DEDICATION

.... fatti non foste a viver come bruti,
ma per seguire virtute e canoscenza

Dante Alighieri "La Divina Commedia" - "Ulisse", Inferno Canto XXVI

.........You were not made to live your lives as brutes,
But to be followers of worth and knowledge

Dante Alighieri "The Divine Comedy" – "Ulysses", Inferno Canto XXVI

ABSTRACT

Quantifying the vocal repertoire of a species is critical for subsequent analysis of signal functionality, geographic variation and social relevance. Vocalisations of free-ranging common dolphins (*Delphinus* sp) have not previously been described from New Zealand waters. Herein, I present the first quantitative analysis of whistle characteristics to be undertaken on the New Zealand population. Acoustic data were collected in the Hauraki Gulf, Auckland between February 2008 and May 2009, during surveys from the tour boat *Dolphin Explorer*. Data were collected from 28 independent dolphin groups using PZ-1A hydrophone and MZ-NH700 digital audio disk. Recordings were analysed using Raven Pro 1.3 and whistles classified into seven contours containing 29 subtypes.

A total of 105.1 minutes of recordings were collected involving 11,715 whistles. Vocalisations of New Zealand common dolphins spanned 3.2 to 23.00 kHz, with most whistles occurring between 11 and 13 kHz. The shortest and longest whistles recorded were 0.01 and 4.00 s (mean = 0.27, SD = 0.32), respectively. Of the twelve whistle types recorded, 82% have previously been recorded within U.K populations. Additional contours, apparently specific to New Zealand *Delphinus* were also identified. Of the 2,663 whistles analysed, downsweeps (35.9%) were the most frequent whistle type, followed by upsweeps (28.5%), constant (16.4%) and sine (7.0%) contours. Concave and convex contours were least observed within the New Zealand population, accounting for just 6.1% each. Of all the whistle types identified in Hauraki Gulf common dolphins, the least modulated subtypes were the most prevalent.

Data presented here offer a first insight into the whistle characteristics of New Zealand common dolphins. Comparsions with previously studied populations reveal marked differences in the whistle frequency and modulation of the New Zealand population. Inter-population differences suggest behaviour and the local environment likely play a role in shaping the vocal repertoire of this species.

Whistles characteristics of common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand

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A thesis submitted in partial fulfilment of the requirements for the Degree of
Doctor of Applied Biology at University of Naples, Italy

In collaboration with Massey University

Auckland, New Zealand, 2009

UNIVERSITA' DEGLI STUDI DI NAPOLI "FEDERICO II"

DOTTORATO DI RICERCA IN BIOLOGIA APPLICATA

TESI

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Coordinatore

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Candidato

Dott. V. Petrella

ANNO

2009

ACKNOWLEDGEMENTS

As an Italian visiting PhD student at the Massey University, Auckland I have been fortunate to have four academics whom have assisted me in different ways with this project.

Firstly, I wish to acknowledge my ITA supervisors, Prof Marianna Crispino and Dr Graziano Fiorito whom have both continued to believe in me and my chosen project. Thanks also to my New Zealand supervisor Assoc Prof Dianne Brunton for giving me the opportunity to work with these amazing animals.

I sincerely would like to thank my New Zealand supervisor Dr Karen Stockin for introducing me to the extraordinary field of marine mammal acoustics, assisting me with my English throughout the thesis and for her support in times of need. She is a model to me and will be forever in my memory. She sets an example that I wish to follow. Additional thanks are extended to Manue Martinez for her assistance during the analysis of my results.

Sincere thanks are extended to Will Goodfellow and the crew of *Dolphin Explorer* for their support throughout this study. I particularly would like to thank Keith Algie and Andy Light who skippered this research platform. I am grateful to them for helping me collect the acoustic recordings – it is perhaps just a pity many of the really good recordings occurred when forgetful tourists flushed the toilet!! Additional thanks go to Prof Mark Orams for his kind loan of the hydrophone.

I especially would like to thank Hui Ling Weng, Manue Martinez, Silvia Scali, Gabriel Machovsky Capuska and Alessandro and Joyce Fantoni for their constant support and encouragement.

Finally, I thank the good side of myself which every day pushes me to watch behind the horizon.

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Chapter 1

Common dolphin (*Delphinus* sp.) travelling in the Hauraki Gulf, Auckland, New Zealand (photo by Author)

Introduction

1.1 Introduction

Marine environments worldwide have drastically changed in the last century, as a consequence of human influences. For example, since the industrial revolution, the threshold of background noise within the world's oceans has increased drastically due to the human activity (Richardson et al. 1995). This change of more than 10 decibels, established a new environment in which marine biota have been forced to adapt and survive (Ross, 1993).

Marine mammals (including the three orders: Cetacea, Sirenia and Carnivora) represent a group of animals that are potentially susceptible to the affects of man-made noise (Richardson et al. 1995). The 68 extant odontocetes (toothed whales and dolphins) are highly diverse, with representatives throughout the world's oceans (Klinowska, 1991; Jefferson et al. 1993). Their communication calls are mainly at moderate to high frequencies (1-20 kHz) but many species also have highly developed echolocation systems operating at high (20 kHz) and very high (150 kHz) frequencies. Mysticetes (baleen whales) including at least 11 extant species, appear most sensitive to low and moderate frequency sounds (8 Hz to 12 kHz) since they lack a high-frequency echolocation system (Richardson et al. 1995).

The hearing organ of cetaceans has special adaptations to their life underwater. In fact, high frequency sound can be received through the tissue of the mandible rather than an air-filled external auditory apparatus as in terrestrial mammals (Thewissen, 2002) (Fig. 1.1). This allows cetaceans to dive to great depths without compromising their hearing ability through pressure effects on air-filled spaces (Ridgway et al. 2001). Audiograms of several odontocetes reveal that they can hear a wide range of frequencies spanning over nine octaves and up to 150 kHz, with best hearing sensitivities around 10-100 kHz (Au, 1993). Since baleen whales produce sounds that are mostly below 1 kHz in frequency, their calls can travel over vast distances, possibly thousands of kilometres (Dudzinski, 2002). At these low frequencies, their communications resonate over large distances without little loss. Such signals have been described as moans, thumps, knocks or pulses (Richardson et al. 1995). Some mysticetes also produce much more complicated vocalisations. The best known example is the humpback whale (*Megaptera novaeangliae*) song which can range in duration from 5 to 30 minutes and consists of several different units, phases and themes (Darling, 2002).

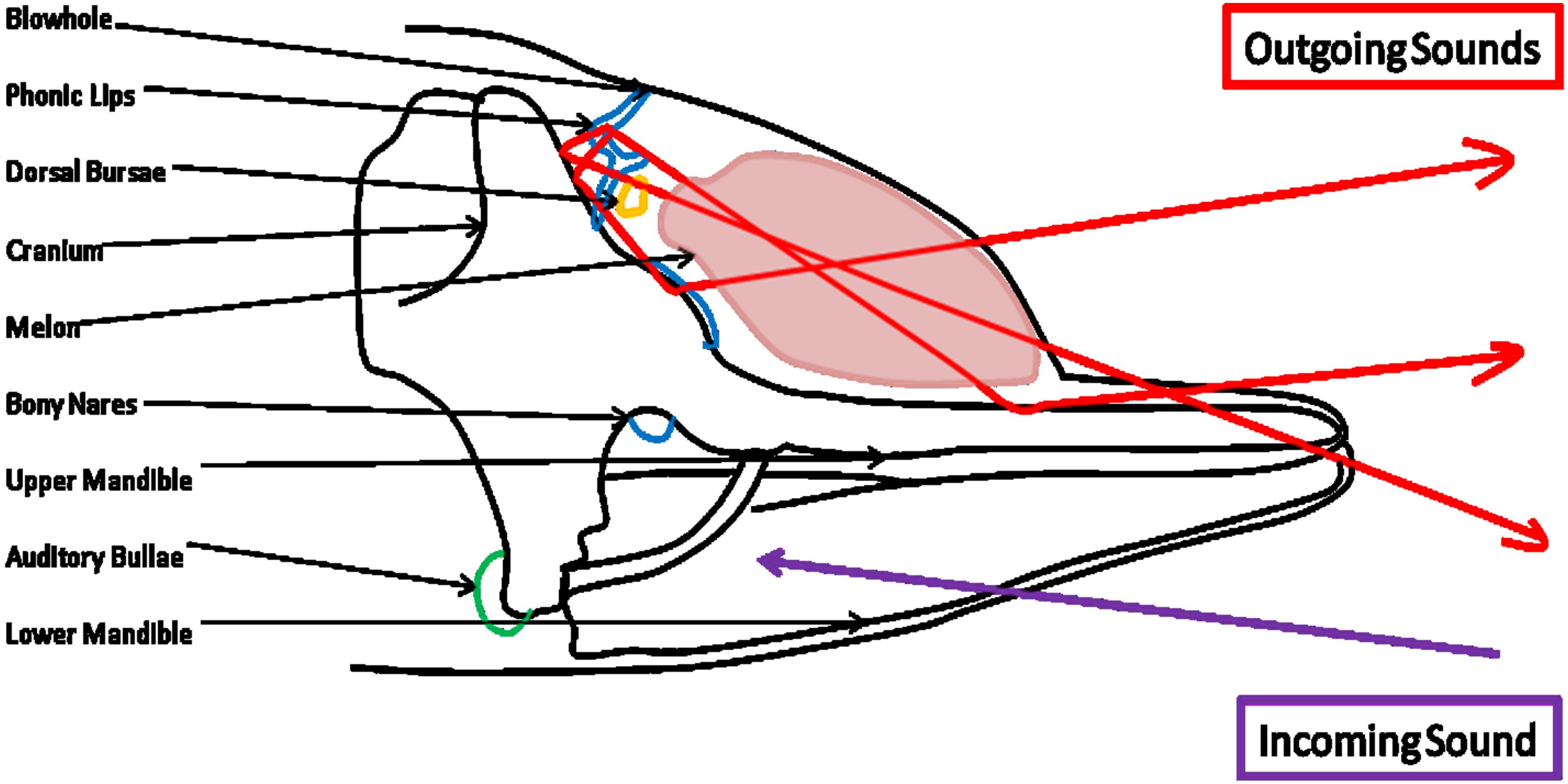

Fig 1.1: Diagram illustrating sound generation, propagation and reception in dolphins

Conversely, the vocalisations of odontocetes are generally grouped into three types: short pulsed sounds that are used in echolocation, less distinct burst pulse calls (described as cries, barks, grunts or squeals with high pulse repetition that makes them audible to humans) and narrowband tonal whistles (Richardson et al. 1995) (Figs 1.2. – 1.4). The latter two seem to be used primarily for communication, although most studies have focused on whistles rather than burst pulse sounds since whistles are largely in the audible or sonic range and therefore, easier to record and analyse (Richardson et al. 1995).

Whistles are narrowband tonal calls with durations up to a few seconds and fundamental frequencies that typically fall between 5 and 20 kHz. They are frequency modulated and usually described based on spectrogram views of their time–frequency contours (Richardson et al. 1995). Contour categories commonly used are unmodulated constant frequency whistles, upsweeps, downsweeps, U-shapes (or concave), inverted U-shapes (or convex), or wavering sinusoidal whistles. However, repertoires are often more complex and may include intermediate types between those categories, as well as whistles that consist of repeated types or a combination of different types. Also, whistle contours may not be continuous but may contain breaks (Richardson et al. 1995).

The whistle repertoires of odontocetes show great variability between different species, different geographically separate populations, different groups within populations, or even between individuals (Rendell et al. 1999). Within populations, parameters such as duration or number of inflections or steps are usually more variable and may carry information about individual identity or behaviour (Rendell et al. 1999; Morisaka et al. 2005). Generally, dolphins living in fluid societies tend to show much variation in the whistle repertoire at the individual level, while those living in stable groups usually do not have distinct whistles, although exhibit group-distinct repertoires often referred to as dialects (Tyack, 1986). Concerning individual distinct whistles, the most significant vocalisation is represented by the signature whistle. This type of whistle exhibits stereotype contour, allowing the identification of dolphins at the individual level. This contour is based on the other signature whistles present in the community (Fripp et al. 2005) and typically develops within the first year after birth, remaining stable throughout the lifetime of the individual (Sayigh, 2002).

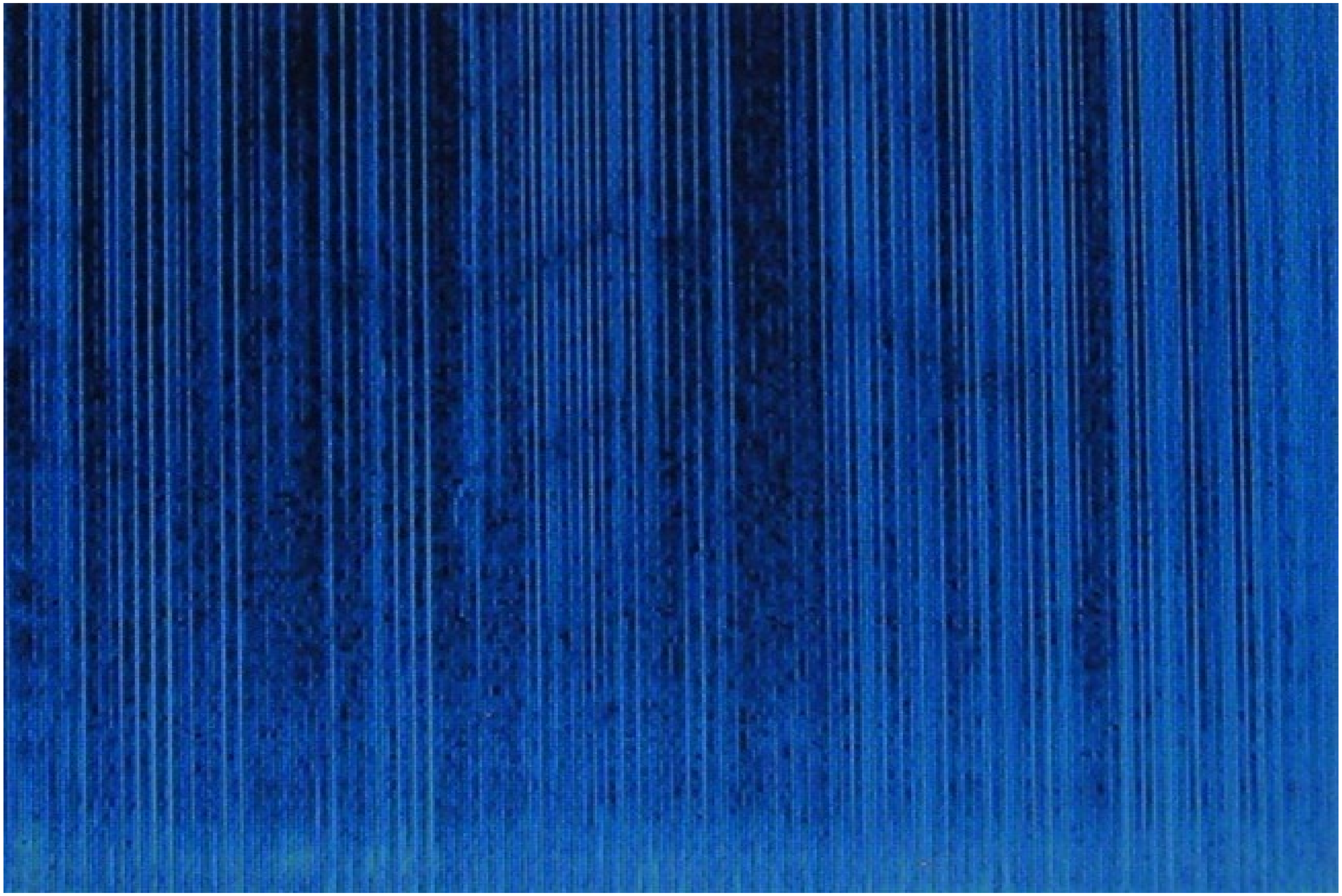

Fig 1.2: Spectrogram showing click trains emitted by common dolphins (*Delphinus* sp) in the Hauraki Gulf, New Zealand

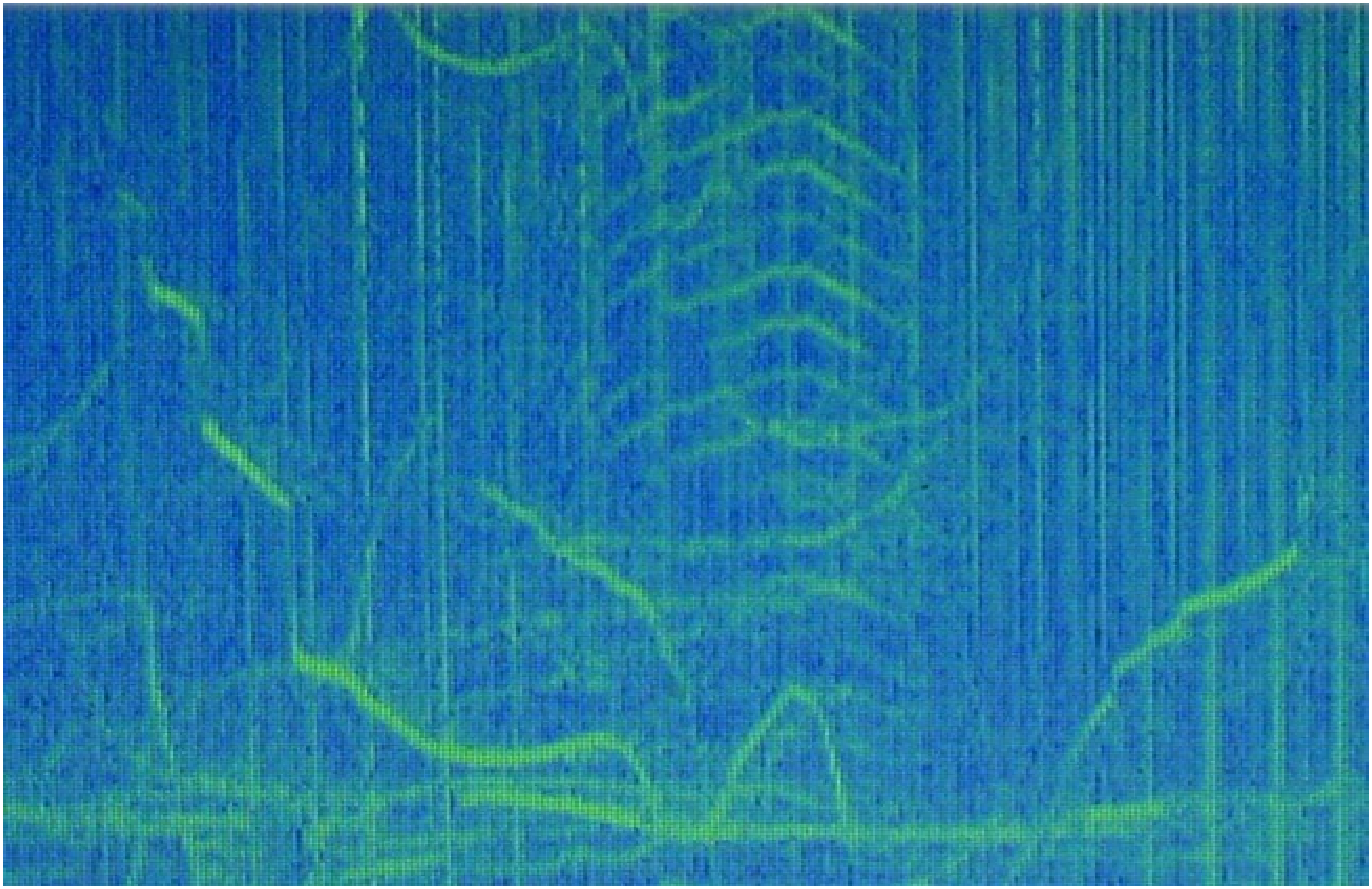

Fig 1.3: Spectrogram showing a click train, whistles and burst pulse sound emitted by common dolphins (*Delphinus* sp) in Hauraki Gulf, New Zealand

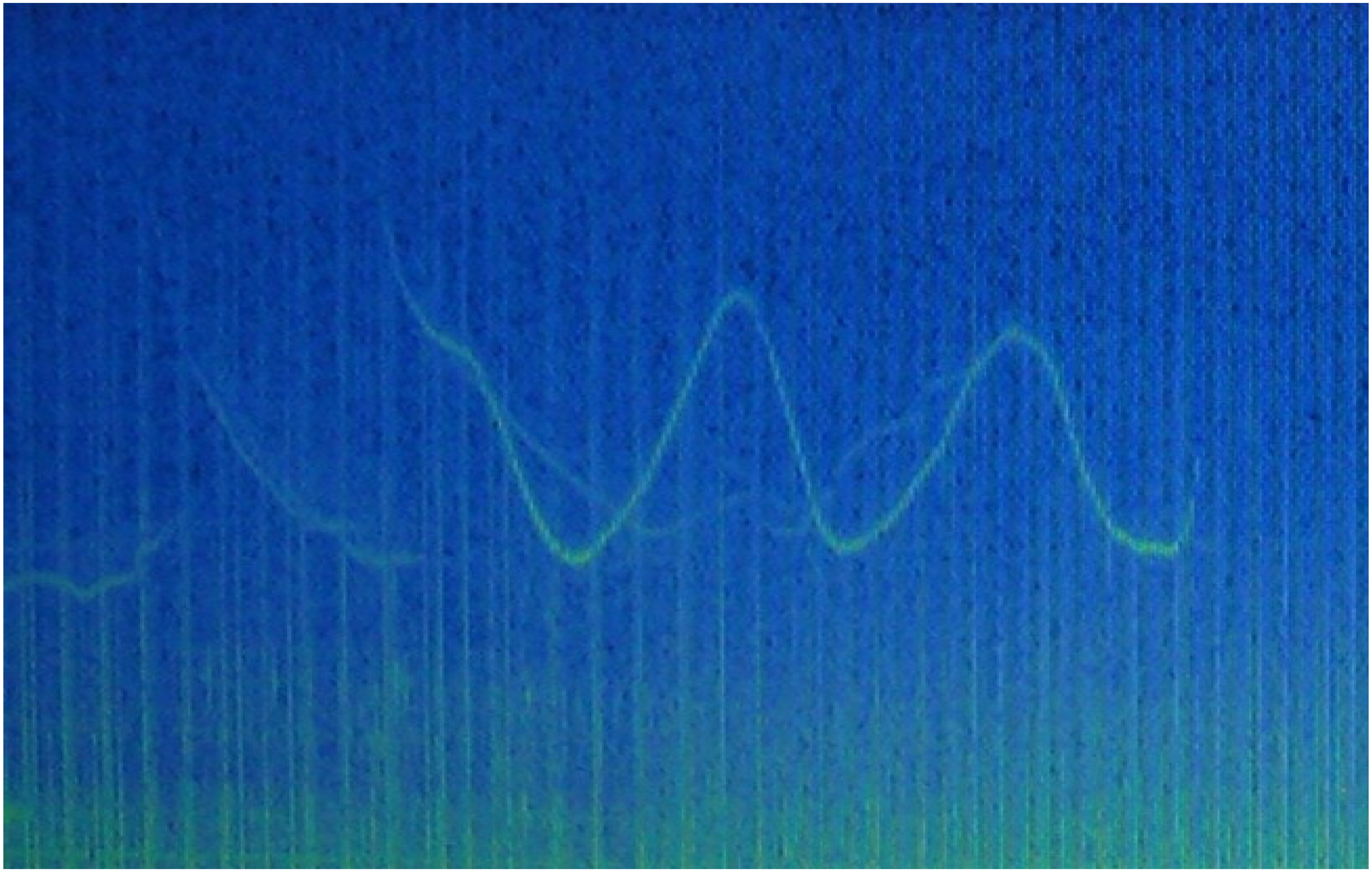

Fig 1.4: Spectrogram showing whistles emitted by common dolphin (*Delphinus* sp) in Hauraki Gulf, New Zealand

Like most delphinids, common dolphins (*Delphinus* spp.) are a vocal species that produce echolocation click trains (Fig. 1.2), burst pulse sounds (Fig. 1.3) and whistles (Fig. 1.4). Based on recordings of captive animals (Caldwell and Caldwell, 1968), their calls have been described as *chirps* with dominant frequencies between 8 and 14 kHz, *barks* with low dominant frequencies below 3 kHz and *whistles* that cover a dominant frequency range from 2 to 18 kHz. This is further supported by more recent recordings collected from wild short-beaked common dolphins (*Delphinus delphis*) monitored within British (Goold 1996; 1998; 2000; Ansmann et al. 2007) and North Pacific (Oswald et al. 2004; 2007) waters.

1.2 Taxonomy

Common dolphins (genus *Delphinus*) are widely distributed in all oceans, from temperate to tropical waters and show high mobility across their habitat (Perrin, 2002). Morphological diversity had led to more than 20 different species being described historically, although they were all subsequently considered local variations of a single species *Delphinus delphis* (Hershkovitz, 1966). The present classification within this genus is still uncertain, although two species of common dolphin are currently recognised based on morphological and genetic differences: *D. delphis* and *D. capensis,* the short- and long-beaked common dolphin (Heyning and Perrin, 1994; Rosel et al. 1994). No apparent gene flow exists between these species, although recent research using amplified fragment length polymorphism (AFLP) suggests *D. delphis* and *D. capensis* may have only recently diverged (Kingston and Rosel, 2004). This separation between the long- and short-beaked forms is based on external morphological characters and includes tooth and the vertebra counts, in addition to colour pattern and rostral length (Heyning and Perrin, 1994) (Figs. 1.5 – 1.6).

