available regarding abundance, life history or mortality levels for either species. Consequently, both long-finned and short-finned pilot whales are listed globally as *data deficient* by the IUCN (Taylor *et al.,* 2008).

Pilot whales were encountered on four separate occasions during spring and summer. This differs from historic reports from the ECBOP Conservancy, which indicate that pilot whales are present throughout the year and occur more frequently than indicated herein (*ca* 77 sightings since 2000: Gaborit-Haverkort & Stockin, in press). This discrepancy is likely attributed to the historic review encompassing a larger area as well as stranding records (of which pilot whales are one of the most frequent species to strand). Pilot whales are "potential offshore residents" of the BOP, occurring more frequently in the eastern BOP in the vicinity of White Island Trench (Gaborit-Haverkort & Stockin, in press.) outside the operational limits of the observation platform, where pilot whale prey species such as mackerel and squid (e.g. Overholtz & Waring, 1991) are known to occur (MFish, 2011b, c).

The depth of sightings ranged from 52.0 m in summer to 83.0 m. Group size was recorded on two occasions, both involving groups of 30 to 50 animals in spring. This concurs with historic reports from the central BOP; although, groups involving 50 to 150 animals have also been reported by tourism operators in the eastern BOP (Gaborit-Haverkort & Stockin, in press.). Calf presence was never recorded, which differs from historic reports, where calves were recorded throughout the year within the BOP Conservancy (Gaborit-Haverkort & Stockin, in press). This is likely attributed to the low sample size ($n = 4$) and the recording of calf presence not being a standardised process on board *Gemini Galaxsea.*

Herein, pilot whales were only ever sighted in association with black petrels (50%) or diving petrels (50%). This differs from historic reports from the BOP where pilot whales were also observed in mixed species groups with either bottlenose dolphins or false killer whales (Gaborit-Haverkort & Stockin, in press; Zaeschmar, unpubl. data). This discrepancy could possibly be attributed to small sample size. Alternatively, pilot whales sighted in the central BOP may have been passing through on their way to the eastern BOP, where the higher productivity may result in a concentration of pelagic delphinids and the perceived associations between these species. However, pilot whales have also been reported travelling in mixed-species groups with false killer whales or bottlenose dolphins in Northern New Zealand (Zaeschmar, unpubl. data). Further research is required in order to gain a full understanding of such associations within BOP waters.

4.5.2 Mysticeti

Baleen whale sightings primarily occurred in the area between Karewa Island, Mayor Island (Tuhua) and Motiti Island during the present study; which likely reflects the daily operational range of the tourism vessel. The majority of sightings involved minke (44.3%), blue (19.0%) and Bryde's whale (16.5%). Humpback (10.1%), sei (8.9%) and southern right whale (1.3%) sightings were less frequent.

4.5.2.1 Blue whale

The blue whale is a cosmopolitan species, found in all oceans except the Arctic (Branch *et al.,* 2007). The Antarctic form (*B. m. intermedia*) occurs in the South Pole region in summer, its winter distribution is poorly known, but the presumption has been that animals migrate in winter to lower latitudes (Branch *et al.,* 2007). Pygmy blue whales (*B. m. brevicauda*) are known to occur off the coast of New Zealand in summer (Branch *et al.,* 2007). Blue whales identified during the present study are most likely the pygmy subspecies, although, an Antarctic blue whale recently washed up on Whale Island (DNA analysis confirmed – K. Young, pers. comm.). However, due to difficulty with species identification, especially at sea, both species are generically referred to as blue whales herein. Despite uncertainties over present abundance, the total population of blue whales has been depleted by at least 70% over the last three generations (Reilly, 2008) and therefore, meets the IUCN criterion for *endangered* (Reilly, 2008). This species is listed as a *migrant* in New Zealand waters (Baker et al., 2010).

Blue whales occurred during spring and summer in the central BOP and were not sighted during autumn or winter, which supports the hypothesis that they most likely represent the pygmy blue whales subspecies (e.g. Branch *et al.,* 2007). These results are consistent with historic reports from the region, which classify the species as "infrequent to rare visitors" within the BOP conservancy (Gaborit-Haverkort & Stockin, in press). Blue whales were sighted over water depths ranging from 24.0 to 110.0 m. Although, group size ranged from solitary to four individuals, the majority (66.7%) were singletons. Like most balaenopterids, blue whales exhibit no well defined social or schooling structure, and in most of their range they are generally solitary or found in small groups (Mizroch *et al.,* 1984a). One cow-calf pair was observed in spring 2010. Historic reports concur, with two further records of calves present in BOP waters during spring (Gaborit-Haverkort & Stockin, in press). These sightings likely represent animals passing through on their annual migration between feeding and subtropical breeding areas (Branch *et al.,* 2007). Blue whales were primarily observed in association with Australasian gannet, black petrel and diving petrel. The nature of these associations could possibly be prey related. However, there is no evidence of blue whales foraging within the BOP. Without further research, the nature of these associations can only be inferred.

4.5.2.2 Bryde's whale

In New Zealand waters, Bryde's whales have historically been considered the larger, *B. brydei* form (Baker & Madon, 2007; Wiseman, 2008). However, due to taxonomic uncertainty for this genus, this study will follow the Society of Marine Mammalogy committee on taxonomy, who state that *B. edeni* applies to all Bryde's whales. Bryde's whales are known to occur in the north eastern coastal region between North Cape and East Cape, especially within the Hauraki Gulf (Gaskin, 1968; Stockin *et al.,* 2008c; Wiseman *et al.,* 2011). The species is listed globally as *data deficient* (Reilly, 2008), due to the unresolved taxonomy of the species. Its small population size and vulnerability to vessel strike (Stockin *et al.,* 2008c; Behrens, 2009) and net entanglement (Lloyd, 2003; Wiseman, 2008) means this species is listed as *nationally critical* within New Zealand waters (Baker *et al.,* 2010).

Bryde's whales were only encountered during winter and spring within the central BOP (n = 3). This differs from historic reports, which indicate that sightings also occur during spring, summer and autumn and may represent "occasional visitors" from neighbouring Hauraki Gulf waters (Gaborit-Haverkort & Stockin, in press; Wiseman *et al.,* 2011). This discrepancy may be attributed to the historic review primarily relying on opportunistic sightings made by commercial and recreational water users who may not be out on the water as much during the winter months. Whereas, the observation platform utilised during this study operated year round and was therefore more likely to record the species during winter. Alternatively, the historic review is based on a wide area and longer time period. Bryde's whales were sighted over water depths ranging from 30.0 to 56.0 m in the central BOP. Almost all sightings (92.3%) were of singletons, which is typical of Bryde's whales (Tershy, 1992; Wiseman *et al.,* 2011). One cow-calf pair was observed in spring 2002, which is further reinforced by the regular presence of calves in the nearby Hauraki Gulf (Wiseman *et al.,* 2011). Bryde's whales were observed in association with common dolphins (foraging), as well as seven avian species including diving petrel, Australasian gannet and giant petrel. The species is known to forage on small schooling fish (e.g. jack mackerel and pilchards, *Sardinops* sp.) and is therefore likely to compete with common dolphins and Australasian gannets for food. This is consistent with reports from the Hauraki Gulf, where mixed feeding aggregations occur with Bryde's whales, common dolphins and Australasian gannets (Stockin *et al.,* 2008c; Wiseman *et al.,* 2011).

4.5.2.3 Humpback whale

The humpback whale is a cosmopolitan species found in all the major ocean basins. All but one of the subpopulations (that of the Arabian Sea) migrate between mating and calving grounds in tropical waters and productive colder waters in temperate and high latitudes (Clapham & Mead, 1999). There are records of humpback whales in BOP waters dating back to 1877 (Gaborit-Haverkort & Stockin, in press). Humpback whales are listed globally as *least concern* (Reilly *et al.,* 2008) due to their unrestricted range and population estimates of 60,000 animals (Reilly *et al.,* 2008). This species is classified as a *migrant* under the New Zealand Threat Classification System (Baker *et al.,* 2010).

Humpback whales were encountered on eight occasions during the study period. In historical reports (including anecdotal evidence), however, sightings were recorded more frequently within the BOP (*ca* 55 sightings since 2000: Gaborit-Haverkort & Stockin, in press). This discrepancy is likely attributed to the reasons aforementioned (i.e. wider range of data over a larger area). Humpback whales were encountered in all seasons except in autumn. These results concur with historic reports (Gaborit-Haverkort & Stockin, in press). The seasonality of sightings may be attributed to BOP waters being positioned within an important southern migratory corridor, which leads from rich Antarctic feeding grounds to tropical breeding/calving grounds. Dawbin (1956, 1997) reported annual humpback whale sightings along the east coast of the North Island during both their southern and northern migrations.

Humpback whales were sighted over water depths ranging from 30.0 to 68.0 m. Only singleton humpback whales were recorded during the study period. This differs from historic reports which indicate that cow-calf pairs were also present within BOP waters during spring and summer (Gaborit-Haverkort & Stockin, in press). This is likely due to the historic review including all sightings made within the BOP, by numerous sources, including the general public, rather than just one observation platform operating within a restricted area. With the exception of cow-calf, pairs humpback whales are largely solitary animals during their migration (Valsecchi *et al.,* 2002). During the present study, humpback whales were observed in association with Australasian gannet, diving petrel, fluttering shearwater and giant petrel. This is likely attributed to the diet of humpback whales, consisting primarily of small schooling fish (Pauly *et al.,* 1998). Seabirds may follow whales hoping to catch scraps if they stop to feed. This is further supported by anecdotal evidence, suggesting that the species occasionally feed as they migrate through BOP waters (Gaborit-Haverkort & Stockin, in press).