A nominal third species, recently confirmed as a subspecies of the long-beaked form, *D. capensis tropicalis* was recently clarified by Jefferson and Van Waerebeek (2002) (Fig. 1.6). To discern between these two species, cranial characteristic have been studied in a wide manner (e.g. Perrin, 1975; Casinos, 1984; Heyning and Perrin, 1991; Perrin, 1993; Perrin et al. 1994). *Delphinus* typically display between 40 and 60 conical teeth in each row of the upper and lower

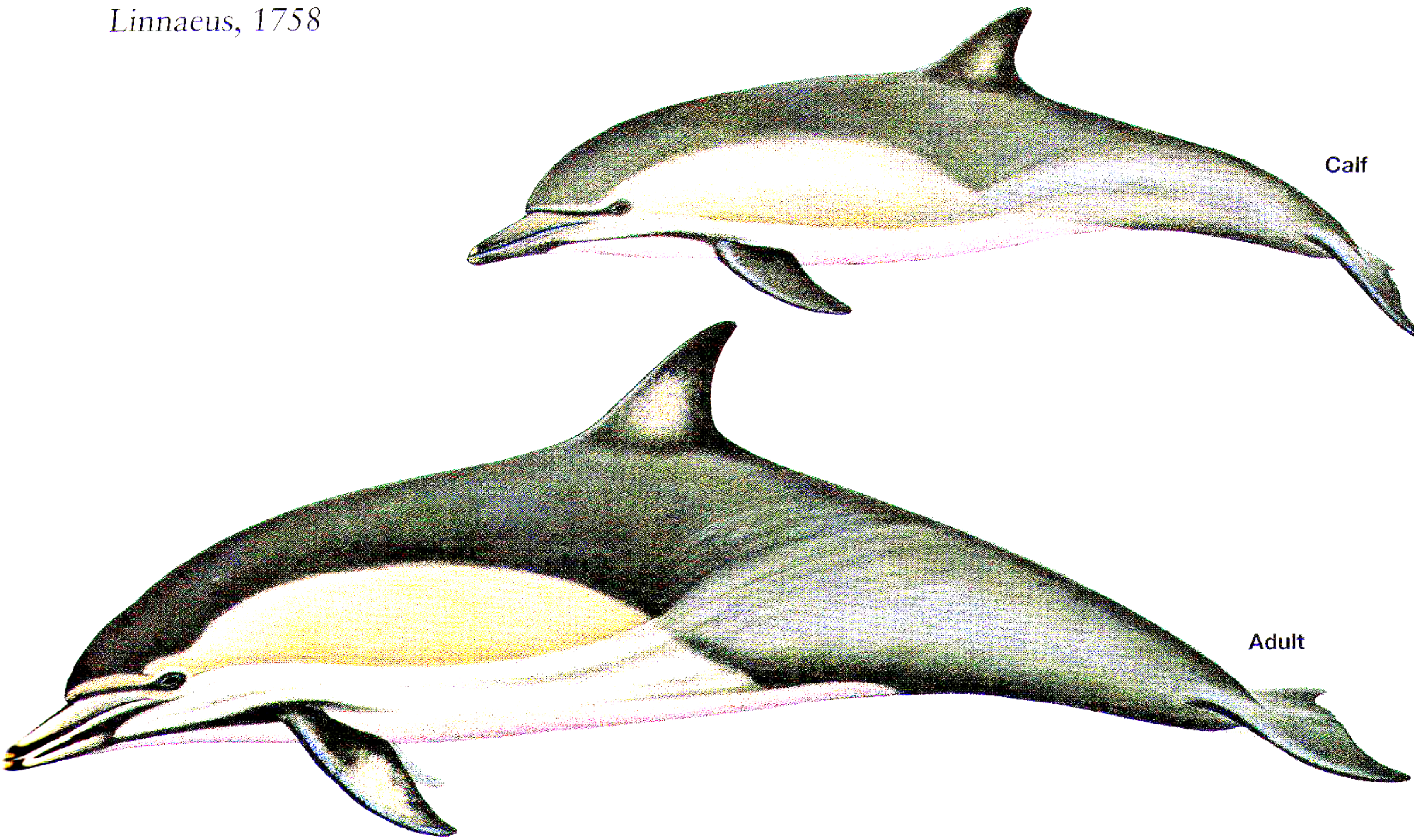

Fig 1.5: Pigmentation patterns of short-beaked common dolphin (*D. delphis*) (Source: Jefferson et al. 2008)

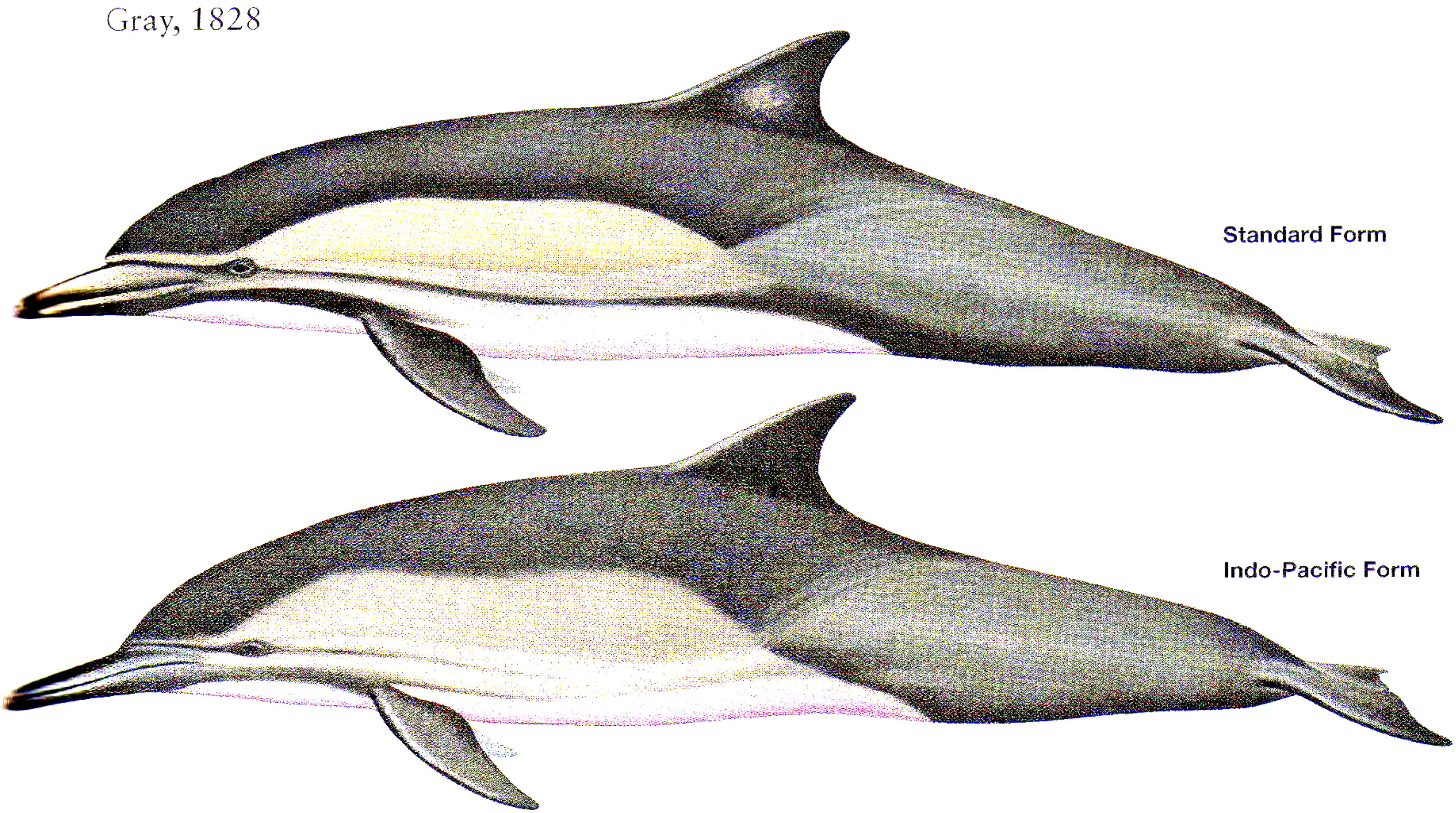

Fig 1.6: Pigmentation patterns of long-beaked common dolphin (*D. capensis*) and sub-species (*D. capensis tropicalis*) (Source: Jefferson et al. 2008)

jaws (Evans, 1975; Heyning and Perrin, 1994; Jefferson and Van Waerebeek, 2002; Perrin, 2002). In New Zealand, genetic and morphometric analyses are currently in progress (Stockin, 2008). As such, for the remainder of this thesis, I refer to *Delphinus* sp when describing common dolphins within New Zealand waters.

1.3 Distribution

Common dolphins (*Delphinus* spp.) have a cosmopolitan distribution within 60° N and 40° S, at temperatures between 10 and 28 °C. Each species of *Delphinus* has a wide but discontinuous distribution. For example, *D. delphis* and *D. capensis* coexist in some near-shore waters; with schools of the two species being observed in the same general area within a single day (e.g. Heyning and Perrin, 1994; Bearzi, 2005). Typically, *D. capensis* prefers shallower and warmer waters and generally occur closer to the coast than *D. delphis* (Bernal et al. 2003; Ramírez Carroz and González-Fernández, 2004). Short-beaked common dolphins can be found in the eastern Atlantic from southern Norway to Gabon in West Africa, including the Mediterranean and Black Seas; and from Newfoundland to Florida in the western Atlantic. In the eastern Pacific common dolphins can be found from Newfoundland to Florida in the western Atlantic and from southern Canada to central Chile; and in the western Pacific around New Caledonia, New Zealand, Tasmania, southern Japan, and Southeast Australia (Perrin, 2002; Reeves et. al 2002).

D. delphis distribution (Fig. 1.7) has often been linked with areas of upwelling along continental drop-offs and underwater banks (Hui, 1979; Dohl et.al. 1986; Perrin, 2002; Reeves et al. 2002). It has been suggested that this species uses offshore ridges as migration channels (Dohl et al. 1986). Very little is known about their movements, although offshore migrations have been reported during the autumn and winter months in the California Bight (USA), North-west Bay of Plenty (New Zealand) and Irish/Celtic Sea (UK) (Dohl et al. 1986; Goold, 1998 and Neumann, 2001).

Specimens of *D. capensis* have been identified in West Africa, from Venezuela to Argentina in the western Atlantic Ocean, from southern California to central Mexico and off Peru in the eastern Pacific Ocean, around Korea, southern Japan and Taiwan in the western Pacific Ocean, and in the waters off Madagascar and South Africa (Fig. 1.8). However, Heyning and Perrin (1994) did not include New Zealand or Australia in the known range of the long-beaked form since they found no morphological data to indicate the presence of this species in those waters, although skull morphometry (Amaha, 1994) and pigmentation patterns (Stockin and Visser 2005) in New Zealand common dolphins has raised issues of taxonomic ambiguity within these waters.

1.4 Diet

Common dolphins (*Delphinus* spp.) feed on a range of different prey items, varying between seasons and different geographic areas. Their prey includes epipelagic shoaling fishes as well as smaller mesopelagic fishes and squids (Perrin, 2002). Shoaling fishes such as mackerel (Scombridae), sardines (Clupeidae) or anchovies (Engraulidae), and to a lesser extent cephalopods made up the majority of the stomach contents of stranded or incidentally caught *D. delphis* in several areas of the world (eastern United States: Overholt and Waring 1991; Portugal: Silva, 1999; Mediterranean Sea: Bearzi et al. 2003; New Zealand: Neumann and Orams 2003). In general, common dolphins seem to be flexible opportunistic feeders that can adjust their diet according to local and seasonal prey availability. Furthermore variance exists between sex and age class (Silva, 1999; Bearzi et al. 2003; Neumann and Orams 2003).

Methods used to gain insight into marine mammal diet (Barros and Clarke, 2002) range from traditional stomach contents analysis (e.g. Santos et al. 2001; Lowry et al. 2004; De Pierrepont et al. 2005; Beatson et al. 2007a,b) to the use of stable isotopes (e.g. Walker and Macko 1999; Mærsk Lusseau and Wing 2006; Niño-Torres et al. 2006), fatty acids (e.g. Iverson et al. 1997; Olsen and Grahl-Nielsen 2003; Learmonth, 2006) and molecular techniques (e.g. Deagle et al. 2005; Jarman et al. 2006). A recent dietary study undertaken on New Zealand common dolphins

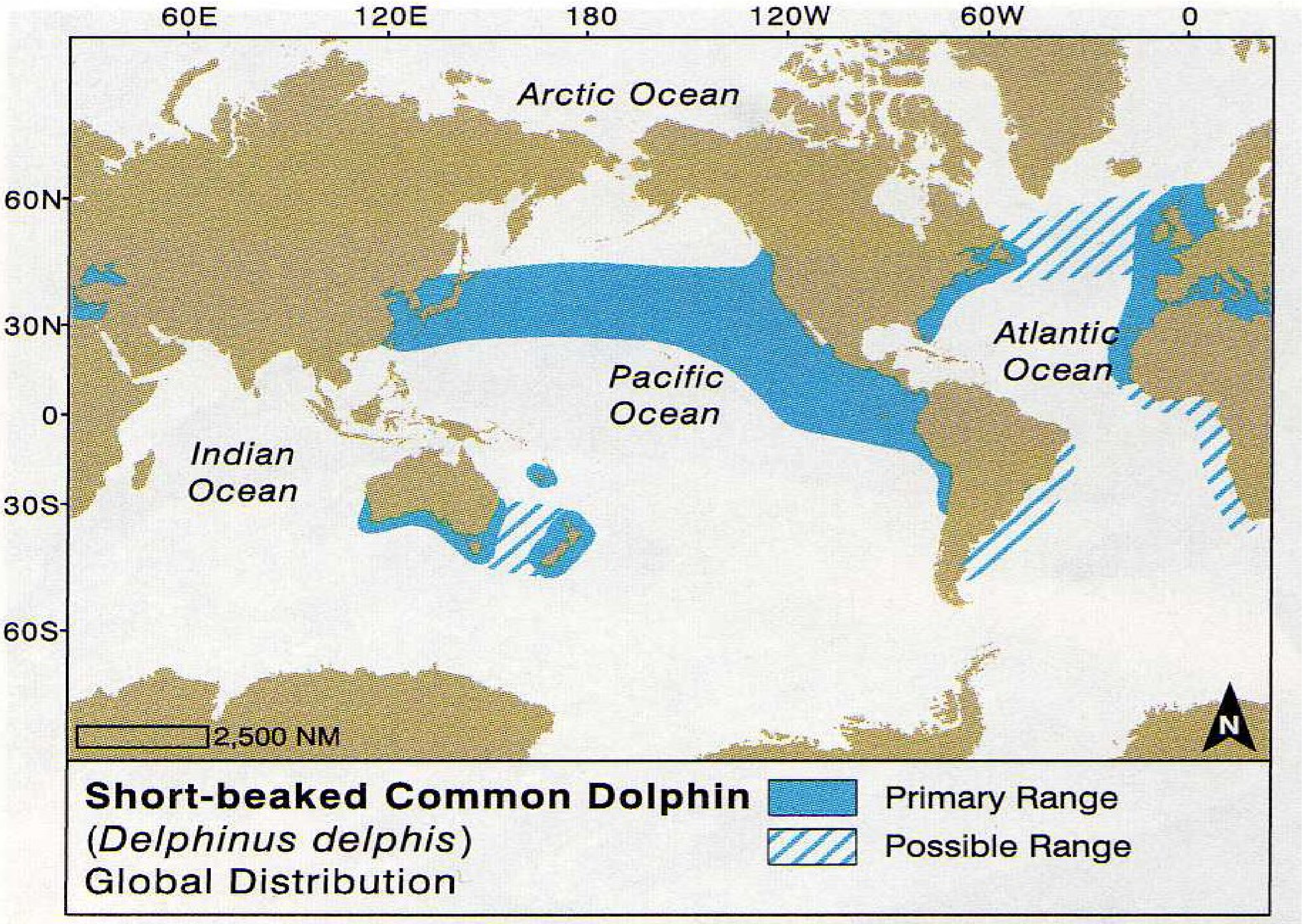

Fig 1.7: Approximate known range of the short-beaked common dolphin (*D. delphis*) (Source: Reeves et al. 2002)

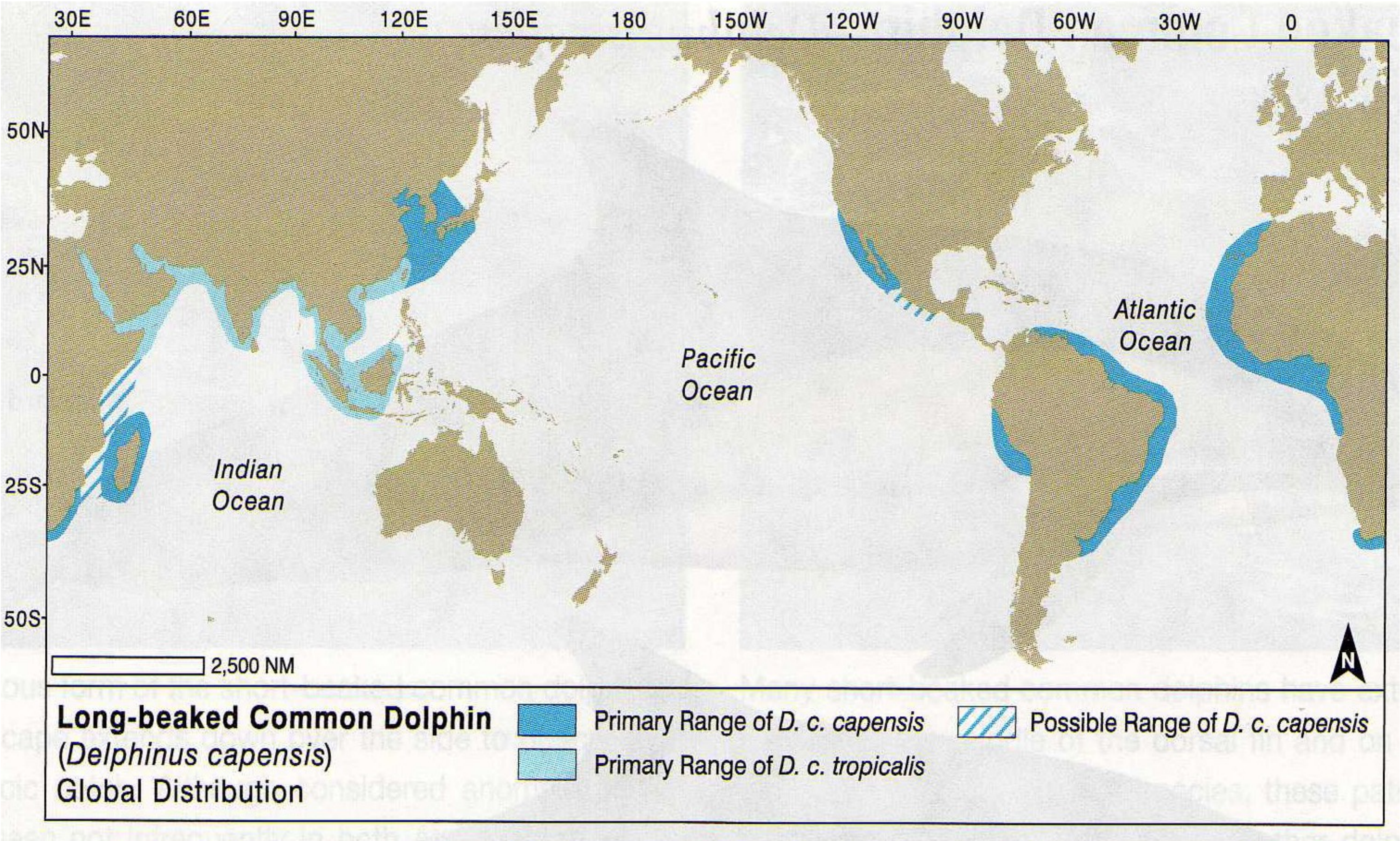

Fig 1.8: Approximate known range of long-beaked common dolphin (*D. capensis*) (Source: Reeves et al. 2002)

revealed arrow squid (*Nototodarus* spp.), jack mackerel (*Trachurus novaezelandiae*) and anchovy (*Engraulis australis*) as the main components of the diet (Meynier et al. 2008). The size range of prey reported was high (2 to > 40 cm) although most prey items identified were < 30 cm in total body length. Arrow squid, a species not abundant in the New Zealand waters (Morrison and Francis, 1999) appeared to be an important prey item for common dolphin feeding within these waters. In the Bay of the Plenty, New Zealand Neumann and Orams (2003) recorded feeding common dolphins predating on jack mackerel, kahawai (*Arripis trutta*), yellow-eyed mullet (*Aldrichetta forsteri*), flying fish (*Cypselurus lineatus*), parore (*Girella tricuspidata*) and garfish (*Hyporamphus ihi*).

1.5 Ecology

Group size recorded for common dolphins is highly variable, both between species and populations. For *D. delphis*, group size comprising up to thousands of individuals are frequently observed in some regions (Oswald et al. 2003), with possible segregations by age and sex also apparent within some aggregations (Perrin, 2002; Reeves et al. 2002). However, in the Hauraki Gulf, group sizes are much smaller (typically <50 animals) and are known to vary significantly by season, depth, sea surface temperature (SST) and latitude (Stockin et al. 2008a). Over 70% of groups encountered during a study by Stockin et al. (2008a) contained immature animals, with 25% of groups including neonates, suggesting this region is a likely calving/nursery area. Calves occur throughout the year although appear most prevalent during the austral summer months (Stockin et al. 2008a).

Common dolphins are often observed in association with other cetacean species (Perrin, 2002). For example, in the Mediterranean Sea *Delphinus* form mixed groups with striped dolphins (*Stenella coeruleoalba*) and/or Risso's dolphins (*Grampus griseus*), showing behaviours such as synchronized swimming and aggressive or playful interactions (Frantzis and Herzing, 2002). During feeding, commons dolphins in New Zealand have also been observed in association with mysticetes such as Bryde's (*Balaenoptera brydei*) or minke whales (*B. acutorostrata*), in addition to seabirds including Australasian gannets (*Morus serrator*) and shearwaters (*Puffinus griseus*) (Neumann and Orams, 2003; Stockin et al. 2008a).

1.6 Behaviour and Social Organisation

Few true behavioural studies have been conducted on common dolphins world-wide (e.g., Neumann, 2001; Stockin et al. 2009a). Those published data have focused on behavioural states (e.g. rest, travel, forage, social, mill) rather than behavioural events (e.g. spy hop, bow ride tail slap). Common dolphin behaviour is relatively cyclical, with dolphins passing from one state to another over relatively short time periods. Activity budgets compiled for common dolphins in the Hauraki Gulf (Stockin et al. 2009a) differ considerably with that previously described for common dolphins in neighbouring waters (Neumann, 2001). Neumann (2001) revealed travel (54.8%) and mill (20.5%) as the predominant behaviours for common dolphins off the northwestern Bay of Plenty. In that study, the author also noted seasonal and diurnal patterns in dolphin behaviour (Neumann, 2001). During research conducted in the Hauraki Gulf, forage (46.6%) and travel (28.9%) accounted for majority of the activity budget (Stockin et al. 2009a), a marked difference to that previously described by Neumann (2001). In the Hauraki Gulf, a correlation was also evident between group size and behaviour (Stockin et al. 2009a). Both small and large group sizes were reported to readily feed, suggesting foraging plasticity exists within this population.

The foraging behaviour of delphinids has been predominantly described in relation to bottom topography, water depth and other environmental factors (e.g. Hanson and Defran 1993; Hoelzel, 1993). Additionally, the spatial arrangement of prey (Acevedo-Guttierrez and Parker, 2000) is also strongly correlated with dolphin feeding behaviour. Dusky dolphins (*Lagenorhynchus obscurus*) have been documented to drive clupeid fish to the surface (Würsig and Würsig, 1980; Würsig et al. 2007), a cooperative strategy which has also been observed in spotted (*Stenella frontalis*) and Clymene (*Stenella clymene*) dolphins (Fertl and Würsig 1995; Fertl et al. 1997). Foraging tactics used by common dolphins remain poorly understood, although the cooperative rounding up of small schooling fish into a compact bait ball has been frequently described for this species (e.g. Würsig, 1986; Bel'Kovich et al. 1991; Gallo Reynoso, 1991; Clua and Grosvalet 2001; Neumann and Orams 2003; Burgess, 2006). Previous studies concerning the foraging ecology of common dolphins have found age/sex segregation evident within some populations (e.g. Young and Cockcroft, 1994; Silva, 1999). Neumann and Orams (2003) suggest feeding methods employed by individuals in New Zealand differ markedly to those used by groups of dolphins. For example, individual animals use *high-speed pursuits*, *fish whacking* and *kerplunking* to secure their prey, as opposed to cooperative feeding strategies such as *line abreast* (Fig. 1.9), *carouseling* (Fig. 1.10) and *wall formation* (Fig. 1.11).

Common dolphins are highly mobile animals (Evans, 1994) with complex behavioural patterns and dynamic social bonds (Neumann et al. 2002). Group dynamics can change both temporally (Stockin et al. 2008a) and spatially (Neumann et al. 2002), and likely reflect group function. For example, Neumann et al. (2002) identified bachelor pods via the presence of post anal humps in the Bay of Plenty. Nursery groups comprising only adult females with juvenile and calves have been recorded during stranding events within the Hauraki Gulf (Stockin et al. 2009b). These data support the findings of Schaffar-Delaney (2004) and Stockin et al. (2008a) in highlighting the potential use of Hauraki Gulf waters as a nursery.

While social bonds remain important in all delphinids, communication between individuals within a group can be complex when living within a marine environment. Despite having excellent eye sight (Dawson, 1980), dolphins live in an environment where visibility is often very limited. As such, dolphins use sound to achieve two functions: to perceive their environment and to communicate. Perception maybe passive – i.e. when sound produced by con-specifics or natural phenomena are heard (Tyack, 2000) or active –i.e. when the animal is both the source and receiver sound. In recent years it has been recognised that dolphins employ sonar for social as well as perceptual purposes (e.g. Herzing, 1996). Dolphin communication is primarily achieved by the use of narrow-band, often frequency modulated sounds commonly termed whistles (Caldwell et al. 1990; Matthews et al. 1999; Tyack, 2000) and by other less well defined vocalisations, variously termed buzzes, barks, grunts and chirps (e.g. Caldwell and Caldwell, 1968; 1970; Van Parjis and Corkeron, 2001).

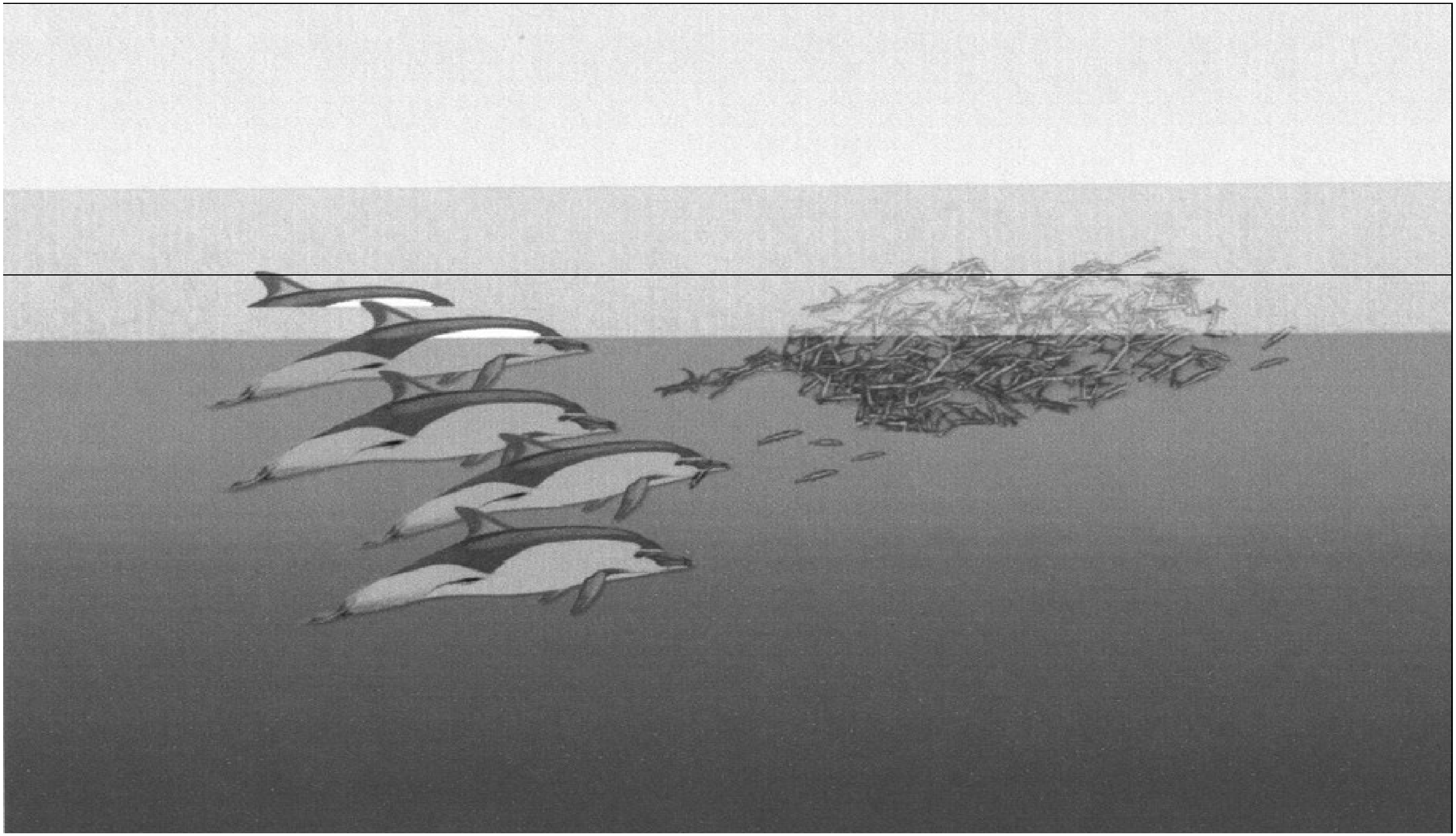

Fig 1.9: Line-abreast: Dolphins swim closely side-by-side and drive fish in front of them (Source: Neumann and Orams 2003)

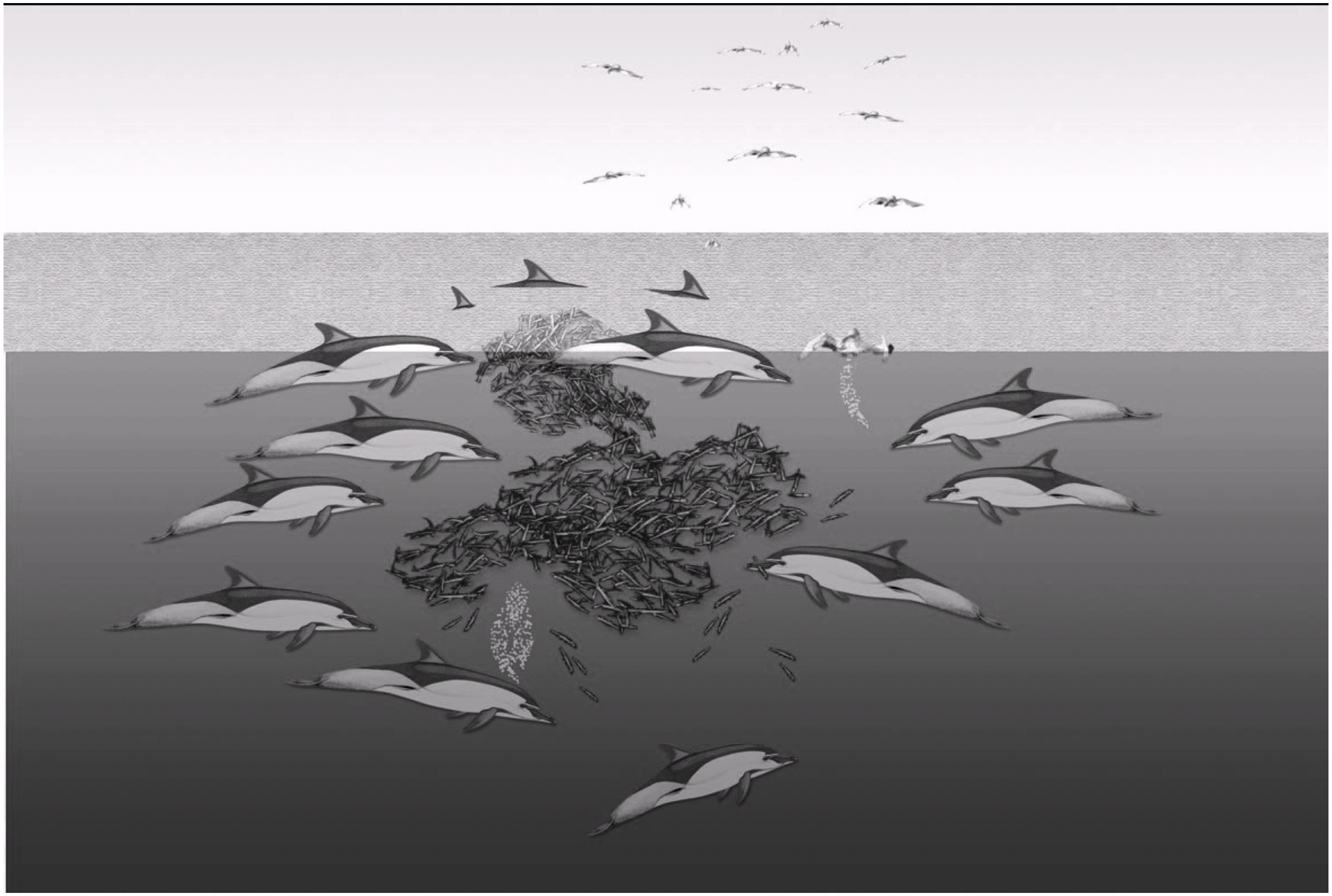

Fig 1.10: Carouseling: Dolphins cooperatively encircle a school of fish and trap them against the surface. Also, showing bubble-blowing underwater (Source: Neumann and Orams 2003)

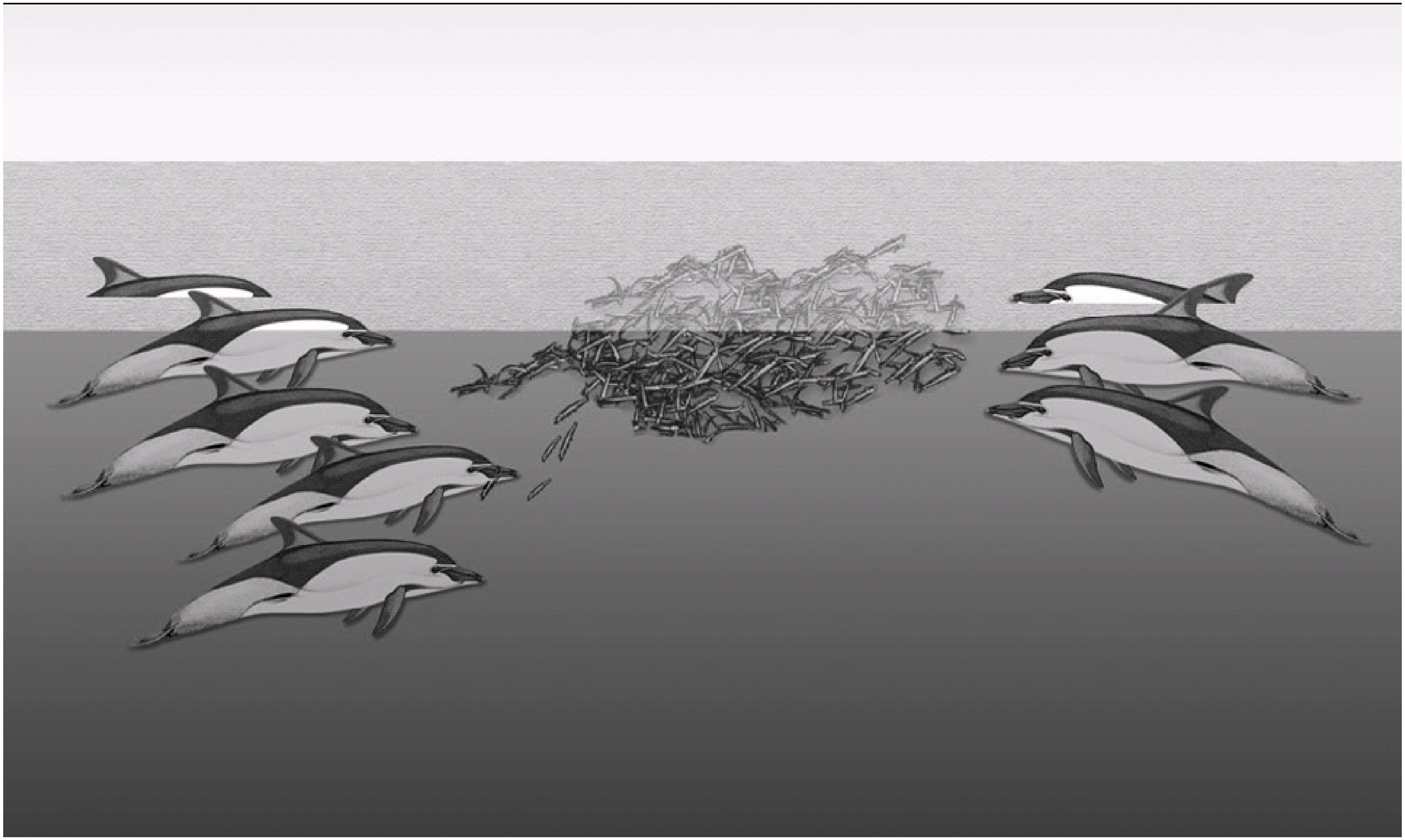

Fig 1.11: Wall formation: Dolphins drive fish towards another group of dolphins (Source: Neumann and Orams 2003)

1.7 Human Impacts

Since the 11th century, cetaceans have increasingly become seen as resource, with whaling operations exploiting these animals for economic growth and recreation (Clapham et al. 2002). As a consequence cetacean populations crashed and in 1986, the International Whaling Commission (IWC) effectively brought an end to commercial whaling by imposing a zero catch quota (Clapam et al. 2002). The effective ending of large scale commercial whaling was an acknowledgement that few now regard whales and dolphins as a mere 'resource'. With the removal of this most imminent danger, scientists turned their attentions to other threats including fisheries by catch (Chou et al. 1995; Slooten and Dawson, 1995; Fertl and Leatherwood 1997; Du Fresne et al. 2007; Rowe, 2007; Stockin et al. 2009b) tourism (Watkins, 1986; Corkeron 1995; Richardson et al. 1995; Donoghue, 1996; Hoyt, 2001; Erbe, 2002; Orams, 2004), ship strike (Laist et al. 2001) and pollution (Kemper et al. 1994; Jones et al. 1996; Zhou et al. 2001; Reijnders and Aguilar, 2002; Borrell and Aguilar, 2005a; Zegers et al. 2005; Tornero et al. 2006; Lahaye et al. 2007; Stockin et al. 2007; Lavery et al. 2008).

Northridge (2002) suggests the fishing industry probably represents the single area of human activity that has the most profound effect on marine mammals. Operational interactions, where marine mammals come into contact with fishing gear, frequently result in the incidental capture and subsequent injury and/or mortality of non target (*by-catch*) species. Understanding the dietary interactions of marine mammals and fish could provide valuable information for solving the conflict between fisheries and conservationists (Chou et al. 1995). Worldwide, 25 cetacean species have been observed to interact with trawls and 15 species have been reported to feed in association with trawling activities (Fertl and Leatherwood, 1997; Broadhurst, 1998). Cetacean interactions with trawls are complex, in part because both fisherman and cetaceans are drawn to areas of high prey density. Furthermore, within such areas, cetaceans are probably often attracted to trawling activities because they make it easier for the animals to exploit a concentrated food source. The bottlenose dolphin (*Tursiops truncatus*) is the cetacean species most often documented to feed in association with trawls (Chilvers and Corkeron, 2001). Within New Zealand waters, common dolphins are incidentally caught in the jack mackerel (*Trachurus declivia*, *T. novaezelandiae* and *T. murphyi*) trawl fishery (Du Fresne et al. 2007; Rowe, 2007) and in recreational set nets (Stockin et al. 2009b). While no estimates of set net mortality are available yet, extrapolations of observer data suggest between 80 and 300 common dolphins are killed annually in the jack mackerel fishery (Slooten and Dawson, 1995). Of 133 common dolphins which stranded between 1998 and 2008 along the NZ coast, 28% of individuals exhibited trauma and lesions indicative of net entanglement (Stockin et al. 2009b). Carcasses examined as part of that study did not include known bycaught animals recovered from the jack mackerel fishery. Thus, the proportion of common dolphin deaths in New Zealand attributable to fisheries bycatch is likely to significantly higher than that reported by Stockin and colleagues.

Concern about the conservation of marine mammal populations inevitably extends to consideration of the impact of contaminants (O'Shea, 1999). The concept of pollution incorporates many different substances to which marine mammals are exposed and might affect their health adversely. These include chemical compounds, oil pollution-derived substances, marine debris, sewage-related pathogens and excessive amounts of nutrients causing environmental changes (Reijnders and Aguilar, 2002). In fact, marine mammal die-offs and morbidity events from harmful algal blooms that seem to be increasing with runoff and other coastal ecosystem changes (Van Dolah, 2005); and an expanding list of chemical contaminants synthesized by humans. Indeed, today's surviving long-lived marine mammals may have been born in seas almost completely free of persistent organic pollutants, given that large-scale use of organochlorine pesticides such as dichlorodiphenyltrichloroethane (DDT) and industrial compounds such as polychlorinated biphenyls (PCBS) did not occur until the 1940s or later (O'Shea, 1999).

Generally, most contaminant levels reported for common dolphin refer to northern hemisphere waters (e.g. ; Zhou et al. 2001; Borrell and Aguilar, 2005a; Zegers et al. 2005; Tornero et al. 2006; Lahaye et al. 2007). Considerably less data is available southern hemisphere waters, with few studies describing pollutant levels in this species (e.g. Kemper et al. 1994; Jones et al. 1996; Stockin et al. 2007; Lavery et al. 2008).

Vessels can be responsible for two kinds of impacts: direct (e.g. physical collisions) (Fig. 1.12) and indirect (e.g. behavioural) impacts. Behaviour changes are caused mainly by engine noise (Bauer and Herman, 1986; Norris, 1994; Richardson et al. 1995). However, indirect behavioural changes can be discrete and more difficult to detect compared with direct vessel strikes. Vessel collisions are of great concern to some marine mammal populations, such as manatees (*Trichechus manatus*) in Florida and North Atlantic right whales (*Eubalaena australis*). Ship strike is the main cause of mortality to these two populations (Ackerman et al. 1995; Ward-Geiger et al. 2005). Collisions between whales and vessels occur generally in coastal waters on feeding or breeding concentrations. Fin (*Balaenoptera physalus*), right (*E.australis* and *E.glacialis*), humpback, sperm (*Physeter macrocephalus*) and gray whales (*Eschrictius robustus*) are the species more frequently affected (Laist et al. 2001).

In connection with acoustic disturbance, the issue of boat disturbance is considered here. During the 1980s, boat-based tourism focusing on watching and interacting with free-ranging whales and dolphins was a relatively isolated occurrence (Hoyt, 1996). However, this type of tourism has experienced rapid growth during the 1990s, with now over 100 countries, including Japan, Norway, South Africa, the United Kingdom, the United States and New Zealand involved in this industry (Hoyt, 2001). In some regions, whale watching has now economically replaced more lethal activities e.g. whaling. Furthermore, in certain scenarios, it has offered scientists a '*platform*' to study whales and increased public awareness of marine mammals (Erbe, 2002). While theoretically idyllic, the reality is that poorly managed tourism operations can have a detrimental impact on the animals targeted (Orams, 2004). A variety of cetacean species in accessible coastal waters has resulted in the rapid growth of dolphin-based tourism in New Zealand (Fig. 1.13). Currently, five dolphin species are targeted commercially by dolphin-watch and swim-with programs in New Zealand: the bottlenose dolphin, common dolphin, dusky dolphin, Hector's dolphin (*Cephalorhynchus hectori*) and killer whale (*Orcinus orca*). In New Zealand, the *Marine Mammals Protection Act* (1978) aims to protect wild marine mammals from harmful human contact. This is facilitated through the *Marine Mammals Protection Regulations* (1992), which attempt to manage human marine mammal interactions (Donoghue, 1996).

Fig.1.12: Mutilated carcass of common dolphin (*Delphinus* sp) calf exhibiting wounds consistent with a propeller strike (photo by Author)

Under this legislation, the New Zealand Department of Conservation (DoC) is charged with ensuring that tourism operations are not detrimental to marine mammals being targeted. Recent growth in commercial whale and dolphin watching has raised concerns about how cetaceans are affected by boats. In fact, reactions to approaching vessels tend to be varied, and are not often easily interpreted. For example, Corkeron (1995) observed an increase in the aerial behaviour of humpback whales in the presence of whale-watching boats off Australia. Often reactions may involve either complete avoidance or attraction (Watkins, 1986). Modifications in vocal behaviour have also been reported in some species (Richardson et al. 1995).

1.8 Acoustic Disturbance

Acoustic disturbance is another form of pollution considered to affect marine mammals, especially cetaceans (Richardson et al. 1995). Most man-made noises that could affect marine mammals arise from a few general types of activities in and near the sea: transportation, dredging, construction, hydrocarbon and mineral exploration and recovery, geophysical surveys, sonars, explosions, and ocean science studies. Sources are categorised as *transient* if their duration is brief (e.g. pulses from airguns, sonars, or explosions); or *continuous* if they persist over a long time (e.g. sounds of an oil drilling platform). Most cetaceans are very sensitive to sounds between 10 kHz and 100 kHz (Richardson et al. 1995). These sensitivities have generated substantial scientific and media discussion about the possible effects of intense anthropogenic sound on the ears of sea mammals (e.g., Mulroy, 1991; Green et al. 1994; Richardson et al. 1995). Intense sonic emissions can mask echolocation, communication, or other sounds that are otherwise important to the individual and its group. Moreover, permanent auditory damage may result from single or repeated exposure to very intense sounds, especially impulsive noise. Therefore at best, noise pollution from motorized vessels and from many other anthropogenic sources can mask the signals that cetacean use to communicate, while at worst it has the potential to cause lasting physiological damage or even death (Richardson et al. 1995).

Fig 1.13: Tour boat approaching a sperm whale (*Physeter macrocephalus*) (Source: Whale Watch Kaikoura, New Zealand)

1.9 Study Aims

Common dolphins are assumed to be abundant in the warm temperate to sub-tropical waters of the southwest Pacific. However, given the apparent taxonomic ambiguity within the genus and absence of abundance data, it is difficult to assess the accuracy of such an assumption (Stockin, 2008). While common dolphins are known to be affected by various human activities, including tourism (Stockin et al. 2008b), it is still not clear whether such impacts are the result of physical or acoustic disturbance by vessels.

No prior research has been undertaken to describe the vocal repertoire of the New Zealand common dolphin population. As such, this study represents the first characterisation of the vocal behaviour of this species within New Zealand waters.

This study aimed to:

- Describe the whistle characteristics of common dolphins in the Hauraki Gulf, Auckland
- Analyse the relationship between behavioural states and vocalisations in order to assess differences between foraging and travelling groups using Hauraki Gulf waters
- Assess population differences within *Delphinus* vocalisations by comparing the whistle characteristics of New Zealand common dolphins with published data available for the Celtic Sea and English Channel populations.

Chapter 2

Australasian gannets (*Morus serrator*) flying over the water in Hauraki Gulf, New Zealand (Photo by Author)

Materials and Methods

2.1 Study Site

Situated 60 km north of Auckland city (36° 51’ S, 174° 46’ E) the Hauraki Gulf (Fig. 2.1) is a shallow (60 m maximum depth), semi-enclosed body of temperate water (Manighetti and Carter, 1999) extending from Bream Head to Cape Colville at the northern tip of the Coromandel Peninsula, on the east coast of North Island, New Zealand (Latitude 36^{o} 10’ to 37^{o} 10’ S: Longitude 174^{o} 40 to 175^{o} 30’ E). Adjacent to New Zealand’s most urbanized city, the gulf is open to the north, while landlocked to the south and west, and partly protected in the east by Great Barrier Island and the Coromandel Peninsula (Fig. 2.1).

Including approximately 47 islands, the Hauraki Gulf spreads over 13,600 km^2 of South Pacific Ocean at approximate latitude of 36° 55' S to 36° 30’ S. Influenced by the subtropical East Auckland Current (EAUC), the region is extremely productive (Booth, 1989) and is of proven importance for feeding (Stockin et al 2009a) and nursing (Stockin et al. 2008a) common dolphins. Unlike other areas around the New Zealand coast, common dolphins occur within the Hauraki Gulf year-round (Stockin et al. 2008a), and have proven susceptible to coastal accumulative impacts (e.g., Stockin et al. 2007; Stockin et al. 2008b; Stockin et al. 2009b). The Hauraki Gulf hosts three shipping channels involving in excess of 4,000 commercial vessel movements per year (Behrens, 2009).

2.2 Data Collection

Non-systematic surveys were conducted in Hauraki Gulf between February 2008 and May 2009 using a 20 m commercial tour catamaran *Dolphin Explorer* powered by 350 hp engines (Fig. 2.2). Surveys were conducted in daylight hours during calm sea conditions (Beaufort < 3, Swell < 1 m) and good visibility (> 1 km). Acoustic recordings of common dolphins (*Delphinus* sp) were made using a PZ-1A (LAB-core systems) hydrophone fitted to a Sony walkman MZ-NH700 digital audio disc (DAT) recorder with a sampling rate of 44.1 kHz (Fig. 2.3).

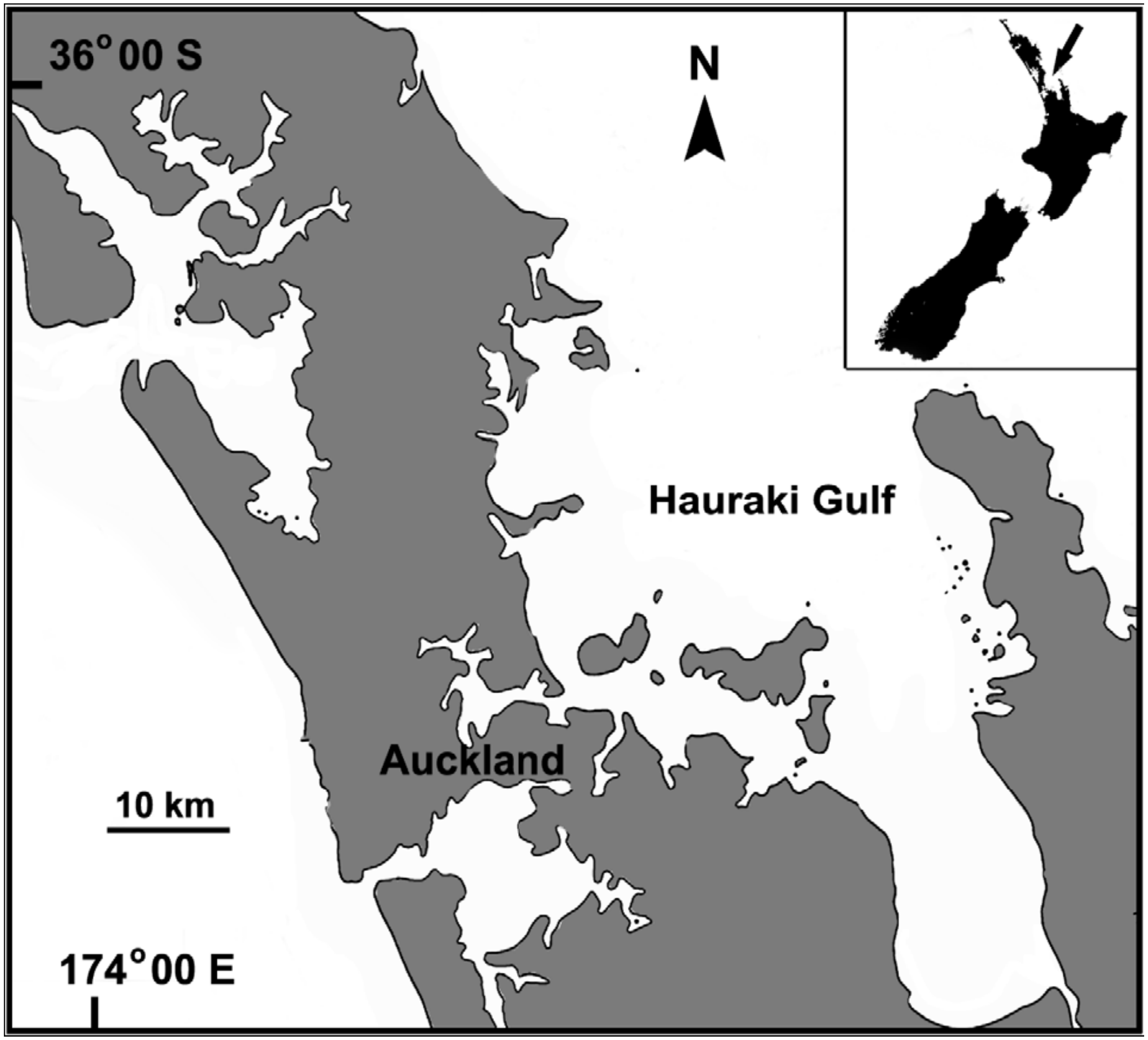

Fig 2.1: Map of Hauraki Gulf, Auckland in relation to the rest of New Zealand (Source: Stockin et al. 2008b)

Fig 2.2: Tour vessel *Dolphin Explorer* used to undertake acoustic recordings of common dolphin (*Delphinus* sp) in the Hauraki Gulf, New Zealand between February 2008 and May 2009 (photo by Author)

Fig 2.3: PZ-1A hydrophone (left) and MZ-NH700 Sony digital audio disk (right) used to record vocalisations of common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand between February 2008 and May 2009 (photo by Author)

Observations were conducted using a continuous scanning methodology (Mann, 1999) by naked-eye and with binoculars (Bushnell 8 x 42 magnification). Sighting cues used to detect dolphins include splashing and/or silhouettes of porpoising animals, water disturbance due to surface activity of animals, sighting of dorsal fins, and/or the presence of key indicator species (e.g. Australasian gannet (*Morus serrator*) and Bryde's whale (*Balaenoptera brydei*). Both of these species are known to associate with schools of common dolphins within this region (Stockin et al. 2008a). A school was defined as any number of dolphins engaged in a similar activity, moving in a uniform direction and within 5 body-lengths of each other (Stockin et al 2008a,b).