4.5.2.4 Minke whale

Much of the data on the occurrence of minke whales in the southern hemisphere is ambiguous with respect to species identification, as dwarf (*B. acutorostrata*) and Antarctic minke whales (*B. bonaerensis*) are partially sympatric (Reilly *et al.,* 2008). Dwarf minke whales are a cosmopolitan species found in all oceans and in virtually all latitudes, from 65°S to 80°N. Antarctic minke whales, as the name suggests, are considered a southern hemisphere species (Rice, 1998). For the purpose of this thesis, both species are generically referred to as minke whales. The New Zealand Threat Classification System lists both the dwarf minke and Antarctic minke as *not threatened* (Baker *et al.,* 2010). This is based on these species apparently being secure in other parts of their natural range. However, the IUCN lists dwarf minke whales as *not threatened* and Antarctic minke whales as *data deficient* (Reilly *et al.,* 2008). As such, a classification of *data deficient* appears more appropriate here as there is limited information available for this species in New Zealand waters.

Minke whales were encountered during winter and spring within the central BOP (n = 35), although, according to the historic reports the species is present year round within the region (Gaborit-Haverkort & Stockin, in press). This discrepancy is likely attributed to the historic review including stranding data, given that minke whales tend to strand more frequently than other baleen whales in the BOP (e.g. Gaborit-Haverkort & Stockin, in press). This may be attributed to their tendency to enter estuaries, bays and harbours (New Zealand Whale Stranding Database).

The water depth for minke whale sightings ranged from 10.0 to 153.0 m. Group size ranged from solitary to three individuals. As for other baleen whale species, the majority (82.4%) were singletons. Historic reports indicate that groups of up to four individuals also occur in

BOP waters (Gaborit-Haverkort & Stockin, in press). Cow-calf pairs were observed on three occasions during spring. These cow-calf pairs are likely on their south bound migration, from tropical breeding and calving grounds in the winter to Antartic feeding grounds in the summer (Kasumatsu *et al.,* 1995).

Minke whales were observed in association with six avian species, including various species of petrel and Australasian gannet. Minke whales and seabirds are likely to be exploiting the same prey species, in particular schooling fish (e.g. Gill *et al.,* 2000). Whales may pursue the fish to the surface prior to lunge feeding, making them more accessible to birds that feed at the surface. This is further supported by anecdotal evidence that minke whales have been observed lunge feeding in the eastern BOP (Gaborit-Haverkort & Stockin, in press). These sightings remain unsubstantiated, however, due to a lack of photographic evidence.

4.5.2.5 Sei whale

Sei whales are another cosmopolitan species, with a mainly offshore distribution, occurring in the North Atlantic, North Pacific and southern hemisphere (Rice, 1998). In the South Pacific, sei whales migrate between tropical and subtropical latitudes in winter and temperate and subpolar latitudes in summer (Rice, 1998). Southern hemisphere sei whales are thought to be more abundant than their northern hemisphere relatives, but due to lack of knowledge about current population trends and large declines attributed to whaling, this species has been listed by the IUCN as *endangered* (Reilly *et al.,* 2008). The species is listed as *migrant* within New Zealand waters (Baker *et al.,* 2010).

Sei whales were encountered during winter and spring in the central BOP, which differs from historical reports, where sei whales were sighted throughout the year within BOP waters (primarily near White Island) (Gaborit-Haverkort & Stockin, in press). This discrepancy is likely attributed the historic review encompassing sightings from a wide range of sources throughout the BOP, rather than from a single observation platform operating within a limited range. Calf presence was not recorded, which concurs with historic evidence (Gaborit-Haverkort & Stockin, in press). This indicates that sei whale cows with calves may not pass through BOP waters during their annual migrations (Reeves *et al.,* 1998). However, this absence is more likely attributed to small sample size and the difficulty in distinguishing between rorqual whales (Balaenopterids) at sea (Jefferson *et al.,* 2007). Group size ranged from solitary to two individuals, with results skewed towards singletons (71.4%). Historic evidence suggests that groups of up to three individuals also occur in the BOP (Gaborit-Haverkort & Stockin, in press).

This species was observed in association with six avian species including: Australasian gannet, diving petrel and giant petrel. Sei whales primarily forage on krill and other zooplankton in southern hemisphere waters (Reeves *et al.,* 1998). In northern hemisphere waters, however, they are known to forage on small schooling fish and squid (Mizroch *et al.,* 1984b). Seabirds may, therefore, follow sei whales for increased foraging opportunities. This can only be inferred pending surveys of Balaenopterid habitat use within BOP waters.