Once within 400 m of a group of dolphins, the vessel would slow to an approach speed (~ 5 knots). At this point, environmental parameters (*i.e.*, water depth, SST, sea state, visibility, and weather) and data relating to group size and composition were recorded. The boat would then travel slowly parallel to the course of moving animals, approaching slightly to the rear of the group in a slow and continuous manoeuvre. Once the boat was within approximately 100 m of the animals, the start time and location for the encounter were recorded. Manoeuvring close to the centre of the focal group, the vessel engines and generator were then switched off so as to reduce disturbance and level of background noise. The hydrophone was then slowly lowered 6 m under the surface of the water and recordings made for up to 5 min per sample.

Visual observations of each focal group resulted in the collection of behavioural data using states (i.e. travel, forage, social, rest and mill) as defined in Table 2.1. Focal group follows with instantaneous scan sampling of the predominant behaviour (Altmann, 1974; Mann 1999) was used as the sampling protocol. Only behaviours that could be reliably and consistently recorded (Mann, 1999) were sampled (Table 2.1). The behavioural state of each focal group was determined by the activity of > 50% of group members. Focal groups were sampled to determine vocalisations at the group, rather than the individual dolphin level. Observations ended when fuel reserves became low or when deterioration of the weather and/or daylight occurred. At the end of an encounter, the hydrophone was removed from the water, cleaned and preliminary analyses of the vocalisations made to ascertain the quality of the recordings prior to resetting the equipment for the next encounter.

Table 2.1: Definitions of behavioural states recorded for common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand between February 2002 and January 2005 (modified from Stockin et al. 2009a)

Behavioural State	**Definition**
Forage	Dolphins involved in any pursuit, capture and/or consumption of prey, as defined by observations of fish-chasing (herding), coordinated deep diving and rapid circle swimming. Prey frequently observed at the surface during foraging activity of the dolphins.
Mill	Dolphins exhibited non-directional movement, frequent in heading prevented animals from making headway in any changes specific direction.
Rest	Dolphins observed in a tight group (< 1 body length between individuals), engaged in slow manoeuvres with little evidence of forward propulsion. Surfacings appeared slow and generally more predictable (often synchronous) than those observed in other behavioural states.
Social	Dolphins observed chasing, copulating and/or engaged in any other physical contact with other dolphins (excluding mother-calf pairs). Aerial behaviours such as breaching frequently observed.
Travel	Dolphins engaged in persistent, directional movement, making noticeable headway along a specific heading.

If more than one dolphin group was encountered during any one survey, acoustic recordings were only sampled from the first group only, unless the distance apart (spatially and temporally) prevented the resampling of the same individuals.

This reduced the possibility of pseudo-replication within a survey, although it cannot exclude the possibility of multiple recording from the same animals within and between surveys.

2.3 Data Analysis

Common dolphin recordings were analysed using Raven Pro 1.3 (Charif et al. 2007). Acoustic data were only included when species identification was confirmed visually by the author (VP). The sounds within recordings were categorised as echolocations, whistles and vocalisations or boat noise. Recordings were digitally downloaded onto an Acer 4720G laptop computer (Fig 2.4) at the end of each encounter.

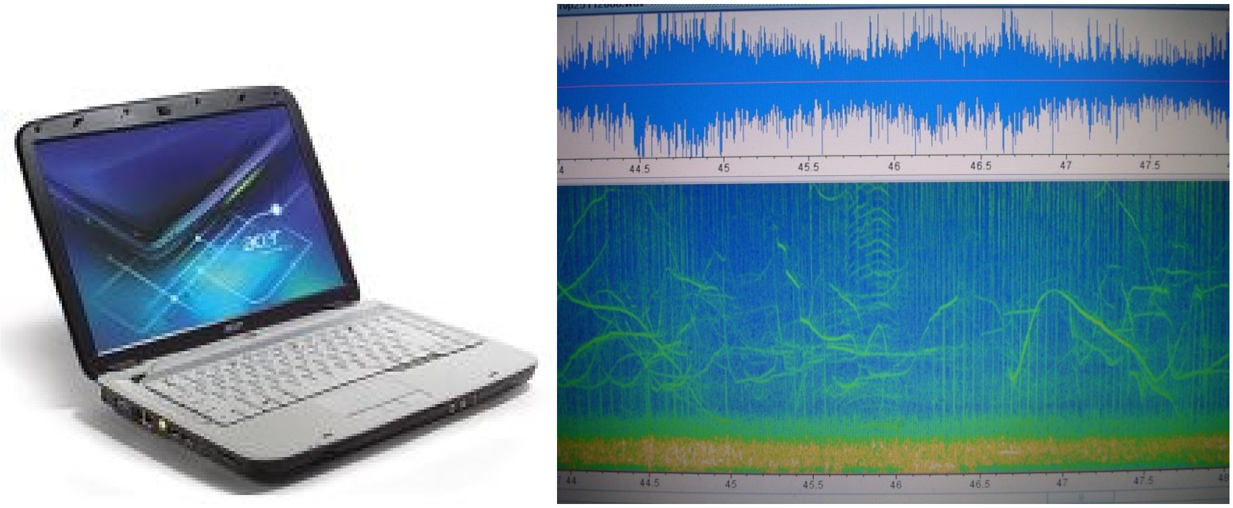

Fig. 2.4: Acer 4720G (left) and spectrogram (right) created in Raven Pro 1.3

2.3.1 Whistle Density in the Hauraki Gulf Population

The continuous recordings of each survey day were first broken down into intervals. The number of whistles in each file was counted visually using Raven Pro 3.0. Four whistle density classes were described based on the amount of whistles per second (Table 2.2). In the present study, the hypothesis concerning the density is that this parameter can be influenced by two main factors: number of dolphins and behavioural state. In order to assess the rate of vocalisations between dolphins engaged in different behaviours, whistle density was calculated only for groups with similar group size and sampling period. Whistle density was calculated as number of whistles per unit of time, expressed in seconds.

Table 2.2: Definitions of density categories used to describe the whistles of common dolphins (*Delphinus* sp) recorded in the Hauraki Gulf, New Zealand between February 2008 and May 2009

Whistles Density	Definitions	Density Range (w/s)
No	No whistle is detected on the spectrogram	0
Low	A maximum of 100 whistles per 60 seconds	0,016 - 1.67
Medium	A maximum of 500 whistles per 60 seconds	1.68 - 8.34
High	Over 501 whistles per 60 seconds	> 8.35

2.3.2 Whistle Classification in the Hauraki Gulf Population

Each whistle was categorised based on the six contours described by Ansmann et al. (2007). These include A: Constant Frequency, B: Upsweep, C: Downsweep, D: Convex, E: Concave and F: Sine. These were further subdivided into subtypes depending on the degree of modulation evident within the general type. Sub-types were coded by numbers, where (1) was no further modulation (e.g. A1 would be a straight line with no other modulation), (2) represented modulation at the start of the general type (e.g. a C2 whistle might have a short constant or falling frequency section just before the start of downsweep which characterizes the overall shape of the whistle), (3) was a modulation at the end of the general type (e.g. D3 might have a short constant or rising frequency section following the convex) and (4) indicated a further modulation at both sides of the main type section of the whistle (Fig. 2.5). Generally, these features were regarded as further modulations rather than part of the main whistle characteristic if they had less than half the frequency span of the main part. For example, whistles were considered upsweeps with further downsweeping modulation at the end rather than a convex whistle if the downsweeping sector covered less than half the frequency span of the main upsweep. For upsweeps and downsweeps, a further sub-group (5) was added which indicated a step within the general whistle type (e.g. B5 would be an upsweep where the rising frequency section is interrupted by a constant frequency period).

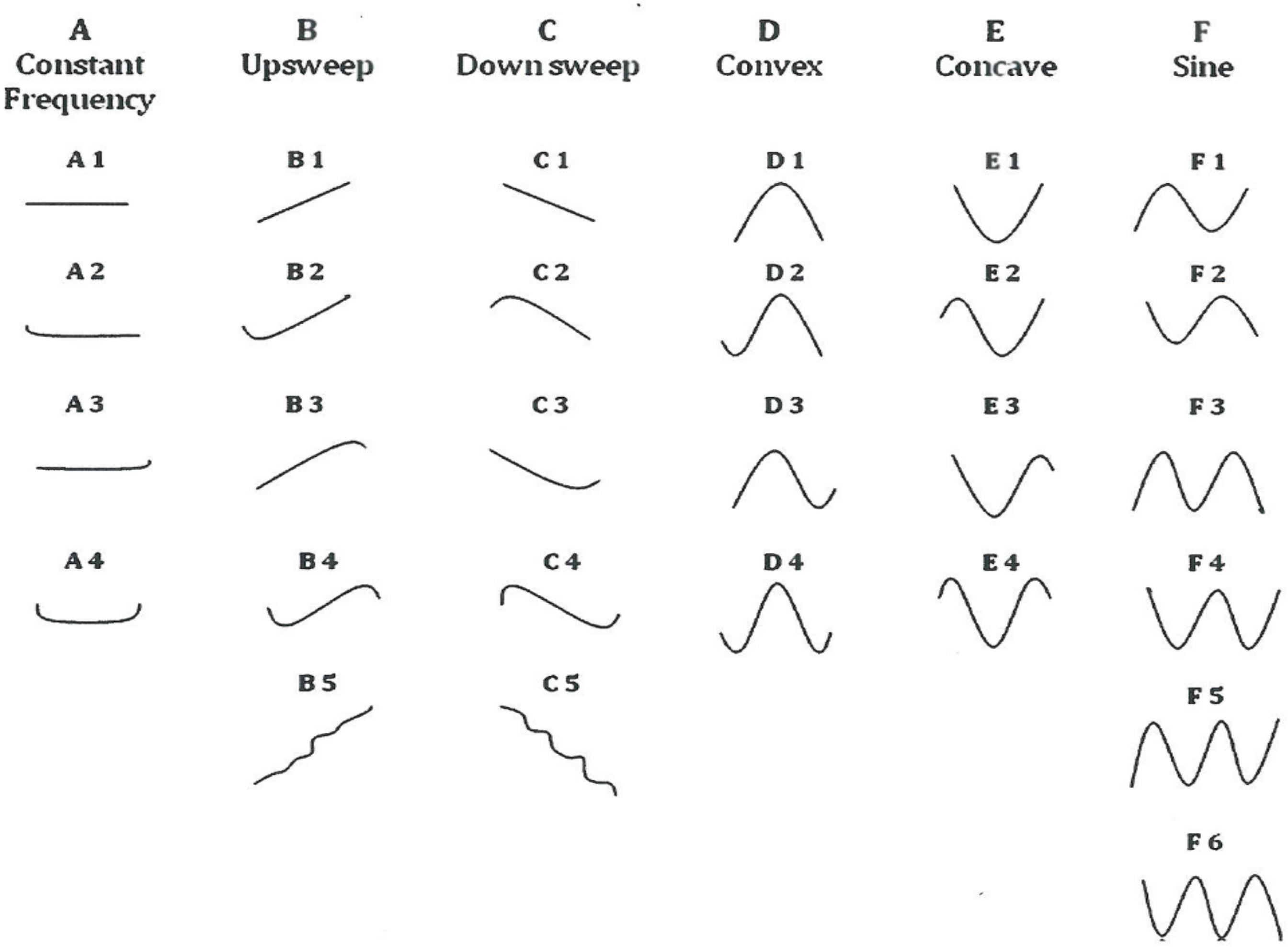

Fig 2.5: Idealized contours of the different whistle types (modified from Ansmann et al. 2007)

For sine types (F) the sub-type numbering followed an alternative system. Rather than describing the further modulation around the main section, it was used to indicate the degree of sinusoidal modulation, that is the number of inflections, as well as whether the sine contour starts with a rising or a falling frequency section: (F1) is a sine contour starting with a rising section and consisting of two inflections, (F2) is a similar contour with two inflections but starting with a falling section. Contours (F3) and (F4) both have three inflections and start with a rising or a falling frequency section, respectively. Whistles (F5) and (F6) follow the same system, with four inflections and (F7) and (F8) combine all sine contour whistles with five or more inflections, also with rising or falling start frequency, respectively (Ansmann et al 2007). Each continuous contour was treated as one whistle. Whistles showing breaks were also considered as one whistle if the parameter of frequency and time that characterise the break are not dissimilar. Any contour which did not match those detailed by Ansmann et al. (2007) were treated as alternatives and catalogued, where possible, on their typology, follow Ina Ansmann et al. (2007). New contours were described based upon the predominant feature indicated within the six existing contours. For example (G: - Prevailing Constant Frequency, H: - Prevailing Upsweep, I: - Prevailing Downsweep, L: - Prevailing Convex, M: - Prevailing Concave and N: - Prevailing Sine). These were further subdivided into subtypes that did not have any link with the degree of modulation. For example, L7 (Present study) is based upon contour D2 (Ansmann et al. 2007, Fig. 2.5).

2.3.3 Whistle Characteristics in the Hauraki Gulf Population

A total of 8 parameters were used to examine whistle characteristics from the spectrogram: End Time, Start Time, Minimum Frequency, Maximum Frequency, End Frequency, Start Frequency, Inflection and Steps (Fig. 2.6). These parameters were imported into Microsoft Excel where End and Start Time, Minimum and Maximum Frequency were combined to calculate Duration (End Time – Start Time), Frequency Gradient (End Frequency – Start Frequency / Duration) and Frequency range (Maximum Frequency – Minimum Frequency). To calculate the mean of frequency, three further points along the whistle in addition to End and Start Frequency were counted. One point was used to mark the half span of the whistle while a further two points marked the half span of each of the first and second sectors.

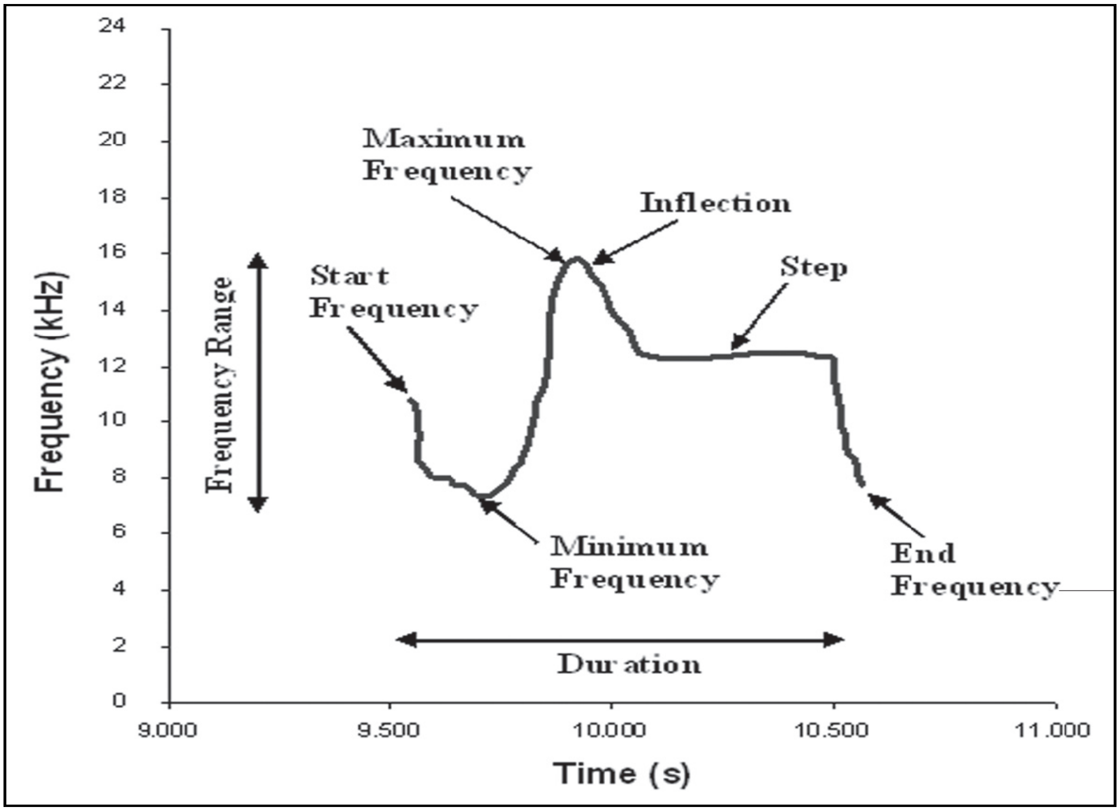

Fig 2.6: Whistle contour illustrating parameters measured by Ansmann et al. (2007) and adopted for comparative purposes in the present study of common dolphins (*Delphinus* sp) in the Hauraki Gulf, New Zealand

2.3.4 New Zealand *versus* United Kingdom Comparison

The dataset acquired in the present study for Hauraki Gulf common dolphins was compared with that available within the published literature. Using summary data detailed in Ansmann et al (2007), a basic comparison of parameters between UK and Hauraki Gulf common dolphins was made. Parameters used in this comparison (Fig. 2.6) involve frequency (e.g. minimum frequency, maximum frequency, frequency range and mean of frequency) and modulation (e.g. duration, inflections and steps). As detailed in Morisaka et al. (2005), frequency parameters are the most important variables when discriminating between populations. Subsequently, these parameters were also taken into consideration for each whistle type (Fig 2.5).

2.3.5 Statistical Analysis

Whistle characteristics calculated for common dolphins in the Hauraki Gulf were analysed in relation to encounter, group size and whistle type using the statistical software StatsDirect version 2.7.7. The distributions of continuous response variables were initially tested for normality using Kolmogorov-Smirnov test (Zar 1996). In most cases, data were non-normal so the non-parametric Kruskal-Wallis test was applied. Mann-Whitney U-Tests were used to assess differences between foraging and travelling dolphin groups. All tests were considered statistically significant at $P \leq 0.05$.

The analysis of the eight described parameters allowed characteristics of the New Zealand population to be compared directly with other studied populations of *Delphinus* (Ansmann et. al 2007; Wakefield, 2001). All the whistles categorized were compared with parameters detailed in Ansmann et al. (2007). A summary of descriptive statistics including the means and ranges of each whistle type was calculated for a comparison of the populations.

Chapter 3

Common dolphin (*Delphinus* sp.) calf porpoising in Hauraki Gulf waters, New Zealand (photo by Author)

Results

3.1 Whistle characteristics of common dolphins in the Hauraki Gulf, New Zealand

3.1.1 Effort Data

Data were collected between February 2008 and May 2009 during 22 boat-based surveys conducted in the Hauraki Gulf, New Zealand (Fig. 3.1). Approximately 150 hrs of field effort was completed, resulting in 29 independent groups of common dolphin (*Delphinus* sp). Of these, vocalisations were recorded during 26 encounters (Table 3.1, Fig. 3.2).

3.1.2 Whistle Density

A total of 105.10 min of recordings were made in the visual presence of common dolphins, resulting in 11,715 whistles. Consequently, a total of 2663 whistles resulting from 28 min of registration were classified from these recordings. These comprised 1831 whistles randomly chosen and 832 whistles analysed in relation to behaviour. Continuous recordings for each encounter (mean = 4.38 min, S.D. = 3.13) were broken down into a total of 105 independent intervals. Out of those, 17 (mean = 0 w/s) had no acoustic detections, 9 (mean = 10.5 w/s) showed high whistles density (up to 501 whistles per min – up to 8.35 w/s), 14 (mean = 4.3 w/s) exhibited medium whistles density (101 to 500 whistles per min - 1.68 w/s to 8.33 w/s) and 65 (mean = 0.5 w/s) were classified as low whistles density (1 to 100 whistles per min - 0,016 w/s to 1.66 w/s) (Table 2.2). Whistle density ranged from 0.015 to 15.2 w/s (mean = 1.96 w/s, S.D. = 2.42), with surveys conducted on the 27/02/2008 and 1/04/2008 exhibiting the lowest whistles density per encounter. Acoustic data collected during these surveys accounted for 113 and 96 s, respectively.

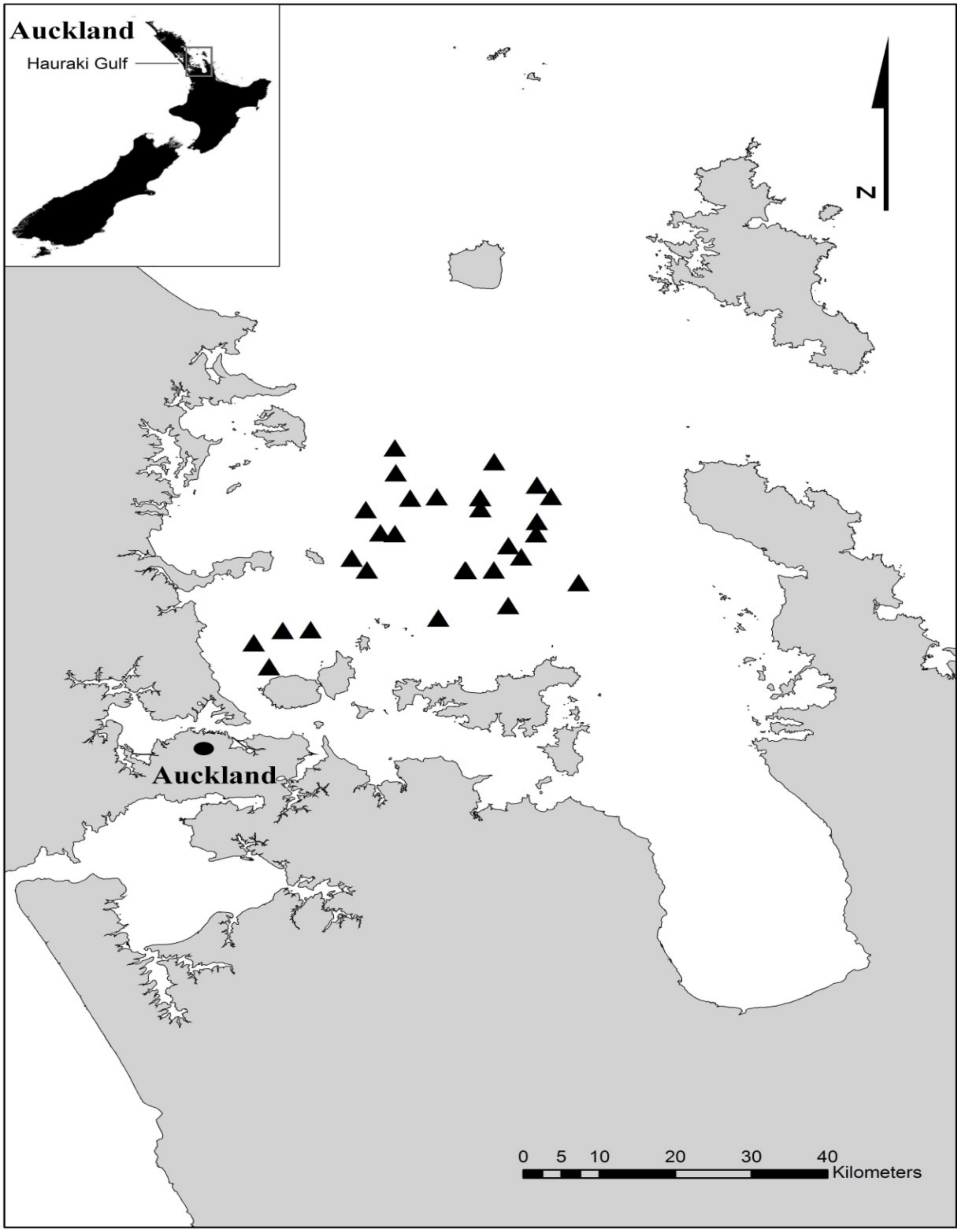

Fig. 3.1: Locations of common dolphin (*Delphinus* sp.) groups sampled during acoustic surveys conducted in the Hauraki Gulf, New Zealand between February 2008 and May 2009

Table 3.1: Location for surveys conducted in the Hauraki Gulf, New Zealand between February 2008 and May 2009

Survey	Date	Latitude	Latitude	Latitude	Longitude	Longitude	Longitude
01	08-Feb-08	36	32	6.15	174	57	0.68
03	27-Feb-08	36	45	4.71	174	50	8.64
03	27-Feb-08	36	32	1.8	175	5	8.2
07	12-Mar-08	36	43	6.1	174	49	3.6
08	01-Apr-08	36	38	8.2	175	12	6
08	01-Apr-08	36	35	4.8	175	7	7
09	11-Apr-08	36	33	4.96	175	9	8.23
09	11-Apr-08	36	31	1.19	175	10	8.68
10	15-May-08	36	31	6.96	175	5	7.11
10	15-May-08	36	31	9.56	175	0	8.89
11	23-Aug-08	36	41	3.2	175	2	8.8
11	23-Aug-08	36	36	7.08	174	56	1
12	25-Aug-08	36	30	5.18	175	9	8.23
14	29-Aug-08	36	37	5.32	174	57	4.86
14	29-Aug-08	36	40	1.06	175	7	6.17
15	12-Nov-08	36	37	8.93	175	4	7.1
16	21-Nov-08	36	28	9.16	175	6	6.36
17	25-Nov-08	36	34	6.19	175	9	5.12
17	25-Nov-08	36	37	5.72	175	6	4.91
18	30-Dec-08	36	42	0.88	174	53	5.54
19	31-Dec-08	36	34	5.59	174	59	4.3
20	06-Jan-09	36	27	1.14	174	59	3.68
21	07-Jan-09	36	31	2.86	175	2	2.74
21	07-Jan-09	36	29	4.16	174	59	8.02
22	15-Jan-09	36	42	4.91	174	51	6.74
22	15-Jan-09	36	37	5.35	175	4	2.5
23	30-Mar-09	36	34	1.11	174	58	2.22
24	28-May-09	36	36	0.59	175	8	1.7

Whistle density was highest (67.3w/s) during 7 mins of recording during a survey conducted on 28/05/2009. If we consider all data collectively (105.10 mins, 11116 whistles), a mean whistle density of 1.81 w/s (Table 3.2) was achieved in the present study.