Sei whales were sighted over water depths ranging from 20.0 to 64.0 m. This is consistent with previous research, indicating that the species prefers deeper offshore waters and avoids semi-enclosed bodies of water (Gambell, 1985). This demonstrates that sei whales sighted within central BOP waters may have been another rorqual whale species, such as Bryde's whales, which are locally frequent within the nearby Hauraki Gulf (Wiseman *et al.,* 2011). However, without photo identification and genetic surveys of cetaceans within the BOP, it is not possible to definitively say whether sei whales do occur within the region.

4.5.2.6 Southern right whale

Southern right whales have a circumpolar distribution in the southern hemisphere; their distribution in winter is concentrated near coastlines in the northern part of their range (Taylor *et al.,* 2008). In summer, this species mainly occurs in latitudes 40 to 50°S, although they have been observed in the Antarctic as far as 65°S (Bannister *et al*., 1999; Caroll *et al.,* 2011). Current breeding areas are near shore off southern Australia, New Zealand (particularly Auckland Islands and Campbell Islands) (Carroll, 2011; Rayment *et al.,* in press), Atlantic coast of South America and southern Africa (Taylor *et al.,* 2008). This species is considered of *least concern* globally (Taylor *et al.,* 2008), due to the estimated population size and the strong observed rate of increase in some well studied parts of the range. This species, although still scarce relative to its historic abundance, is not considered under threat at the hemispheric level. However, under the New Zealand Threat Classification System, southern right whales are classified as *nationally endangered* (Baker *et al.,* 2010), due to an estimated national population size of only 50 animals.

The only sighting of a southern right whale between March 1998 and May 2011 consisted of a cow-calf pair in spring 1998. Conversely, Patenaude (2003) reported that within New Zealand coastal waters the majority (54.5%) of southern right whale sightings involving cow-calf pairs occurred in the BOP, within 200 m of shore. This is further supported by historic reports of 20 southern right whale sightings occurring within the ECBOP Conservancy between 2000 and 2010, primarily during winter (40.0%) and spring (50.0%) (Gaborit-Haverkort & Stockin, in press). Southern right whales appear to be "seasonal migrants" within BOP waters as they pass through on their way to breeding and calving grounds (Patenaude, 2003; Gaborit-Haverkort & Stockin, in press). However, the inshore coastal bays of the BOP have also been identified as potential calving habitats for the species (Patenaude, 2003), which requires further research.

4.6 Conclusion

A wide range of cetacean species are found year round or seasonally within central BOP waters, including a number of nationally endangered/critical species such as bottlenose dolphins, killer, Bryde's and southern right whales. Several migrant species also utilise BOP waters at different times of the year. This highlights the need to establish species specific management plans for the region. This will ensure that these species are better protected from anthropogenic threats such as net entanglement and resource depletion attributed to over fishing in the area.

Chapter Five: Conclusion and management implications

Figure 5.1: Common dolphin (*Delphinus* sp.) sighted in the central Bay of Plenty (BOP), New Zealand (Photo: Hayden Butler).

5.1 Introduction

Managing cetacean populations is problematic, especially when dealing with a species for which there is limited biological information available. There are fundamental differences between terrestrial and coastal/marine ecosystems that must be recognised before effective management and conservation can be put in place (e.g. Frontier, 1985; Bakun, 1986). Marine ecosystems are poorly understood, having a much shorter history of study and presenting logistical difficulties for researchers (e.g. Hayden *et al.,* 1991; Agardy, 1992). Consequently, to save on survey costs researchers are increasingly utilising cetacean-watching vessels as opportunistic observation platforms for collecting data on the occurrence, distribution and demographics of cetaceans in New Zealand waters (e.g. Constantine & Baker, 1997; Wiseman, 1998; Lusseau & Slooten, 2002; Dahood *et al.,* 2007; Martinez, 2010; Martinez *et al.,* 2010).

For most marine organisms there is a very limited understanding of what constitutes a population and how those populations are sustained (James *et al.,* 1990; Havens, 1992). This means that the identification of appropriate units for management is difficult (Sherman, 1991). Habitats associated with feeding, resting and breeding could be set aside as Special Areas for Conservation (SACs). However, a sound knowledge of the occurrence and habitat use by that population or species is required before an area can be nominated. Site protection, compliance and awareness plans are being enforced on a regional and national level in many countries. However, there is a general lack of comprehensive species specific management plans for *Delphinus* sp. (Hammond *et al.,* 2008). In New Zealand, the Department of Conservation (DOC) is charged under the Marine Mammals Protection Act (MMPA, 1978) to provide for the protection, conservation and management of marine mammals within New Zealand and within New Zealand fisheries waters. However, despite the year round occurrence of common dolphins in New Zealand waters, they remain the only resident cetacean to lack species specific management objectives (Suisted & Neale 2004).