All vocalisations analysed from different pods in the Hauraki Gulf showed a mean whistle duration of 0.27 s (Range = 0.01s-4s; SD = 0.319) and a range frequency of 2211.63 Hz (Fig. 3.3). Minimum and maximum frequencies for this population were 11393.1 and 13604.93 Hz, respectively. The mean number of inflection and steps recorded for Hauraki Gulf common dolphins was 0.56 (SD = 0.862) and 0.06 (SD = 0.349), respectively (Fig. 3.4). Data represented in Table 3.3 describe the main whistle characteristics determined for common dolphins in the Hauraki Gulf.

3.1.3 Whistle Types

All seven contours (A-F) described by Ansmann et al. (2007) for UK *Delphinus* were evident in the New Zealand sample set. Of the 2663 whistles analysed from Hauraki Gulf common dolphins (Table 3.4), downsweep contours were the most frequent whistle type, comprising 35.9% of whistles examined. The next most frequent whistle types were upsweeps and constant types, accounting for 28.5 and 16.4%, respectively. Concave and convex contours had an equal rate of 6.1% and accounted for the smallest proportion of whistles identified within the repertoire of Hauraki Gulf common dolphins. Sine contours were detected in 7% of recordings analysed from the New Zealand dataset. Of all the whistle types identified in the present study, the least modulated subtypes appeared to be the most frequent (Fig. 3.5 – 3.6).

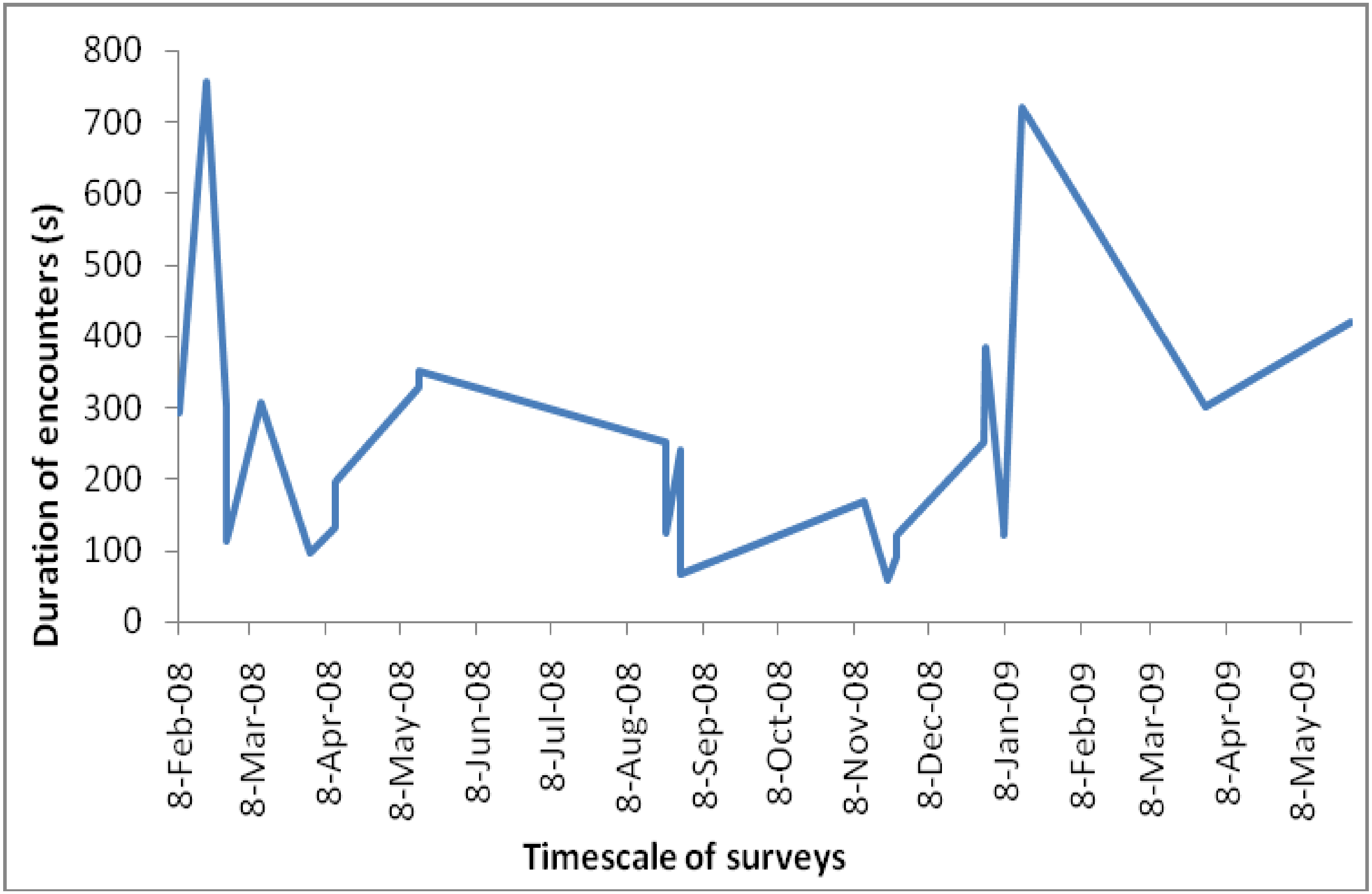

Fig. 3.2: Duration of recordings collected during surveys in Hauraki Gulf, New Zealand between February 2008 and May 2009

Table 3.2: Parameters describing whistles detected in the population of common dolphins (*Delphinus* sp.) in Hauraki Gulf, New Zealand between February 2008 and May 2009. Note: s = seconds, w/s = whistles per second

Survey	Date	Duration (s)	Whistles counted	Density (w/s)
01	08-Feb-08	293	1612	5.50
02	19-Feb-08	755	45	0.06
03	27-Feb-08	300	380	1.27
03	27-Feb-08	113	3	0.03
07	12-Mar-08	305	55	0.18
08	01-Apr-08	96	4	0.04
09	11-Apr-08	132	4	0.03
09	11-Apr-08	197	4	0.02
10	15-May-08	328	145	0.44
10	15-May-08	350	231	0.66
11	23-Aug-08	250	1004	4.02
11	23-Aug-08	124	4	0.03
14	29-Aug-08	240	125	0.52
14	29-Aug-08	65	5	0.08
15	12-Nov-08	169	29	0.17
16	21-Nov-08	58	0	0
17	25-Nov-08	91	730	8.02
17	25-Nov-08	120	1115	9.29
18	30-Dec-08	250	24	0.10
19	31-Dec-08	384	74	0.19
21	07-Jan-09	130	441	3.39
21	07-Jan-09	120	488	4.07
22	15-Jan-09	720	833	1.16
23	30-Mar-09	300	320	1.07
24	28-May-09	420	4040	9.62
Total		6310	11715	1.86

Table 3.3: Range, mean and standard deviations for different parameters of vocalisations recorded for common dolphin (*Delphinus* sp) in the Hauraki Gulf, New Zealand between February 2008 and May 2009

	Minimum	**Maximum**	**Mean**	**Standard deviation**
Duration (s)	0.01	4.00	0.27	0.319
Start Frequency (HZ)	3531	22006	12593	4069
End Frequency (Hz)	3341	22050	12295	4075
Minimum Frequency (Hz)	3198	21902	11393	3895
Maximum Frequency (Hz)	3389	23000	13605	4131
Mean Frequency (Hz)	3350	23608	12461	3807
Frequency Gradient (Hz/s)	-109319	128830	-893	14395
Frequency Range (Hz)	0	14572	2213	2606
Inflections	0	6	0.56	0.863
Steps	0	10	0.06	0.349

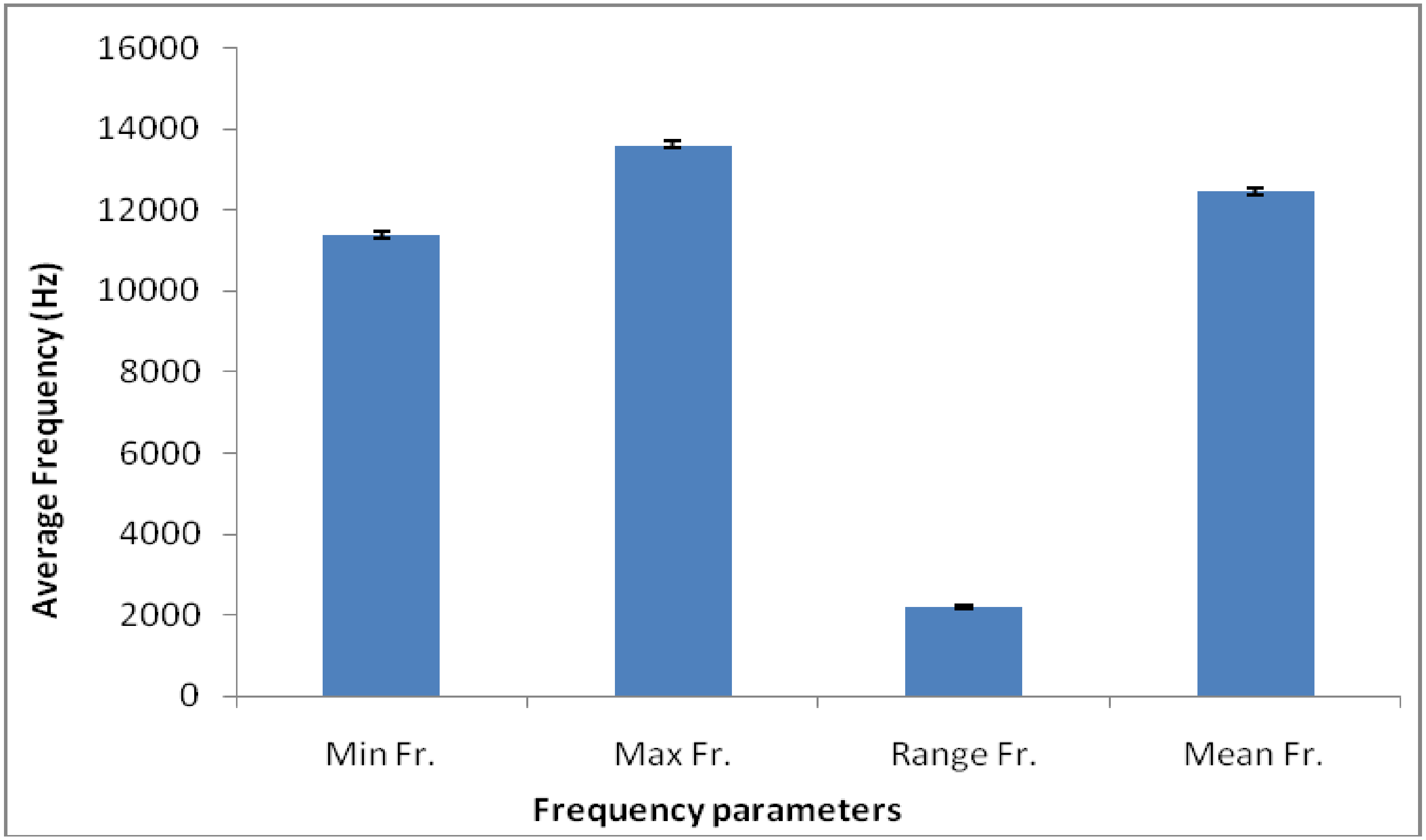

Fig 3.3: Parameters used to describe vocalisations of common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand between February 2008 and May 2009. Note: MinFr. = Minimum Frequenct, MaxFr. = Max Frequency, RangeFr. = Frequency Range and MeanFr. = Mean Frequency. Error Bars: Standard Errors

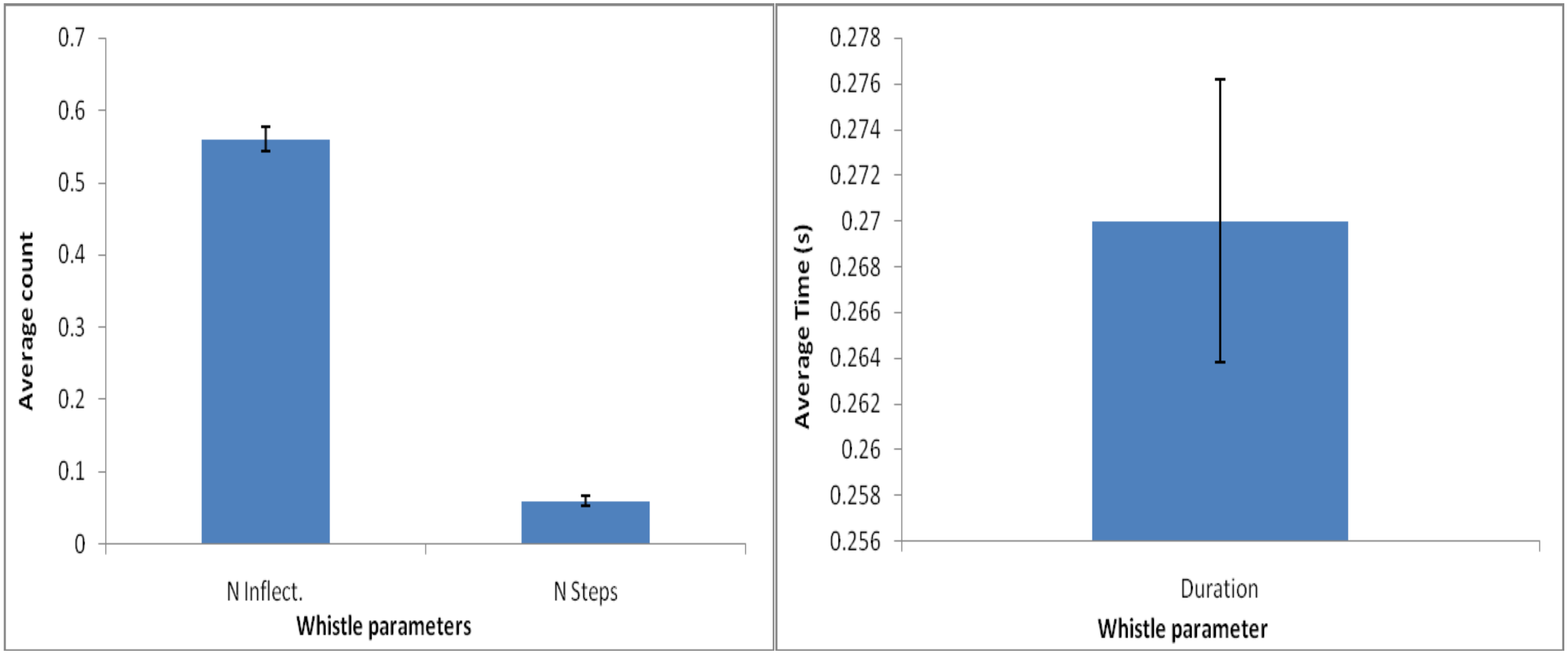

Fig 3.4: Averages of the parameters used to describe vocalisations of common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand between February 2008 and May 2009. Note: N Inflect = Number of Inflections, N Steps = Number of Steps. Error Bars: Standard Errors

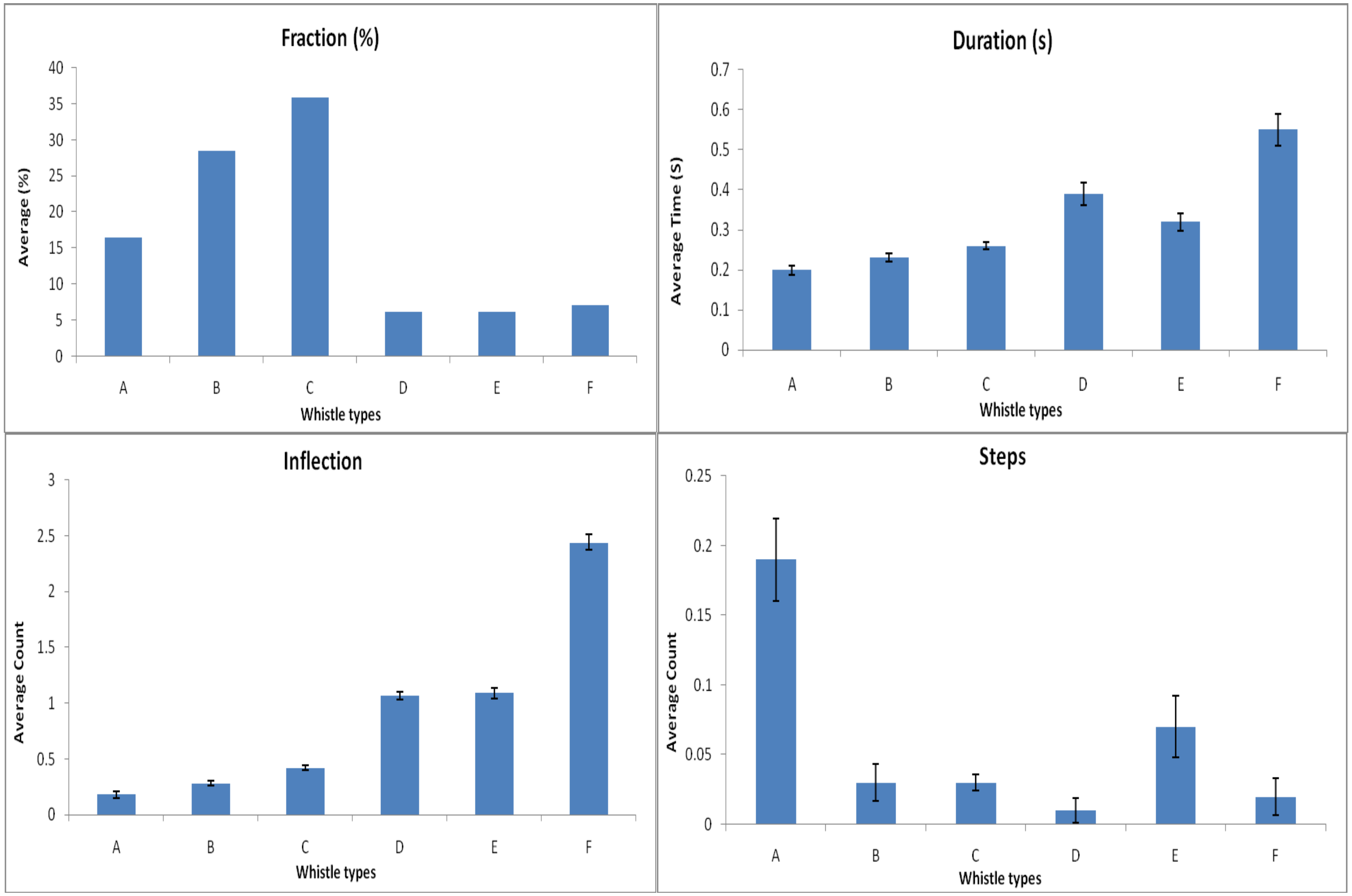

Fig 3.5: Fraction percentage, duration (s), inflection and steps for each whistle type produced by common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand between February 2008 and May 2009, in relation to whistle type. Note: A – F described by Ansmann et al. (2007). Error Bars: Standard Errors.

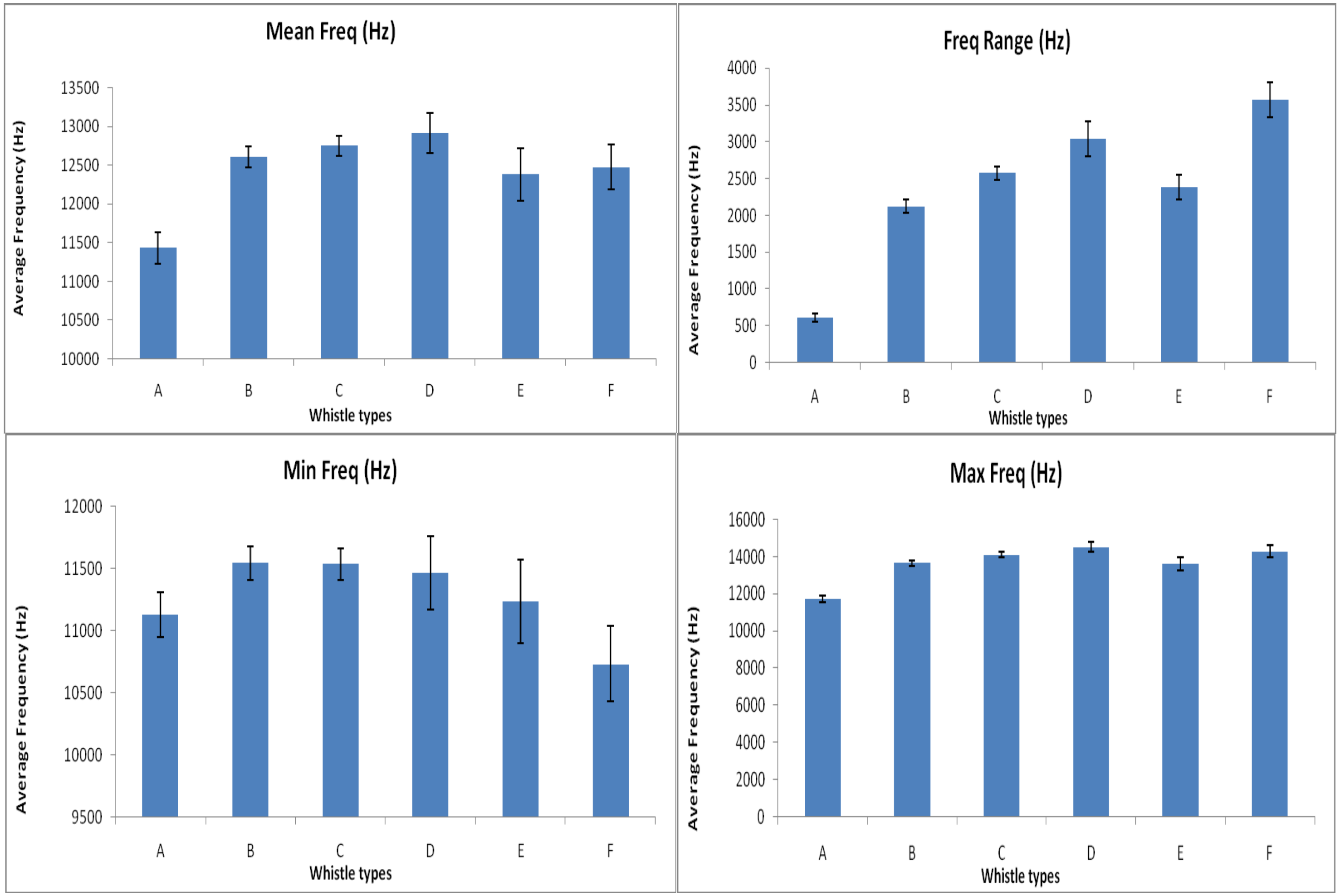

Fig 3.6: Frequency parameters (mean, range, minimum and maximum) for each whistle type produced by common dolphin (*Delphinus* sp.) in the Hauraki Gulf, New Zealand between February 2008 and May 2009. Note: A – F described by Ansmann et al. (2007). Error Bars: Standard Errors

Table 3.4: Parameters used to describe vocalisations of common dolphin (*Delphinus* sp.) in Hauraki Gulf, New Zealand between February 2008 and May 2009, in relation to whistle type. Minimum and Maximum values are shown in parentheses

Type	Fraction (%)	Duration (s)	Start Freq (Hz)	End Freq (Hz)	Min Freq (Hz)	Max Freq (Hz)	Mean Freq (Hz)	Freq Gradient (Hz/s)	Freq Range (Hz)	Inflection	Steps
A	16.4	**0.2** (0.01-1.35)	**11478.95** (4095-21902.3)	**11415.12** (4095-21902.3)	**11128.86** (4095-21902.3)	**11742.19** (4095-21913.30)	**11435.03** (4095-21902.3)	**333.53** (-22500-37412.50)	**613.33** (0-8964.3)	**0.18** (0-5)	**0.19** (0-2)
B	28.5	**0.23** (0.01-1.56)	**11652.71** (3915-21493.70)	**13543.34** (4558.7-22050)	**11546.07** (3915-21493.7)	**13670.12** (4558.7-22050)	**12604.61** (4449.66-23608.32)	**12047.2** (-9684.40-128830)	**2124.05** (49.20-13565.5)	**0.28** (0-4)	**0.03** (0-9)
C	35.9	**0.26** (0.01-1.75)	**13825.42** (5071.5-22005.7)	**11709.65** (4328.80-21825)	**11539.66** (4328.80-21825)	**14112.56** (5261.40-22005.7)	**12751.78** (4983.28-21924)	**-9069.44** (-109319.05 – 89365.06)	**2572.9** (52.20-14572.20)	**0.42** (0-4)	**0.03** (0-2)
D	6.1	**0.39** (0.01-1.44)	**12222.57** (4956.60-20936.40)	**11776.85** (5486.40-21827.30)	**11467.5** (4956.60-20936.40)	**14505.4** (6084.30-23000)	**12913.93** (5927.22-21640.22)	**-1466.53** (-27426.09 – 8578.47)	**3037.9** (98.4-12044.5)	**1.07** (0-3)	**0.01** (0-1)
E	6.1	**0.32** (0.01-1.29)	**13207.56** (6170-22004.9)	**13082.91** (6174-22050)	**11237.92** (4419.4-21607)	**13622.96** (6174-22050)	**12380.77** (5472.54-21695.60)	**-118.91** (-15737.5 – 13216.67)	**2385.04** (149.70-10596.60)	**1.09** (0-6)	**0.07** (0-2)
F	7	**0.55** (0.02-4)	**12507** (3531.80-21847.70)	**12076.09** (3340.9-22006.30)	**10732.72** (3197.70-21133.30)	**14301.97** (3388.60-22044.7)	**12477.21** (3350.44-21615.08)	**-323.41** (-20801.89 – 25779.02)	**3569.26** (98.20-10506.5)	**2.44** (0-5)	**0.02** (0-2)

Analyses of the Hauraki Gulf dataset revealed 45 alternative whistles contours that could not be accounted for within Ansmann et al. (2007). Consequently, this resulted in six new whistle contours being described for the G and H classes, five for the M class and a further seven and eight for classes L and I, respectively. Finally, 13 new whistles contours were added within N class (Fig. 3.7).