There is vast paucity in our knowledge of New Zealand *Delphinus*, with basic data required for management (e.g. abundance, life history, taxonomy) still absent for this population. Currently, Baker *et al.* (2010) list common dolphins as *not threatened* within New Zealand waters due to a lack of evidence showing a population decline. However, there is no population estimate available for this species that would indicate a decline should it happen.

As such, this classification appears to be based on assumption as opposed to any empirical data per se. Arguably, a classification as *data deficient* appears more appropriate, as argued in Stockin and Orams (2009).

Although common dolphins are the most prevalent species of dolphin found off the east coast of the North Island of New Zealand (Stockin & Orams, 2009), there has been no empirical investigation of the species in the central Bay of Plenty (BOP) area. *Butlers swim-with dolphin* crew have been recording marine mammal sightings within central BOP waters from March 1998 to May 2011. This albeit opportunistic dataset, represents the longest record of *Delphinus* in the area and provides a unique opportunity to examine the effects of abiotic factors on the long-term occurrence patterns of common dolphins and other cetaceans recorded in the region over time. Analyses of these sighting data offer valuable information about the occurrence of common dolphins and other cetacean species found in the central BOP. These data are crucial in determining important management areas.

5.2 General findings

This thesis examined the occurrence and habitat use of common dolphins within the central BOP, with reference made to other species encountered from the same platform, including bottlenose dolphin (*Tursiops truncatus*), pilot (*Globicephala* spp.), killer (*Orcinus orca*), false killer whale (*Pseudorca crassidens*), and various species of baleen whales (Mysticeti). Group characteristics, habitat use, and behaviour were further examined using ecological methods.

The central BOP appears to constitute an important area for common dolphins, especially during the warmer months when large aggregations of dolphins with calves are present within 12 nm of shore (Chapter Two). Foraging and socialising dolphins frequently occurred in the presence of the observation platform (Chapter Three), which supports the hypothesis that the region is used for feeding and nursing groups of common dolphins. However, how representative this is, given the current study was conducted solely from a platform of opportunity, still remains to be determined.

In order to ascertain the relative importance of central BOP waters for *Delphinus* and other cetacean species, Chapter Four assessed the occurrence and group dynamics of other cetaceans utilising these waters, in order to compare and contrast habitat use. This chapter identified a wide range of other cetacean species, which reside in or migrate through BOP waters, including a number of nationally endangered/critical species such as bottlenose dolphins, killer, Bryde's (*Balaenoptera edeni*) and southern right whales (*Eubalaena australis*). Several migrant species also utilise BOP waters at different times of the year. Based on multiple species presence and frequency of sightings, the coastal waters out to 12 nm off the central BOP appear to constitute an important habitat for most seasonally resident and some migrant marine mammal populations. This highlights the need to establish species specific management plans for the region.

While no specific breeding areas could be identified within the central BOP, common dolphins, bottlenose dolphins and killer whales, in addition to some migrant and infrequent species have been observed with calves within the region, especially over the warmer months. Managers of the region need to take account of this. It is crucial that areas deemed to be utilised by a population for important biological functions such as breeding and calving are protected.

In terms of feeding habitats, it has been suggested that the harbours and bays of the BOP region may offer critical feeding areas for killer whales that predate primarily on stingray (Visser, 1999a; Clement, 2009; Gaborit-Haverkort & Stockin, in press). The year round presence of common dolphins within central BOP, as highlighted by the current study and the historic review (Gaborit-Haverkort & Stockin, in press), suggests that these waters are likely rich in prey species such as arrow squid (*Nototodarus* sp.), jack mackerel (*Trachurus* sp.) and anchovy (*Engrauliis australis*) (Meynier *et al.,* 2008). This is further supported by unconfirmed reports of lunge feeding Bryde's, minke and humpback whales in the region (Gaborit-Haverkort & Stockin, in press). All three species are known to forage on small schooling fish (e.g. jack mackerel and pilchards, *Sardinops* sp.) (e.g. Pauly *et al.,* 1998; Gill *et al.,* 2000; Stockin *et al.,* 2008c; Wiseman *et al.,* 2011) and are therefore, likely to compete with common dolphins for food. These sightings remain unsubstantiated, however, due to a lack of photographic evidence.

5.3 Management considerations

Central BOP waters are an important economic and recreational resource, supporting a variety of human activities, including commercial fishing, recreation, tourism and shipping. Considering that inshore waters are utilised by dolphins for feeding and likely nursing purposes (e.g. Neumann, 2001c; Gaborit-Haverkort & Stockin, in press), it is critical that potential anthropogenic effects are managed accordingly to take into consideration these critical biological processes.

5.3.1 Fisheries interactions

Cetaceans are susceptible to interference from man-made structures placed in marine habitats (Baker, 2006). For example, the possible effects of green lipped mussel (*Perna canaliculus*) farming on marine mammals can include: entanglement in mussel farm structures and spat catching lines, ingestion of litter from farms, changes in prey abundance due to phytoplankton depletion, as well as exclusion from habitat by physical structures (Baker, 2006). The principal species at risk from such manmade structures within central BOP waters are likely to be larger baleen whales (e.g. Lloyd, 2003; Patenaude, 2003; Behrens, 2009). However, common dolphins and killer whales have also been known to become fouled in crayfish pot lines within the BOP (NZ Whale Stranding Database). Würsig and Gailey (2002) recommend that all proposed developments of marine aquaculture be subjected to scientific evaluations on a case by case basis; in terms of likely species at risk of entanglement, reductions in prey abundance and/or exclusion from habitat within the proposed area.

New Zealand's commercial trawl net fisheries can pose a serious threat to marine mammals (Duignan *et al.,* 2003; Boren *et al.,* 2006; Chilvers, 2008; Stockin & Orams, 2009). Between 1998 and 2008, 115 common dolphins were reported as incidental bycatch within commercial fisheries (Stockin & Orams, 2009; Stockin *et al.,* 2009b). Observer effort within the jack mackerel (JMA) fishery ranged from five to 40% during this period. Of the confirmed bycatch reported, 86% (n = 99) occurred within the commercial trawl fishery for JMA, which includes the following species *Trachurus declivis, T. murphyi* and *T. novaezelandiae* (Stockin & Orams, 2009). The remaining 14% of common dolphins were incidentally captured by vessels targeting hoki (*Macruronus novaezelandiae*), skipjack tuna (*Katsuwonus pelamis*), barracouta (*Thyrsites atun*), snapper (*Pagrus auratus*) and trevally (*Pseudocaranx dentex*) (Stockin & Orams, 2009). Commercial long-liners may also pose a threat to cetaceans, with three reported cases of killer whales becoming tangled in commercial long-lines in the BOP and off the west coast of the North Island between 1990-2002 (Visser, 2000; NZ Whale Stranding Database).

Additionally, common dolphins (Stockin & Orams 2009; Stockin *et al.,* 2009a), killer whales (NZ Whale Stranding Database; Visser, 2000), dusky dolphins (*lagenorhynchus obscurus*) (NZ Whale Stranding Database), Hector's dolphins (*Cephalorhynchus hectori*) (NZ Whale Stranding Database; Dawson, 1991; Slooten, 2007) and New Zealand fur seals (*Arctocephalus forsteri*) (Boren *et al.,* 2006) are incidentally killed within coastal set nets. For more site specific information concerning potential threats, fine scale, scientifically systematic data need to be collected for cetaceans within the central BOP. This research is crucial for the development of guidelines for commercial and recreational fisheries to ensure that unsafe fishing practices are controlled within areas deemed to be ecologically significant to cetacean species.

Prey depletion caused by overfishing may also pose a serious threat to cetacean populations (e.g. Bushuyev, 2000; Bearzi *et al*., 2006; Birkun, 2006). Jack mackerel populations in the southern Pacific Ocean are in decline, in 20 years the landings of this species have reduced by over 90% (South Pacific RMFO, 2012). Similar trends are also shown for jack mackerel in New Zealand waters (85% decline in landings of *Trachurus murphyi* since 1993; South Pacific RMFO, 2012). This, coupled by the fact that the majority of jack mackerel caught in New Zealand waters between 1991 and 2011 was taken from the BOP (MFISH, 2011c), highlights the importance of ensuring that fish stocks in the region are maintained at a level which can sustain populations of common dolphins and other resident or migrating cetacean species within BOP waters.