Out of 11,715 whistles, certain whistles (R contours) appear to have a high repetition rate over a short time scale (Fig. 3.8). Each of these vocalisations exhibited an extraordinary similarity in duration and other whistle frequency parameters, and appear as trains of low density clicks within each repetition. A total of 20 different repetitions were recorded, 12 of which occurred only within one encounter, while a further 8 occurred over multiple (two to three) encounters. R12 was the whistle repetition that showed the highest number of repetitions in association with the highest number of encounters (Table 3.5). Conversely, R16 displayed the lowest number of encounters and whistles (Table 3.5). Fortunately, R12 was easily recognisable due to a specific protuberance on the left side of the convex curvature (Fig. 3.9).

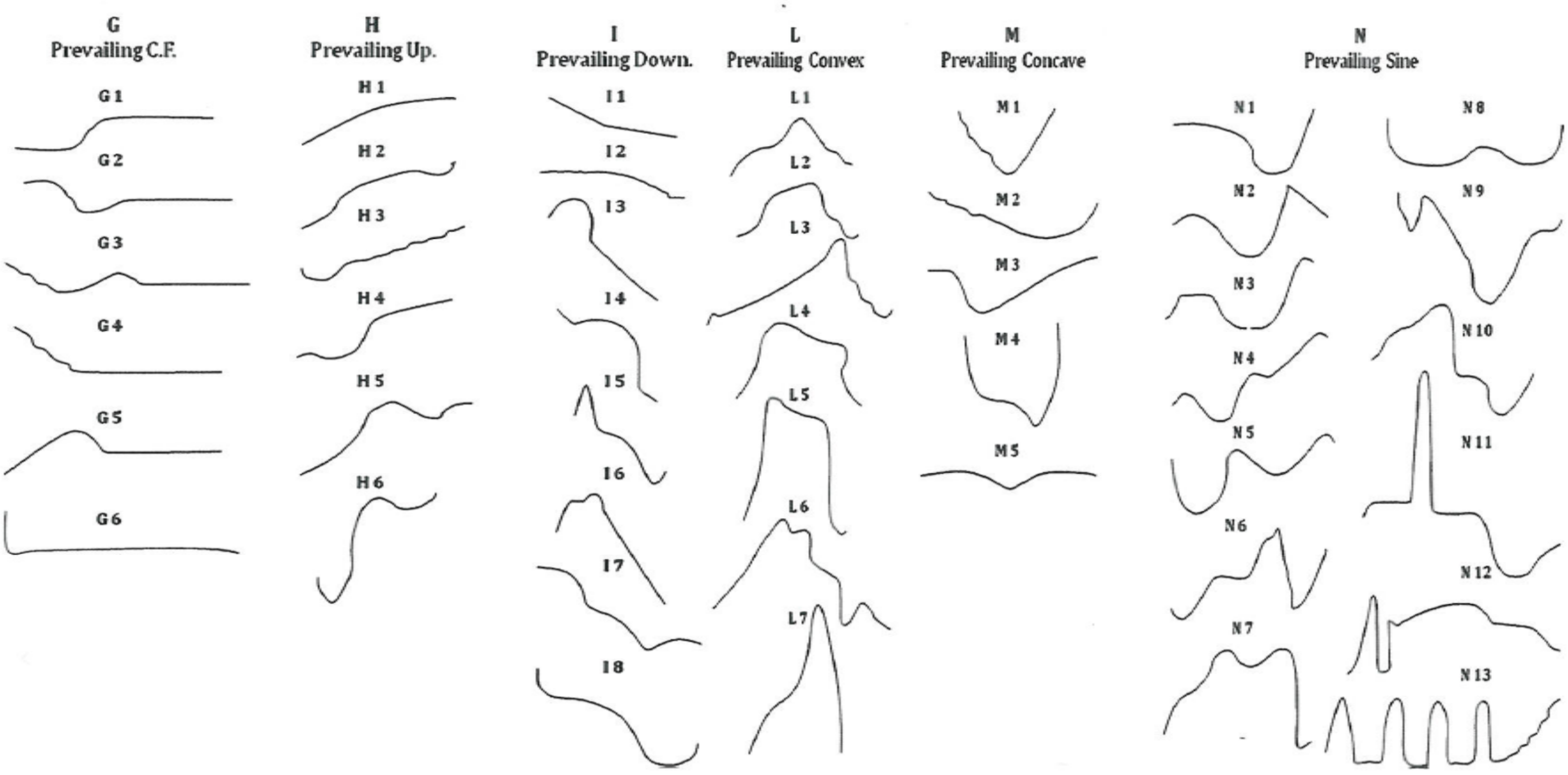

Fig. 3.7: Alternative idealized contours of the different whistle types detected in the population of common dolphins (*Delphinus* sp) in the Hauraki Gulf, New Zealand between February 2008 and May 2009

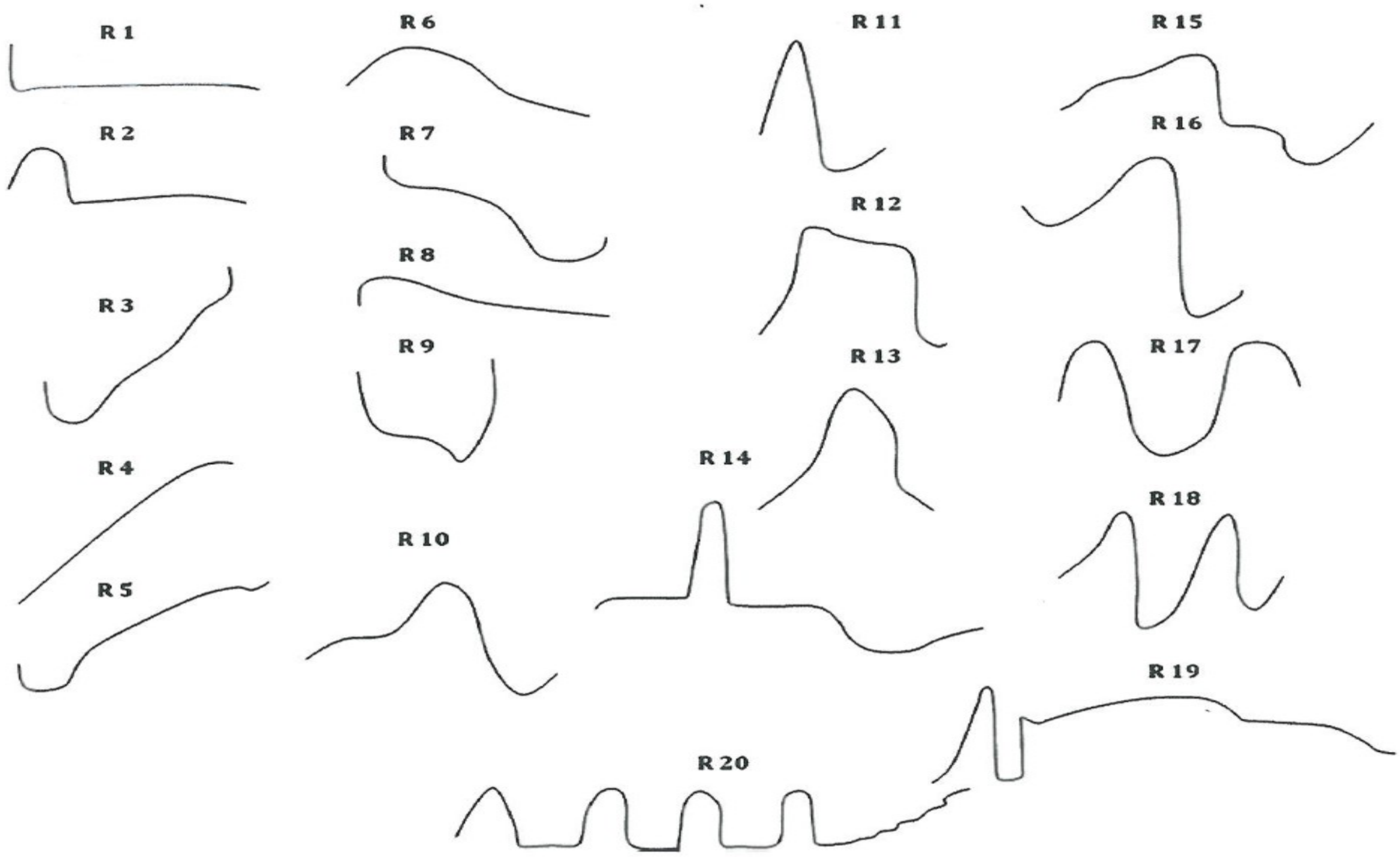

Fig. 3.8: Idealized contours of whistle repetitions detected in the population of common dolphins (*Delphinus* sp) in Hauraki Gulf, New Zealand between February 2008 and May 2009

Table 3.5: Parameters concerning whistle repetitions detected in the population of common dolphins (*Delphinus* sp) in Hauraki Gulf, New Zealand between February 2008 and May 2009. Note: w/s = whistles per second

Type	Survey	Survey	Survey	N Encounters	N Repetitions	Min-Max Density w/s
R1	15-May-08	28-May-09	-	2	13	0.08 - 0.13
R2	15-Jan-09	-	-	1	3	0.02 - 0.03
R3	08-Feb-08	27-Feb-08	07-Jan-09	3	10	0.02 - 0.05
R4	15-May-08	-	-	1	13	0.07 - 0.08
R5	07-Jan-09	-	-	1	7	0.05 - 0.07
R6	15-May-08	25-Nov-08	-	2	16	0.05 - 0.22
R7	27-Feb-08	25-Nov-08	25-Nov-08	3	13	0.03 - 0.1
R8	28-May-09	-	-	1	8	0.13
R9	07-Jan-09	15-Jan-09	-	2	16	0.12 - 0.15
R10	27-Feb-08	15-Jan-09	28-May-09	3	5	0.02 - 0.03
R11	07-Jan-09	-	-	1	7	0.03 - 0.08
R12	27-Feb-08	25-Nov-08	28-May-09	3	35	0.03 - 0.18
R13	28-May-09	-	-	1	26	0.43
R14	07-Jan-09	-	-	1	7	0.12
R15	08-Feb-08	07-Jan-09	15-Jan-09	3	4	0.02
R16	30-Mar-09	-	-	1	5	0.03 - 0.05
R17	08-Feb-08	-	-	1	11	0.03 - 0.1
R18	30-Mar-09	-	-	1	17	0.05 - 0.15
R19	15-Jan-09	-	-	1	20	0.02 - 0.15
R20	28-May-09	-	-	1	9	0.15

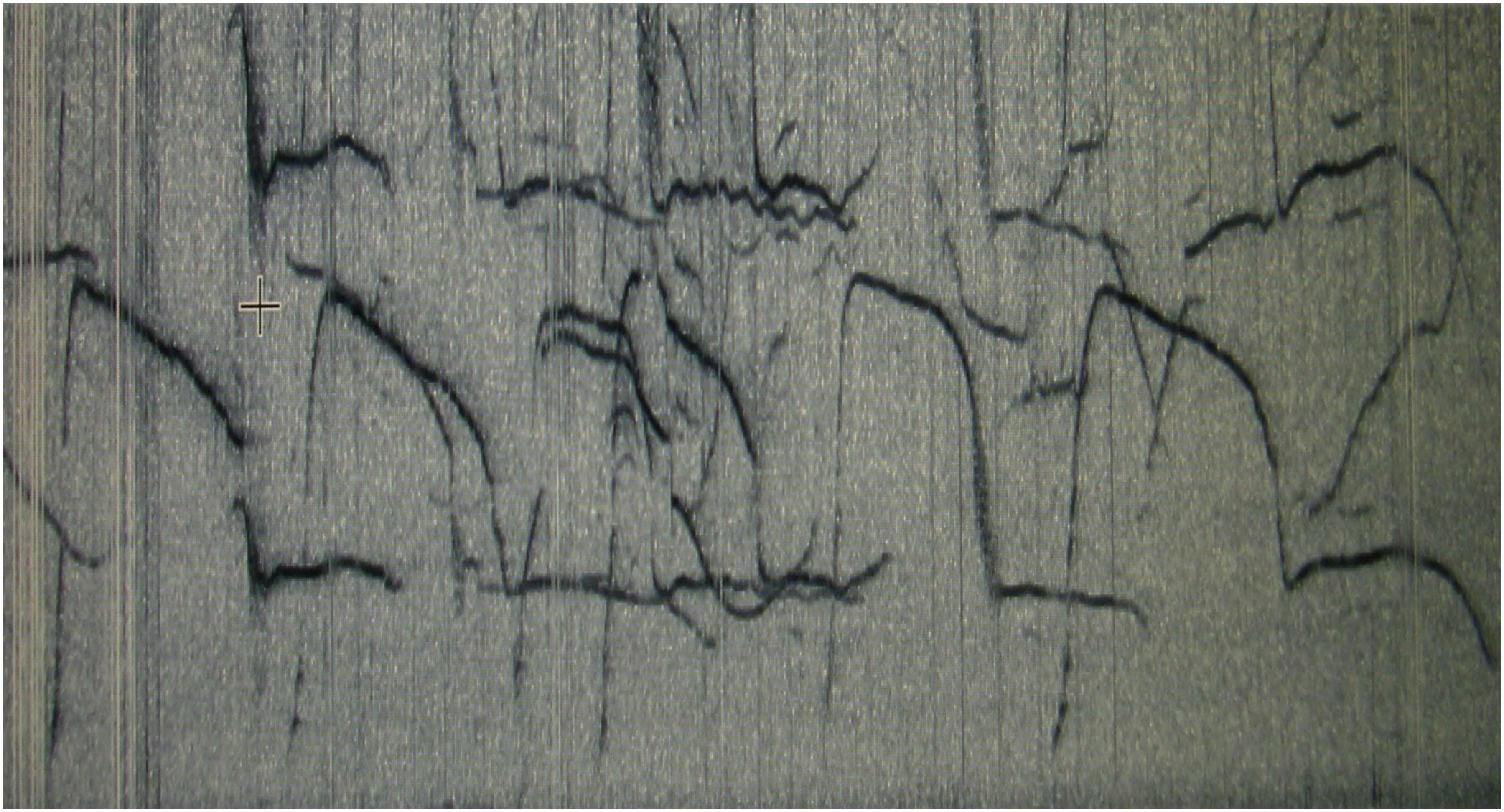

Fig. 3.9: Whistles repetitions (R12 type) of a common dolphin (*Delphinus* sp) recorded on 27/02/2008 in Hauraki Gulf, New Zealand

3.1.4 Data analyses

All parameters examined in the present study were found to be highly significantly different between encounters (P < 0.0001), except for mean frequency (P = 0.0807) and number of steps (P = 0.9919) (Table 3.6).

All examined parameters were also found to be significantly different between the different whistle types (P < 0.0001) (Table 3.7).

Finally, all parameters with the exception of the number of steps (P = 0.0931) were found to significantly vary with group size (Table 3.8).

Table 3.6: Kruskal -Wallis statistics for whistle parameters by encounter in common dolphin (*Delphinus* sp) detected in the Hauraki Gulf, New Zealand between February 2008 and May 2009. Note: X = signifciant at p < 0.05

Parameters	Groups	df	Total observations	T	P	Significant
Duration (s)	9	8	2662	1075.67	<0.0001	X
Start Frequency	9	8	2662	30.21	<0.0002	X
End Frequency	9	8	2662	68.75	<0.0001	X
Range Frequency	9	8	2662	764.19	<0.0001	X
Min Frequency	9	8	2662	86.36	<0.0001	X
Max Frequency	9	8	2662	36.84	<0.0001	X
Mean Frequency	9	8	2662	14.04	0.0807	
Frequency Gradient	9	8	2662	133.65	<0.0001	X
N Inflections	9	8	2662	96.23	<0.0001	X
N Steps	9	8	2662	1.63	0.9919	

Table 3.7: Whistle parameters by whistle type in New Zealand common dolphin (*Delphinus* sp) detected in Hauraki Gulf between February 2008 and May 2009. Note: X = signifciant at $p < 0.05$

Parameters	Groups	df	Total observations	T	P	Significant
Duration (s)	6	5	2662	154.84	<0.0001	X
Start Frequency	6	5	2662	161.63	<0.0001	X
End Frequency	6	5	2662	117.47	<0.0001	X
Range Frequency	6	5	2662	484.28	<0.0001	X
Min Frequency	6	5	2662	15.92	0.0071	X
Max Frequency	6	5	2662	116.99	<0.0001	X
Mean Frequency	6	5	2662	39.53	<0.0001	X
Frequency Gradient	6	5	2662	1814.2	<0.0001	X
N Inflections	6	5	2662	795.74	<0.0001	X
N Steps	6	5	2662	20.47	<0.0001	X

Table 3.8: Whistle parameters by group size in common dolphins (*Delphinus* sp) detected in Hauraki Gulf, New Zealand between February 2008 and May 2009. Note: X = signifciant at $p < 0.05$

Parameters	Groups	df	Total observations	T	P	Significant
Duration (s)	5	4	2662	178.45	<0.0001	X
Start Frequency	5	4	2662	101.43	<0.0001	X
End Frequency	5	4	2662	47.71	<0.0001	X
Range Frequency	5	4	2662	435.12	<0.0001	X
Min Frequency	5	4	2662	18.46	<0.0001	X
Max Frequency	5	4	2662	96.84	<0.0001	X
Mean Frequency	5	4	2662	27.67	<0.0001	X
Frequency Gradient	5	4	2662	855.93	<0.0001	X
N Inflections	5	4	2662	626.29	<0.0001	X
N Steps	5	4	2662	7.96	0.0931	

3.2 Whistle Characteristics of Hauraki Gulf Common Dolphins in Relation to Behaviour

3.2.1 Whistle Density in Relation to Behaviour

Common dolphin behaviour is considered to be relatively cyclical (Fig. 3.10) and is typically characterised by five main behavioural states: forage, mill, rest, social and travel (Neumann 2001, Stockin et al. 2009a).

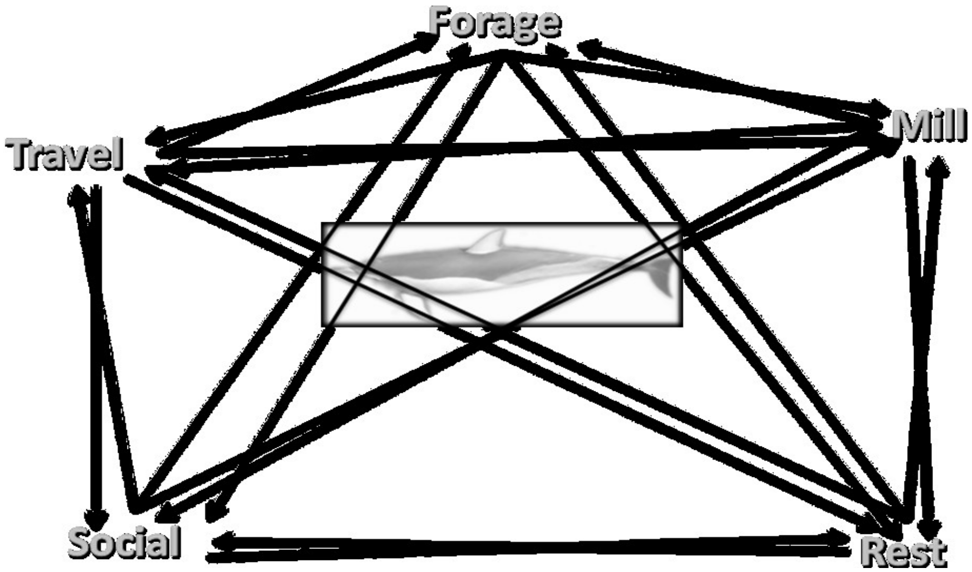

Fig. 3.10: Representation of the different behavioural states observed in the common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand

With the exception of rest, all behavioural states previously described by Stockin et al. (2009a) were observed during the present study (Table 3.9). However, only forage and travel were recorded in isolation of any other behavioural state. Furthermore, only these two states were observed consistently throughout the period of recorded vocalisations. While milling and socialising dolphins were detected, these behaviours only ever occurred in combination with other behavioural states. As such, it was not possible to decipher which vocalisations related to each behavioural state (Table 3.9; Fig. 3.11).

Table 3.9: Location, behaviour, dolphin group characteristics and parameters describing the whistles emitted by common dolphin (*Delphinus* sp.) during surveys in the Hauraki Gulf, New Zealand between February 2008 and May 2009. Note: T = travel, F = forage, M = mill, S = social, MB = multiple behaviour, w/s = whistles per second. All grey cells indicate groups showing single behaviour, dark grey cells indicate groups analysed for whistle density

Survey	Date	Latitude	Latitude	Latitude	Longitude	Longitude	Longitude	Group size	Behavioural states	Duration	Whistles counted	Density (w/s)
01	08-Feb-08	36	32	6.15	174	57	0.68	50	F	293	1612	5.50
02	19-Feb-08	independent boat - no coordinates							-	755	45	0.06
03	27-Feb-08	36	45	4.71	174	50	8.64	10	MB(T/S)	300	380	1.27
03	27-Feb-08	36	32	1.8	175	5	8.2	10	T	113	3	0.03
07	12-Mar-08	36	43	6.1	174	49	3.6	30	T	305	55	0.18
08	01-Apr-08	36	35	4.8	175	7	7	40	T	96	4	0.04
09	11-Apr-08	36	33	4.96	175	9	8.23	20	F	132	4	0.03
09	11-Apr-08	36	31	1.19	175	10	8.68	20	F	197	4	0.02
10	15-May-08	36	31	6.96	175	5	7.11	20	MB(F/S)	328	145	0.44
10	15-May-08	36	31	9.56	175	0	8.89	20	MB(F/S)	350	231	0.66
11	23-Aug-08	36	41	3.2	175	2	8.8	40	MB(T/S)	250	1004	4.02
11	23-Aug-08	36	36	7.08	174	56	1	40	T	124	4	0.03
14	29-Aug-08	36	37	5.32	174	57	4.86	40	MB(F/S)	240	125	0.52
14	29-Aug-08	36	40	1.06	175	7	6.17	30	MB(F/S)	65	5	0.08
15	12-Nov-08	36	37	8.93	175	4	7.1	30	-	169	29	0.17
16	21-Nov-08	36	28	9.16	175	6	6.36	20	T	58	0	0
17	25-Nov-08	36	34	6.19	175	9	5.12	50	MB(F/T)	91	730	8.02
17	25-Nov-08	36	37	5.72	175	6	4.91	50	MB(F/T)	120	1115	9.29
18	30-Dec-08	36	42	0.88	174	53	5.54	10	MB(T/S)	250	24	0.10
19	31-Dec-08	36	34	5.59	174	59	4.3	20	MB(M/S)	384	74	0.20
21	07-Jan-09	36	31	2.86	175	2	2.74	30	MB(T/S)	130	441	3.39
21	07-Jan-09	36	29	4.16	174	59	8.02	30	MB(T/S)	120	488	4.07
22	15-Jan-09	36	42	4.91	174	51	6.74	30	F	720	833	1.15
23	30-Mar-09	36	34	1.11	174	58	2.22	30	F	300	320	1.07
24	28-May-09	36	36	0.59	175	8	1.7	30	F	420	4040	9.62

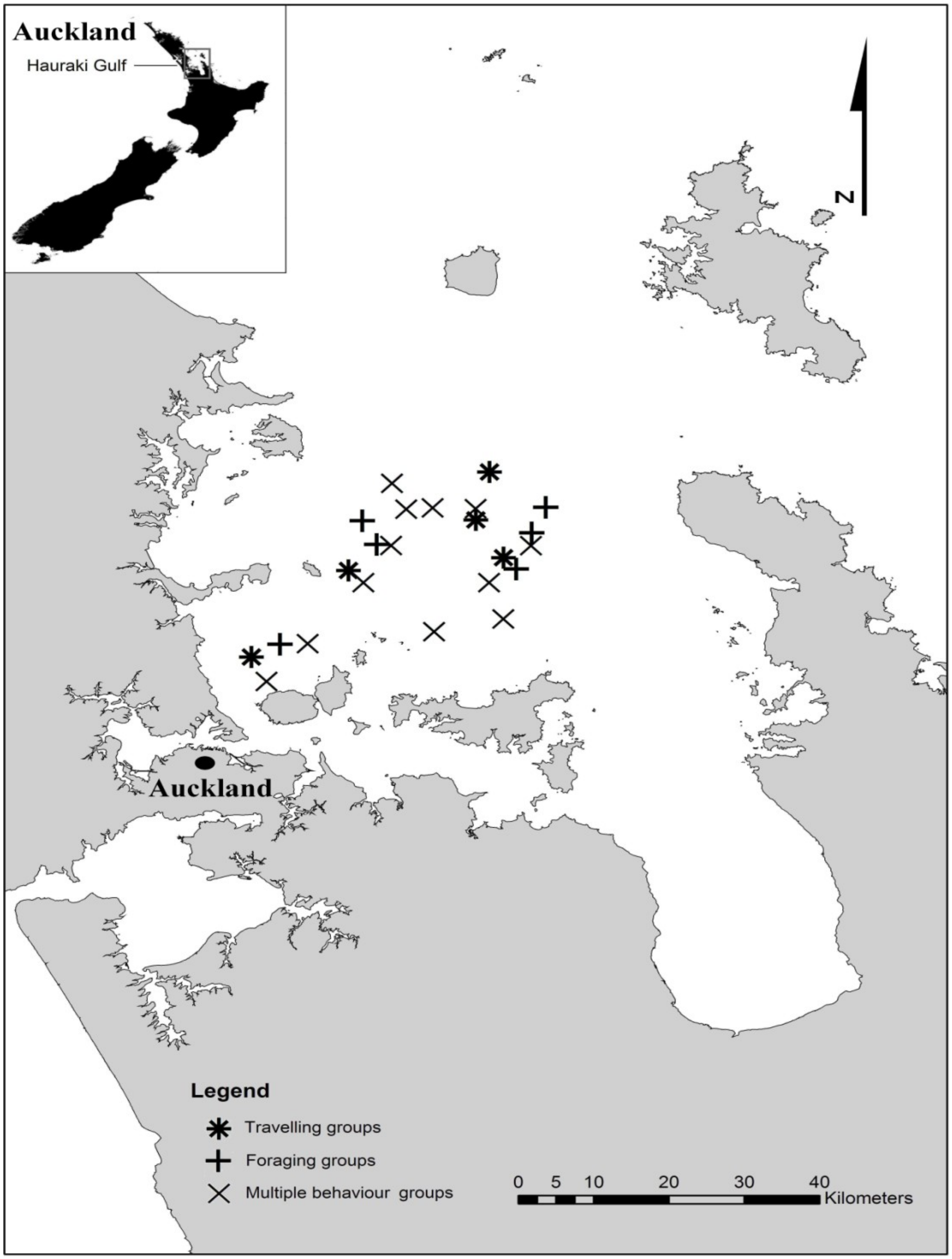

Fig. 3.11: Behaviour of common dolphin (*Delphinus* sp.) groups sampled during acoustic surveys in the Hauraki Gulf, New Zealand between February 2008 and May 2009

Only groups with similar numbers of dolphins were used to assess differences between behaviour. As only forage and travel were observed consistently during acoustic recordings, just these two behaviours were statistically assessed. This resulted in six independent encounters (Table 3.9 – dark grey cells) where group size and behaviour were consistent for comparisons. The number of whistles between these behavioural states varied (Table 3.10).

Table 3.10: Group size, number of whistles and duration of recordings for common dolphin (*Delphinus* sp) groups engaged in (a) travel and (b) forage in Hauraki Gulf, New Zealand, between February 2008 and March 2009

(a)

Survey	**Group size**	**Number of whistles**	**Duration of recordings (s)**
27-Feb-08	10	0	60
12-Mar-08	30	26	60
12-Mar-08	30	7	58
12-Mar-08	30	9	60
12-Mar-08	30	13	60
12-Mar-08	30	0	64
01-Apr-08	40	2	60
21-Nov-08	20	0	58
Mean	**27.5**	**Total 57**	**480**

(b)

Survey	**Group size**	**Number of whistles**	**Duration of recordings (s)**
15-Jan-09	30	82	60
15-Jan-09	30	166	60
15-Jan-09	30	115	60
15-Jan-09	30	108	60
30-Mar-09	30	123	60
30-Mar-09	30	66	60
30-Mar-09	30	47	60
30-Mar-09	30	65	60
Mean	**30**	**Total 772**	**480**

Analyses revealed large differences between vocalisations of dolphins engaged in different behavioural states. Firstly, whistle density was markedly different between forage and travel groups, despite a comparable sample period (*ca* 8 min) and a similar group size. To be more precise, the whistle density within the foraging groups was on average, approximately 13 times higher than that recorded in travelling groups (Fig. 3.12). This resulted in a whistle density of 1.61 w/s *versus* 0.12 w/s for foraging and travelling dolphins, respectively.

3.2.2 Whistle Characteristics in Relation to Behaviour

A comparison of whistle duration, range frequency, inflections and steps revealed similarities between the foraging and travelling dolphins, with the exception of duration ($P < 0.0001$) and frequency range ($P < 0.0001$) (Figs. 3.13 – 3.14).

During travelling, whistles were typically longer (T - 0.55 s / F - 0.34 s) than those recorded in foraging dolphins ($P = 0.0001$). The range of frequency was also different between these two behavioural states, with the minimum frequency lower (T - 9622 Hz / F – 11,036 Hz) during travelling activity ($P = 0.0007$). The maximum frequency was found to be marginally higher (T - 14664 Hz / F – 14046 Hz) in travelling groups, although this was not statistically significant ($P = 0.876$).

Finally, the frequency range was larger (T – 5042 Hz / F – 3010 Hz) in travelling groups ($P < 0.0001$), with minimal difference (T – 0.08 / F – 0.07) evident in the steps ($P = 0.7613$) or inflection (T – 0.68 / F – 0.73) ($P = 0.6661$) between the two behaviours (Table 3.11).

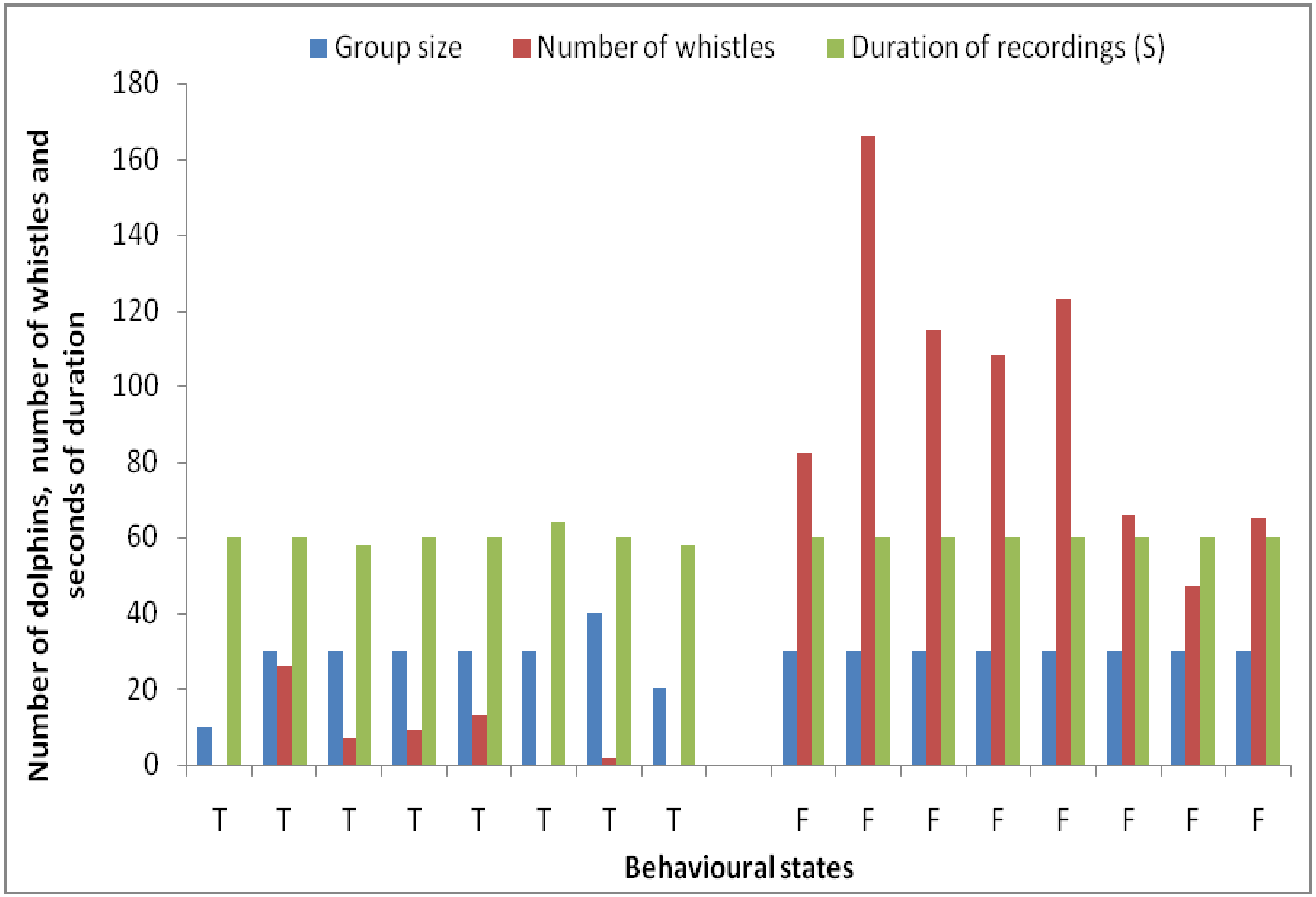

Fig. 3.12: Parameters used to describe vocalisations of travelling *versus* foraging common dolphins (*Delphinus* sp) in Hauraki Gulf, New Zealand between February 2008 and May 2009. Note: T = travel, F = Forage

Table 3.11: Whistle parameters in relation to behaviour (forage *vs.* travel) of common dolphins (*Delphinus* sp) detected in Hauraki Gulf, New Zealand between February 2008 and May 2009. Note: X = signifciant at $p < 0.05$

Parameter	U	Two sided P	Significant
Duration (s)	137649.5	<0.0001	X
Start Frequency	229481.5	0.6018	
End Frequency	272019	<0.0001	X
Range Frequency	192530.5	<0.0001	X
Min Frequency	262282.5	0.0007	
Max Frequency	235184.5	0.876	
Mean Frequency	249276.5	0.0671	
Frequency Gradient	278259.5	<0.0001	X
N Inflections	230635.5	0.6661	
N Steps	236568.5	0.7316	

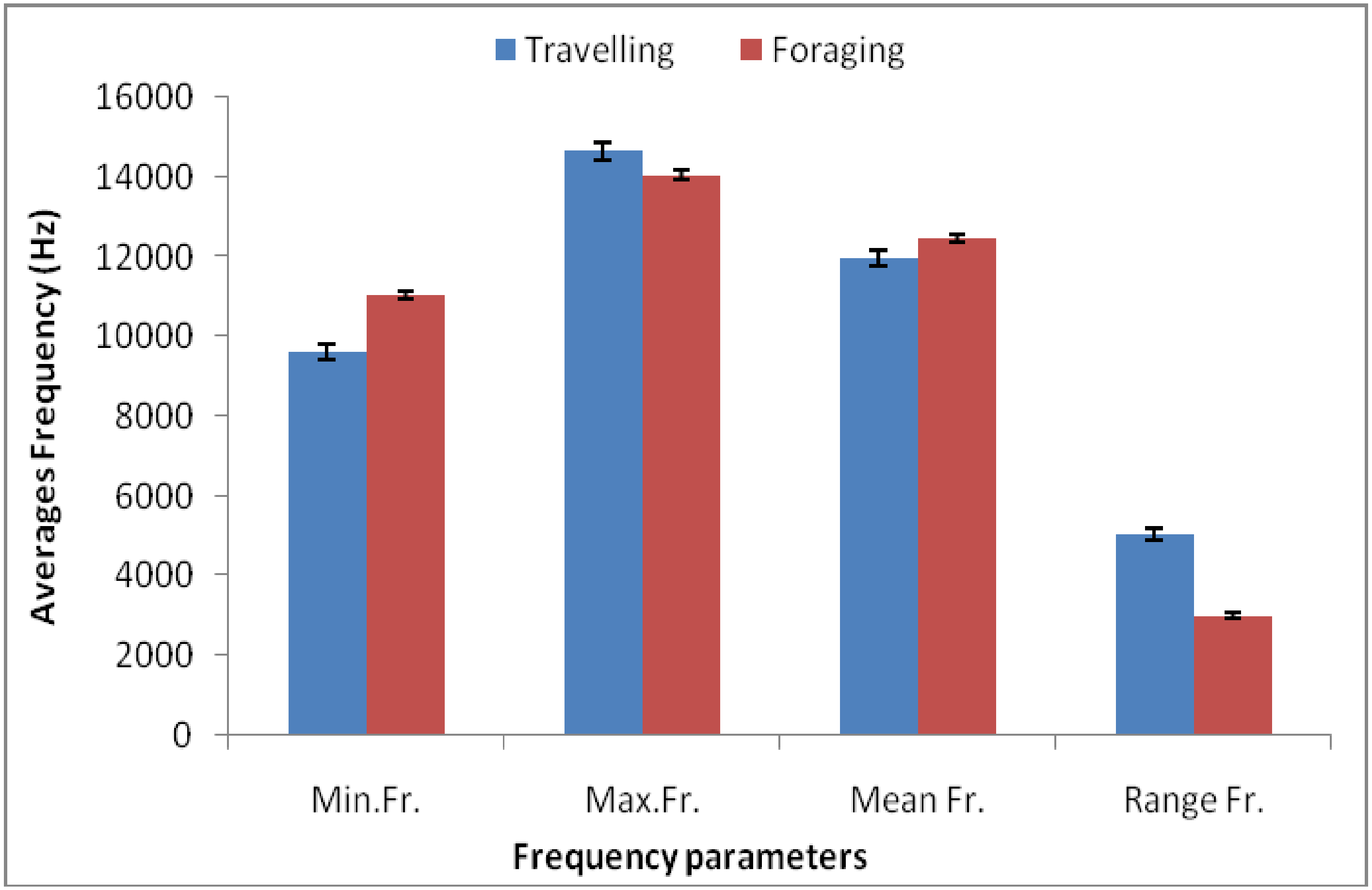

Fig. 3.13: Frequency parameters in the vocalisations of travelling *versus* foraging common dolphins (*Delphinus* sp) recorded in the Hauraki Gulf New Zealand between February 2008 and May 2009. Error Bars: Standard Errors

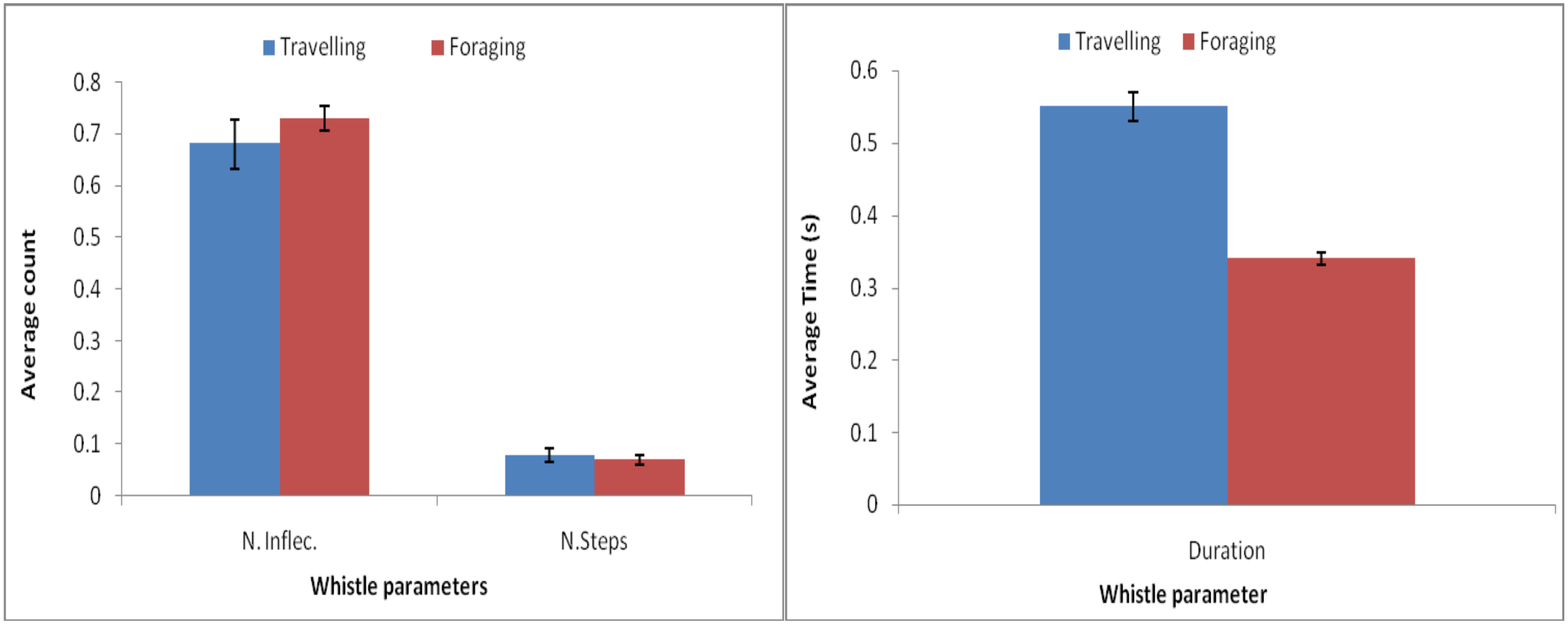

Fig. 3.14: Number of inflections and steps in the vocalisations of travelling *versus* foraging common dolphins (*Delphinus* sp) in Hauraki Gulf, New Zealand between February 2008 and May 2009. Note: N Inflect = Number of Inflections, N Steps = Number of Steps. Error Bars: Standard Errors

3.3 A Comparison of New Zealand *versus* United Kingdom Population Characteristics

3.3.1 Whistle Parameters

As the raw datasets relating to the UK populations were not included within Ansmann et al. (2007), it was not possible to statistically compare New Zealand *Delphinus* directly with these overseas populations. However, using summary data provided by Ansmann and colleagues, the following observations and trends are noted.

Firstly, frequency ranges reported for the Celtic Sea (CS) and English Channel (EC) populations compared with the Hauraki Gulf population appear to vary. Range in the UK populations varied from 5238 to 6034 Hz (Ansmann et al. 2007). This is considerably higher than the 1760 Hz reported for Hauraki Gulf common dolphins. This large difference is likely due to the minimum frequency, which in the Hauraki Gulf population was 13386 Hz, compared with 14685 and 15,835 Hz for the Celtic Sea and English Channel populations, respectively (Fig. 3.15). All three populations have a comparable maximum frequency (Table 3.12).

Within the present study, the whistle duration of Hauraki Gulf dolphins (Fig. 3.16) was shorter than that reported in either of the English populations. More precisely, duration in the Celtic Sea common dolphins were more than double that reported in the present study (HG: Mean = 0.27 s, SD = 0.319; CS: 0.65 s, SD = 0.324; EC: Mean = 0.64 s, SD = 0.319) (Fig. 3.16). Steps and inflections were generally more similar between all of the populations examined (Fig. 3.16). Steps within the Hauraki Gulf animals were on average almost half that previously reported for common dolphins occupying English waters (HG: Mean = 0.06; CS: mean = 0.13 and EC Mean = 0.10). However, inflection of the English Channel dolphins was similar to that reported in the present study (Mean = 0.56), although slighter higher (Mean = 0.64 that than previously described for the Celtic Sea (Fig. 3.16; Fig 3.16).

Table 3.12: Vocalisation parameters in common dolphins (*Delphinus* sp) from the Hauraki Gulf, New Zealand between February 2008 and May 2009 compared with UK populations detailed in Ansmann et al. (2007). Note: standard deviations shown in parentheses.

	Hauraki Gulf	**Celtic Sea**	**English Channel**
	23 kHz Bandwidth limit	24 kHz bandwidth limit	48 kHz bandwidth limit
Start Frequency (Hz)	12.59 (4.07)	12.03 (3.47)	12.64 (3.95)
End Frequency (Hz)	12.29 (4.07)	11.97 (3.25)	12.48 (3.97)
Min Frequency (Hz)	11.39 (3.89)	9.45 (2.06)	9.80 (2.46)
Max Frequency (Hz)	13.60 (4.13)	14.69 (3.13)	15.84 (3.28)
Mean Frequency (Hz)	12.46 (3.81)	11.89 (2.05)	12.67 (2.37)
Frequency Gradient (Hz/s)	-0.89 (-14.39)	0.38 (9.73)	0.51 (11.63)
Frequency Range (Hz)	22.13 (2.60)	5.24 (3.25)	6.03 (3.42)
Duration (s)	0.27 (0.32)	0.65 (0.33)	0.64 (0.32)
N. Inflection	0.56 (0.863)	0.64 (0.98)	0.56 (0.91)
N. Steps	0.06 (0.349)	0.13 (0.39)	0.10 (0.34)

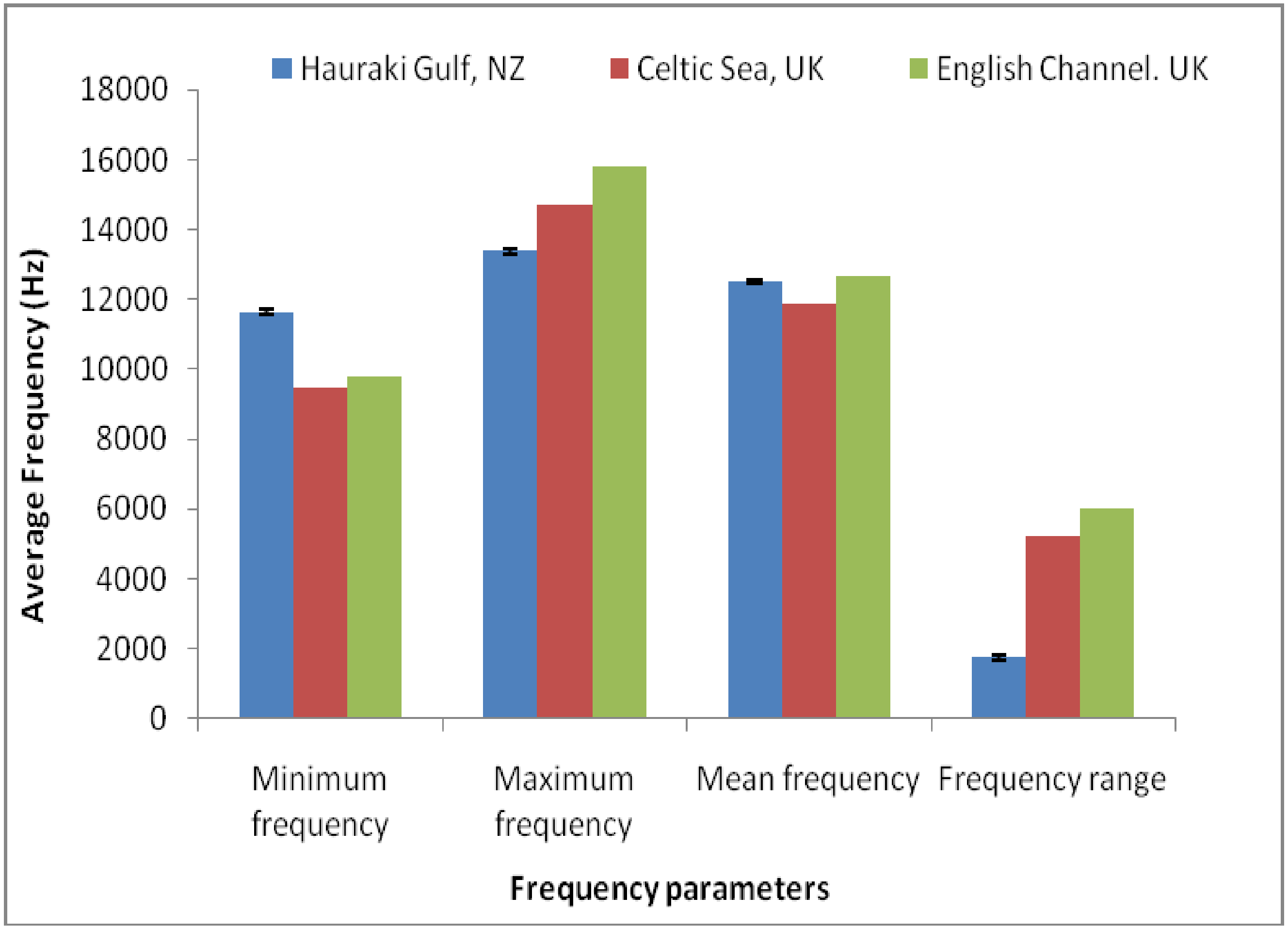

Fig. 3.15: Frequency parameters used to describe vocalisations of common dolphin (*Delphinus* sp) in the Hauraki Gulf, New Zealand between February 2008 and May 2009, in relation to frequency parameters detailed by Ansmann et al. (2007) for UK common dolphins. Error Bars: Standard Errors.