5.3.2 Pollution

Another potential threat to cetaceans within the central BOP stems from Persistent Organic Pollutants (POPs) entering the ocean from land use activities near Tauranga Harbour. Historically, persistent pollutants such as dichlorodiphenyltrichloroethane (DDT) were widely used in New Zealand and are still leaching into groundwater and streams which flow into coastal environments (e.g. Stockin *et al.,* 2010). Such pollutants have been associated with a variety of toxic effects to cetaceans including: immune suppression and the development of infectious diseases (Kuiken *et al.,* 1994; Jepson *et al.,* 2005), reproductive impairment (Schwacke *et al.,* 2002; Wells *et al.,* 2005) and the generation of tumours (De Guise *et al.,* 1994). It is widely acknowledged that dolphins living in near-shore waters close to agricultural and industrial activity tend to accumulate higher concentrations of toxins (O'Shea, 1999; McHugh *et al.,* 2007). Baleen whales, which are oceanic and feed at lower trophic levels, are likely to be least impacted by POPs within central BOP waters (Jones *et al.,* 1999). Whereas, toothed cetacean species feed at higher trophic levels and are more likely to accumulate POPs. The current conception for oceanic cetaceans such as common dolphins is that wider habitat usage places them at lower risk from inshore activities. However, as highlighted by Stockin *et al.* (2007, 2010), polychlorobiphenyl (PCB) concentrations for New Zealand *Delphinus* span a similar range to those reported for Hector's dolphins (*Cephalorhynchus hectori*). This may reflect high usage of coastal waters by New Zealand common dolphins, thus highlighting the potential vulnerability of this species to coastal anthropogenic effects. Therefore, in order to protect cetacean species in the central BOP, it is important from a management perspective that pollution levels are continually monitored from all water sources flowing into the sea, with procedures instigated to reduce identified sources of pollution.

As well as POPs, the ingestion and/or inhalation of hydrocarbons can be problematic for cetceans (e.g. Griffiths *et al.,* 1987; Geraci, 1990; Neff, 1990; Loughlin, 1994; Matkin *et al.,* 2008; Pierce *et al.,* 2008; Williams *et al.,* 2011). This is particularly pertinent following the recent grounding of a container ship (*Rena*) on Astrolabe Reef 3 nm north of Motiti Island in October 2011. Hydrocarbons in fuel oil have considerable environmental persistence (Blumer & Sass, 1972) and do bio-accumulate up the food chain (Baines *et al.,* 1997). Another potential risk associated with the grounding of the *Rena* is the ingestion of container debris. The ingestion of plastics has been implicated in mortality and reduced reproductive success in marine mammals (e.g. Gregory, 1978; Mato *et al.,* 2001; Derraik, 2002; Laist 1997, 2006).

While to date, there have been no confirmed mortalities of cetaceans directly related to the *Rena* spill, historic evidence suggests that only 2% of cetacean carcasses may be recovered following an oil spill (Williams *et al.,* 2011). Long term impacts on cetacean occurrence and reproductive success will need to be monitored within the BOP region. Trends identified in this thesis with regards to occurrence and habitat use will at least provide some baseline information on which future research can be based.

5.3.3 Tourism

A number of studies have been undertaken to investigate potential effects associated with both cetacean-watching activities (e.g. Leitenberger, 2001; Erbe, 2002; Lusseau, 2003; Constantine *et al.*, 2004; Bejder *et al.*, 2006a,b; Neumann & Orams, 2006; Williams *et al.,* 2006; Stockin *et al.,* 2008b; Markowitz *et al.,* 2009; Martinez *et al.,* 2011). Boat presence has also been linked to significant changes in the activity budgets of killer whales (Williams *et al.,* 2006), common dolphin (Constantine & Baker, 1997; Stockin *et al.,* 2008b), Hector's dolphin (Martinez, 2010; Marinez *et al.,* 2011) and bottlenose dolphin (e.g. Lusseau, 2003; Constantine *et al.,* 2004; Bejder *et al.,* 2006a, b), resulting in both short-term and long-term changes, including reduced energy acquisition and increased energetic demand. It has been suggested that due to cetacean-watching vessels spending extended periods of time with target species, they have a greater potential to disturb species of interest than general vessel traffic (e.g. Martinez, 2010).

Information yielded by the current study will aid the Department of Conservation to appropriately manage the expanding tourism industry in the central BOP. The use of the region by feeding and nursing common dolphins and other species is of notable management importance, particularly considering the apparent effect of vessel disturbance on foraging dolphins in the Hauraki Gulf (Stockin *et al.,* 2008b). The authors reported that the amount of time spent foraging overall was 10% lower in the presence of a tour boat. This difference is significant at the current level of tourism with only one tour boat operating within the Hauraki Gulf. Thus, the introduction of another tour vessel could have a significant impact on common dolphin foraging in the long-term within the Hauraki Gulf. Since common dolphins are the most abundant cetacean in the BOP (Gaborit-Haverkort & Stockin, in press), they remain the primary target species for the tour vessels currently operating in the area. Considering that there are already six permits issued for the central BOP, and a further two in the eastern BOP, and no research thus far on the impact of tour vessels on common dolphins in this region, it is possible that the threshold has already been surpassed. Consequently, it is recommended that the number of current permits in the central BOP be reviewed and revised accordingly.

5.4 Study limitations and future research

This study relies on an opportunistic database rather than data collected as part of systematic, effort-related surveys. As such, trends highlighted here pertaining to habitat use within the central BOP require careful consideration. The perceived low number or absence of some species (e.g. 4 pilot whale sightings; no beaked whale sightings) may not represent the actual number present within the central BOP. As discussed by Clement (2009), factors such as the unobtrusive surfacing behaviour exhibited by some species or difficulty in identifying species correctly may result in lower sighting rates. To help counter such bias, a full literature review of cetacean occurrence in the region was conducted which incorporated both at sea and strandings data for this region (Gaborit-Haverkort & Stockin, in press). Given that the data collection process was largely sstandardised since 2000, it is recommended that the post 2000 data is re-analysed at a higher resolution in comparison to data collected during the same timeframe by other tour opperators within the region.

The current dataset was somewhat limited in terms of distinguishing between immature age classes (e.g. neonate, calf, juvenile, immature, mature), a factor primarily attributed to the ambiguity around what constitutes a calf as opposed to a juvenile, especially during the earlier years of data collection onboard *Gemini Galaxsea*. Consequently, the majority of immature animals were recorded as calves, regardless of whether or not these individuals constituted neonates or juveniles. As such, it is difficult to ascertain the real significance of these waters for nursing groups since the clarity with which historical data have been collected, has been compromised. It is recommended that future research conducted onboard platforms of opportunity mitigates this by having the definitions of each age class on board and thus recording the proportion of different age classes present during each encounter. Additionally, there were biases in the diel cattegories used. The earliest time sequence runs from 0800- 0959 h, and the tour vessel was usually only just leaving the harbour at 0900 h.

Behavioural data collected during the present study were recorded in the presence of the observation platform only, and thus, could only be compared to impact data (in the presence of tour vessels) collected in other regions of New Zealand. There is evidence which suggests that common dolphins alter their behaviour in the presence of boats (e.g. Neumann & Orams, 2006; Stockin *et al.,* 2008b). However, without control data (i.e. in the absence of *Gemini Galaxsea*), it is not possible to ascertain whether the behaviour of common dolphins was altered by the presence of the tour vessel. Behavioural responses to boat presence may vary according to the distance from, type and number of vessels, type of approach, length of interaction, cetacean species, age class and gender (e.g. Constantine & Baker, 1997; Constantine, 2001; Lusseau, 2003; Richter *et al.,* 2006; Stockin *et al.,* 2008b; Martinez *et al.,* 2011). These differences highlight the need to assess the impacts of cetacean-watching activities on a case by case basis. Current research underway in the region (Meissner & Stockin, 2011) aims to mitigate this by using an independent research vessel and systematic methodology based on previous tourism impact assessments conducted in the Hauraki Gulf (e.g. Stockin *et al.,* 2008b) and western BOP (Neumann, 2001b).

The frequency of multi-species groups encountered during this study may be an overestimate owing to the use of binoculars to detect seabirds when locating common dolphins. A random-based survey design, as detailed by Stockin (2008), which does not rely on binoculars to detect indicator species, would equal the probability of observing both single and multi-species groups (e.g. Meissner, unpubl. data). Additionally, ensuring that search effort is evenly distributed among sectors of the central BOP, would counter any bias associated with previous sighting success in certain areas.

Herein, only the presence/absence of associated species was recorded, the number of species present and the exact nature of these associations were not recorded. Avian species may interact with cetacean species in a number of ways (not always foraging related) (e.g. Burgess, 2006). Therefore, pending further results from systematic surveys (Meissner, unpubl. data) the importance of common dolphin associations within the central BOP can only be inferred.

Finally, this research is limited to common dolphins studied in the inshore waters (within 12 nm) of the central BOP. Further research in offshore waters would allow comparisons to be drawn with dolphins inhabiting open, oceanic waters. Different environmental variables (e.g. depth, sea surface temperature and currents), food resources and predators may occur, and are likely to influence the occurrence, demographics and behaviour of common dolphins in offshore regions, outside the scope of this study.

Despite the limitations described, the present study provides an insight into cetacean occurrence within the central BOP. Such information is of management value since previous research on common dolphins has been so far limited within BOP waters (Neumann, 2001a,b,c; Clement, 2009; Meissner & Stockin, 2011; Gaborit-Haverkort & Stockin, in press).

5.7 Conclusion

The central BOP is an important ecological area for common dolphins as well as a number of ‘seasonally resident’ and ‘migrant’ cetacean species. In addition to competition and predation, cetaceans are faced with a wide range of potential human induced threats within BOP waters, primarily related to fishing, prey depletion and tourism activities as well as potential long term health affects associated with the *Rena* oil spill. It is therefore important that these populations are effectively managed via the implementation of species specific management plans for the region. These should include guidelines set in place for commercial and recreational fisheries to ensure that harmful fishing practices are not used in areas deemed to be ecologically significant to cetacean species. It is especially recommended that the current cetacean-watching permits in the central BOP be revised on a case by case basis, pending results from a current tourism impact study underway within the region (Meissner, unpub. data).

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