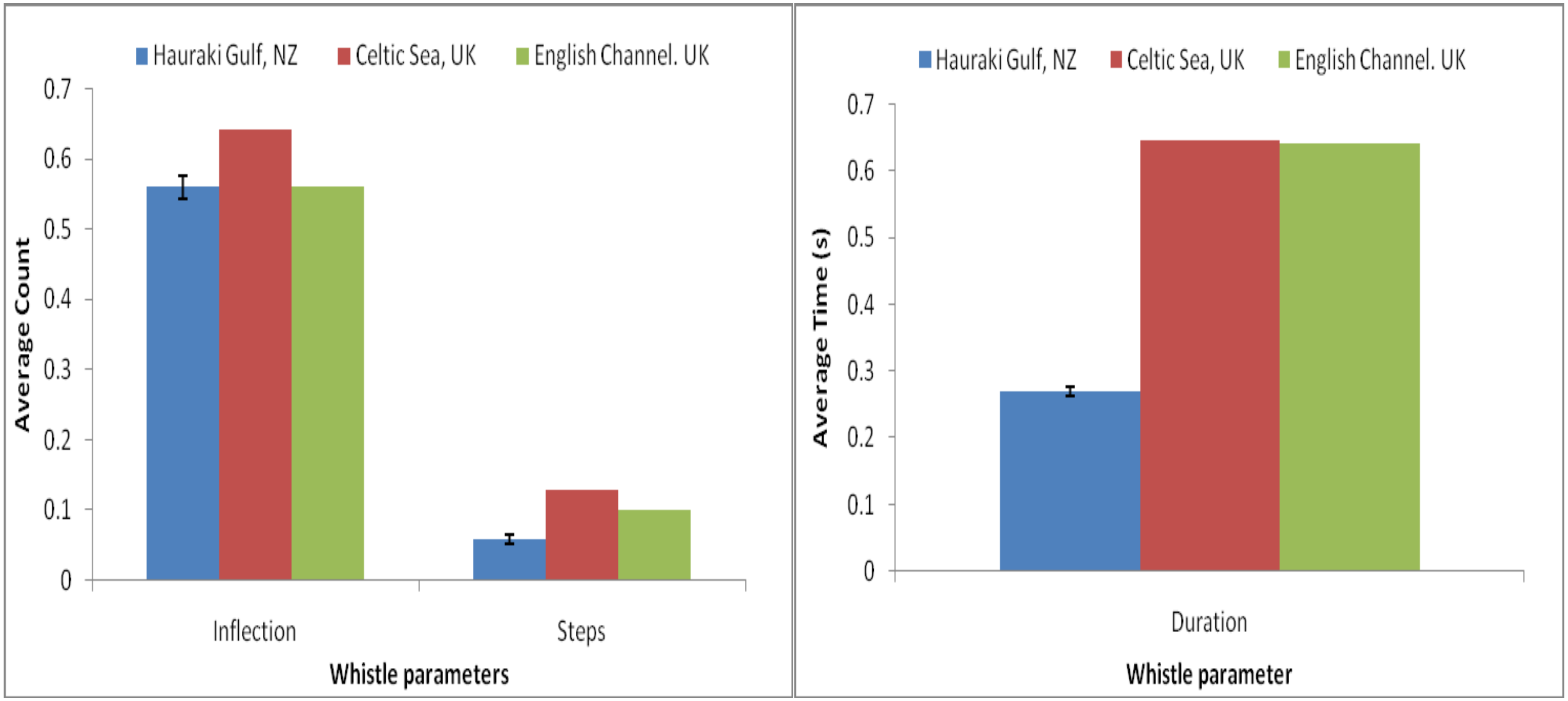

Fig. 3.16: Modulation and duration parameters used to describe vocalisations of common dolphin (*Delphinus* sp) in Hauraki Gulf, New Zealand between February 2008 and May 2009, in relation to UK common dolphins described by Ansmann et al. (2007). Error Bars: Standard Errors.

3.3.2 Comparison of Whistle Parameters

Using the single typology of each whistle (A, B, C, D, E, F), a comparison of duration, number of steps, number of inflections, minimum and maximum frequency, mean and range of frequency was compiled for all of six whistle contours (Figs 3.17 – 3.24). Data from UK populations (Celtic Sea and English Channel) were pooled and compared against the Hauraki Gulf dataset.

Fraction

In the Hauraki Gulf population, the most common type was downsweep (C - 35.9%) and the least frequent was convex (D - 6.1%) and concave (E - 6.1%). Conversely, in UK waters, the upsweep (B - 31%) whistle type occurred most, with sine displaying the lowest frequency (F - 7.3%) within the population (Fig. 3.17).

Duration

In both Hauraki Gulf and UK *Delphinus*, the longest and shortest whistle types were Sine (F - HG -0.55s / UK - 1.013s) and constant (A – HG - 0.2s / UK - 0.44s), respectively (Fig. 3.18).

Inflections

Surprisingly, the value of the inflections in both populations were comparable with a similar maximum (F - HG - 2.44 / UK - 2.87) and minimum values (A – HG - 0.18 / UK - 0.1) (Fig. 3.19).

Steps

The Hauraki Gulf common dolphins displayed a high number steps within whistle A type (A - HG - 0.19), whereas within the UK populations, the F type showed the maximum number of steps (F - UK - 0.2). For all others whistle types, the number of steps is comparably larger in the UK population/s (UK - B - 0.15 / C - 0.16 / D - 0.12 /E - 0.12) than in the Hauraki Gulf population (HG – B - 0. 03 / C - 0.03 / D - 0.01 / E - 0.07) (Fig. 3.20).

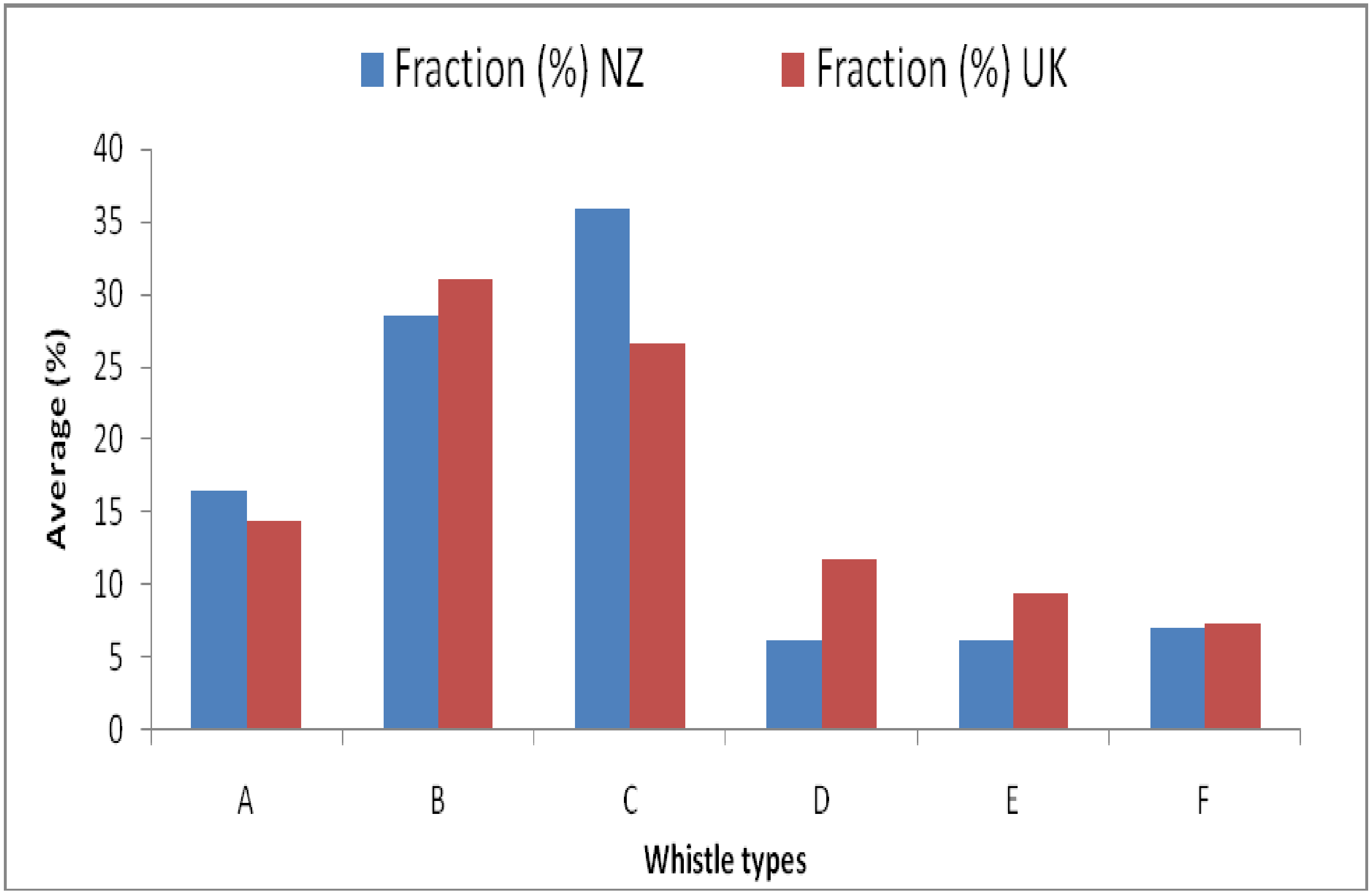

Fig. 3.17: Fraction percentage of vocalisation types from common dolphins (*Delphinus* sp) in Hauraki Gulf, New Zealand between February 2008 and May 2009, in relation with those described by Ansmann et. al (2007) for UK waters. Note: A = constant frequency; B = upsweep; C = downsweep; D = convex; E = concave; and F = sine

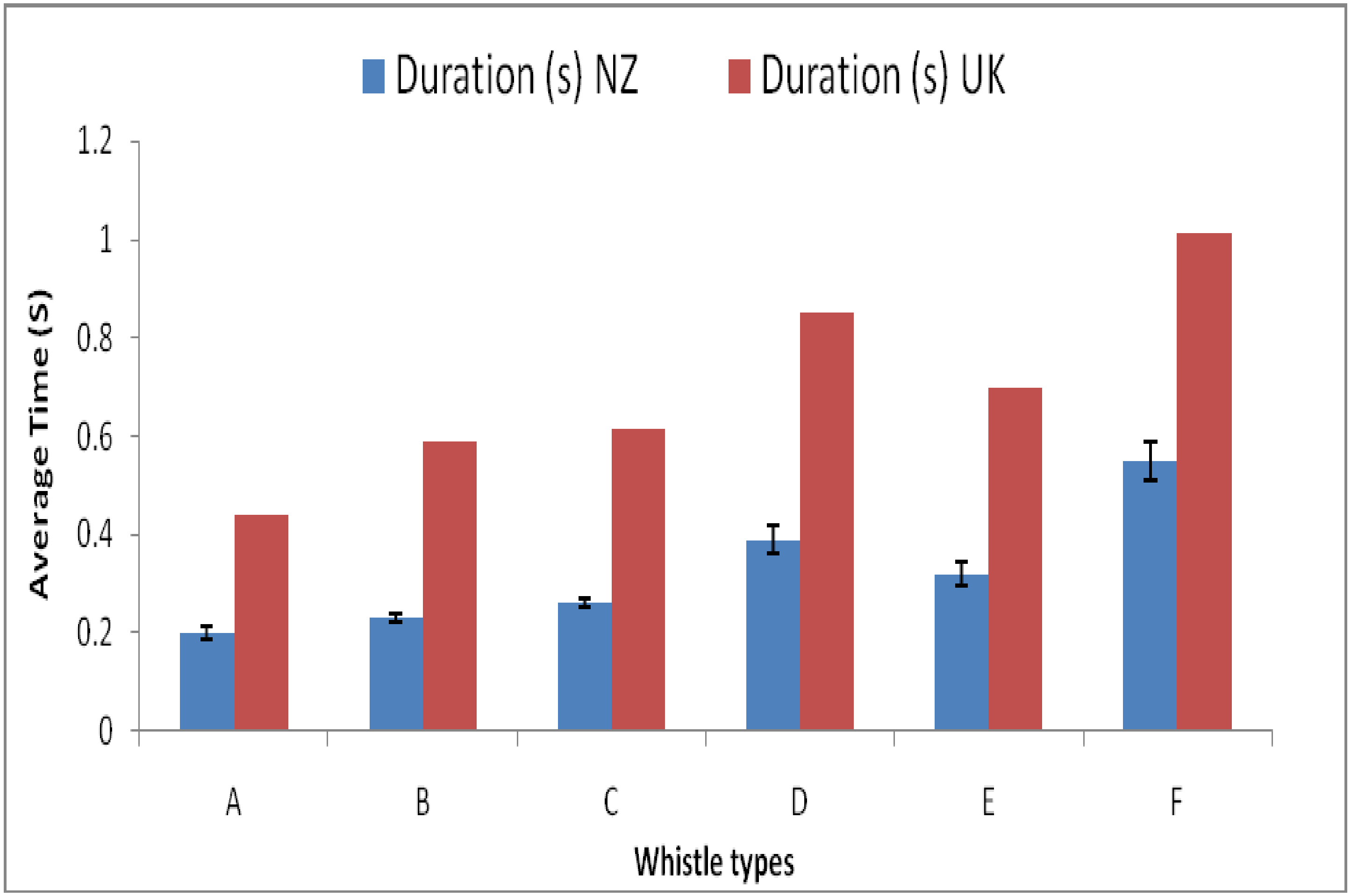

Fig. 3.18: Duration of vocalisations in common dolphins (*Delphinus* sp) in Hauraki Gulf, New Zealand between February 2008 and May 2009, in relation with parameters described by Ansmann et. al (2007) for UK waters. Note: A = constant frequency; B = upsweep; C = downsweep; D = convex; E = concave; and F = sine. Error Bars: Standard Errors.

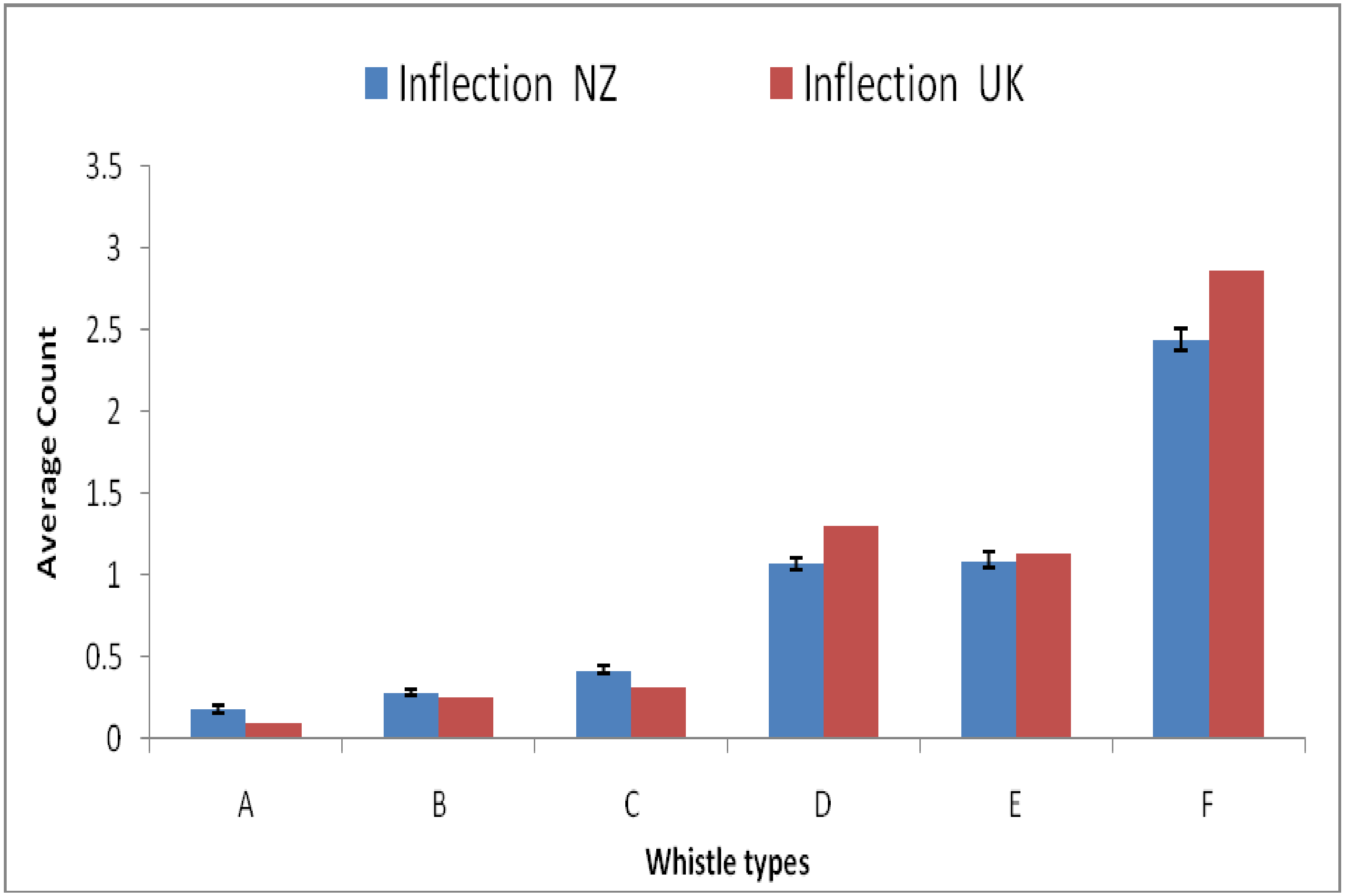

Fig. 3.19: Inflection in the vocalisations of common dolphins (*Delphinus* sp) in the Hauraki Gulf, New Zealand between February 2008 and May 2009, in relation with parameters described by Ansmann et. al (2007) for UK waters. Note: A = constant frequency; B = upsweep; C = downsweep; D = convex; E = concave; and F = sine. Error Bars: Standard Errors.

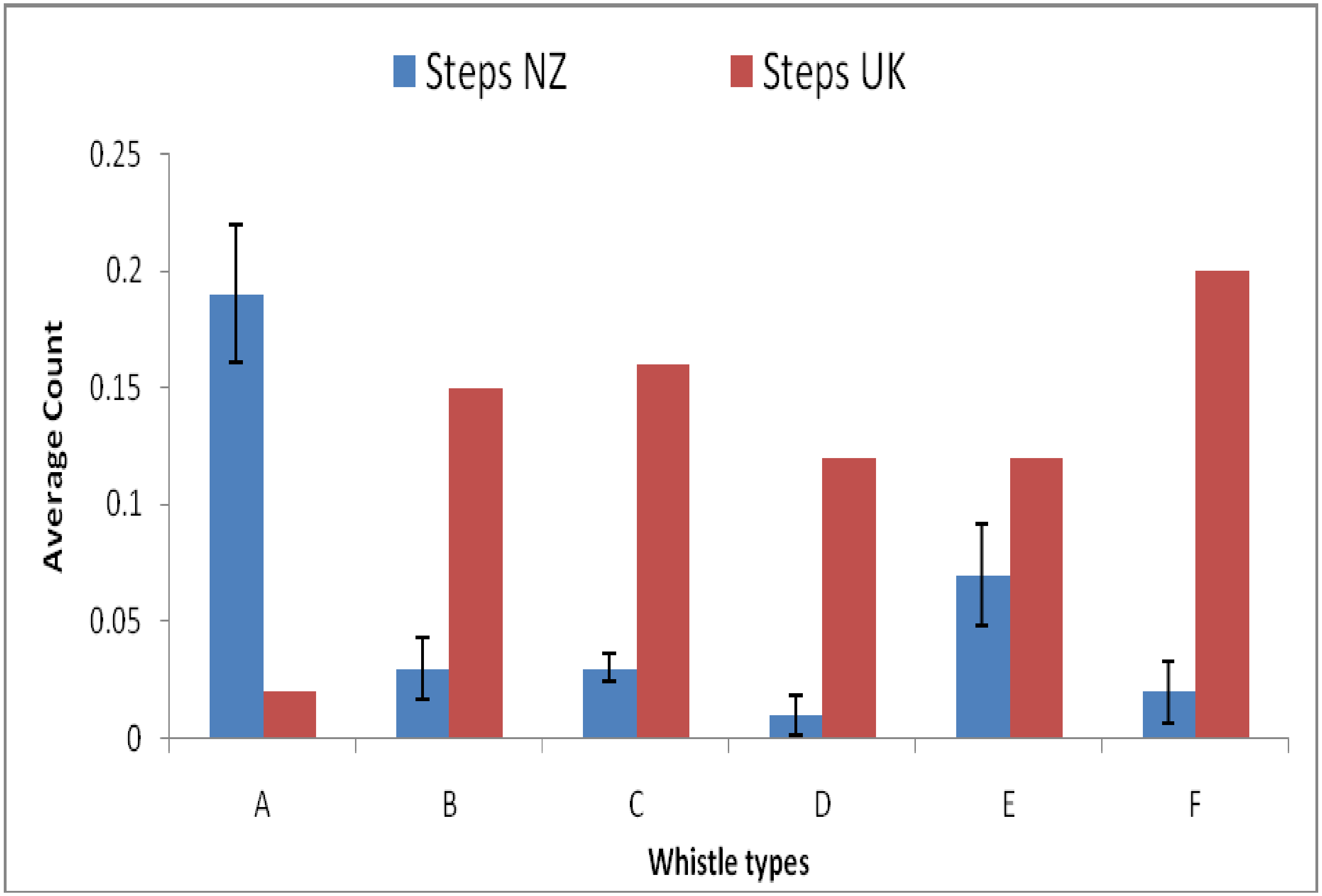

Fig. 3.20: Steps in the vocalisations of common dolphins (*Delphinus* sp) in Hauraki Gulf, New Zealand between February 2008 and May 2009, in relation with parameters described by Ansmann et. al (2007) for UK waters. Note: A = constant frequency; B = upsweep; C = downsweep; D = convex; E = concave; and F = sine. Error Bars: Standard Errors.

Concerning frequency parameters, a similar trend in all whistle types was evident except for frequency ranges between the Hauraki Gulf and UK populations (HGFR = 1760 Hz – UKFR = 5636 Hz).

Mean Frequency

In both the present study and Ansmann et al (2007), mean frequency from highest to lowest was as follows: D/Convex (HG – 12914 Hz / UK – 12719 Hz), C/Downsweep (HG – 12792 Hz / UK – 12019 Hz), B/Upsweep (HG – 12605 Hz / UK – 11876 Hz), F/Sine (HG – 12447 Hz / UK – 12261 Hz), E/Concave (HG – 12381 Hz / UK – 11556 Hz), A/Constant (HG – 11435 Hz / UK – 11031 Hz) (Fig. 3.21).

Range Frequency

Range frequency differed considerably between the present study and UK populations, although these differences were consistent throughout all whistle types (Fig. 3.22).

Minimum Frequency

The minimum frequency of Hauraki Gulf common dolphins was higher than that previously recorded for *Delphinus* within English waters. The largest discrepancy was found between the D/Convex whistle types (HG – 11468 Hz / UK – 9181 Hz), with least difference observed between the A/Constant whistle types (HG – 11129 Hz / UK – 10539 Hz) (Fig. 3.23).

Maximum Frequency

Maximum frequency was relatively comparable between the present study and previously studied UK populations. The maximum frequency observed with UK common dolphins was consistently higher than that recorded in the Hauraki Gulf, with the exception of the A/Constant whistle type (Fig. 3.24).

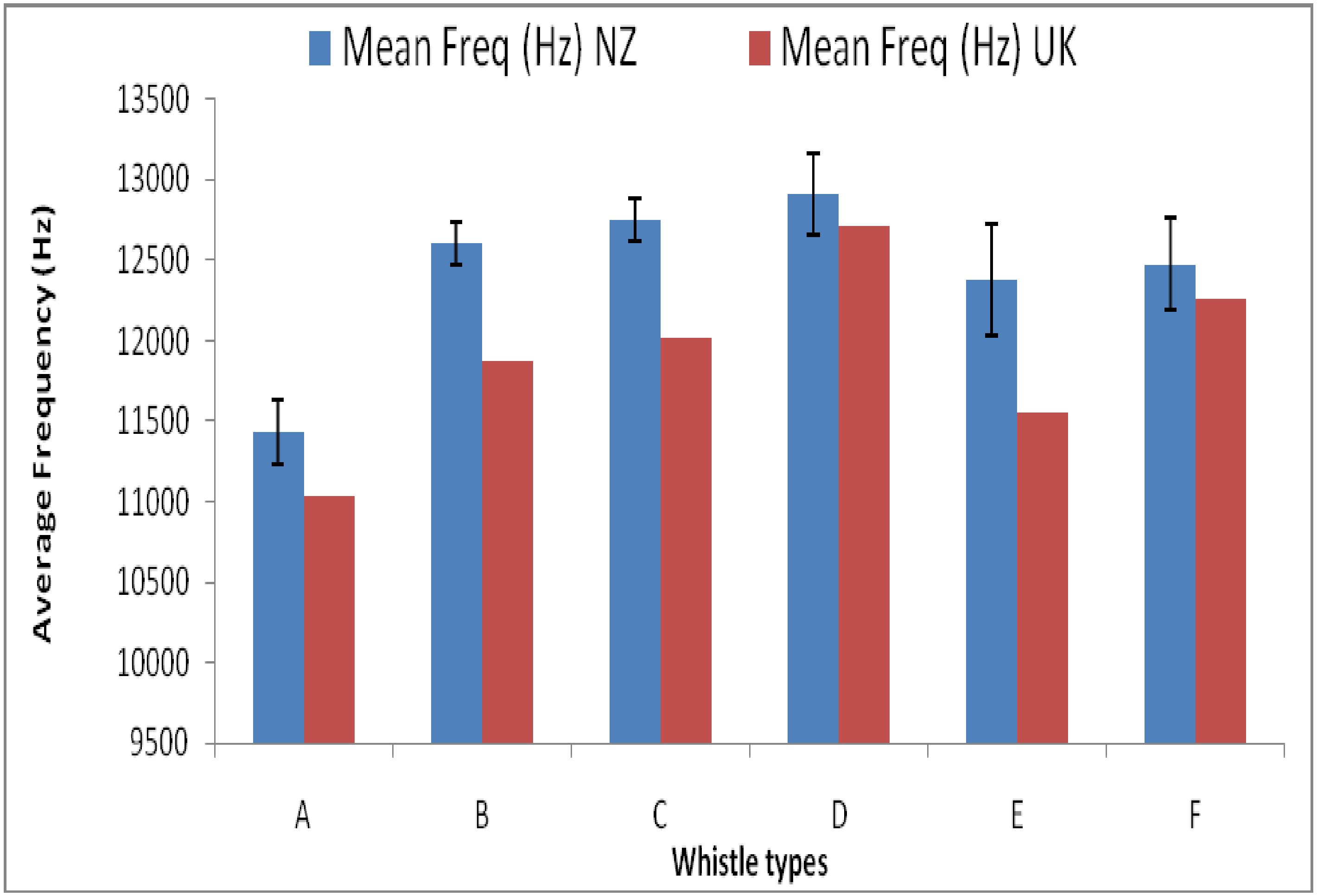

Fig. 3.21: Mean frequency in the vocalisations of common dolphins (*Delphinus* sp) in Hauraki Gulf, New Zealand between February 2008 and May 2009 compared with *Delphinus* from UK waters (Ansmann et. al 2007). Note: A = constant frequency; B = upsweep; C = downsweep; D = convex; E = concave; and F = sine. Error Bars: Standard Errors.

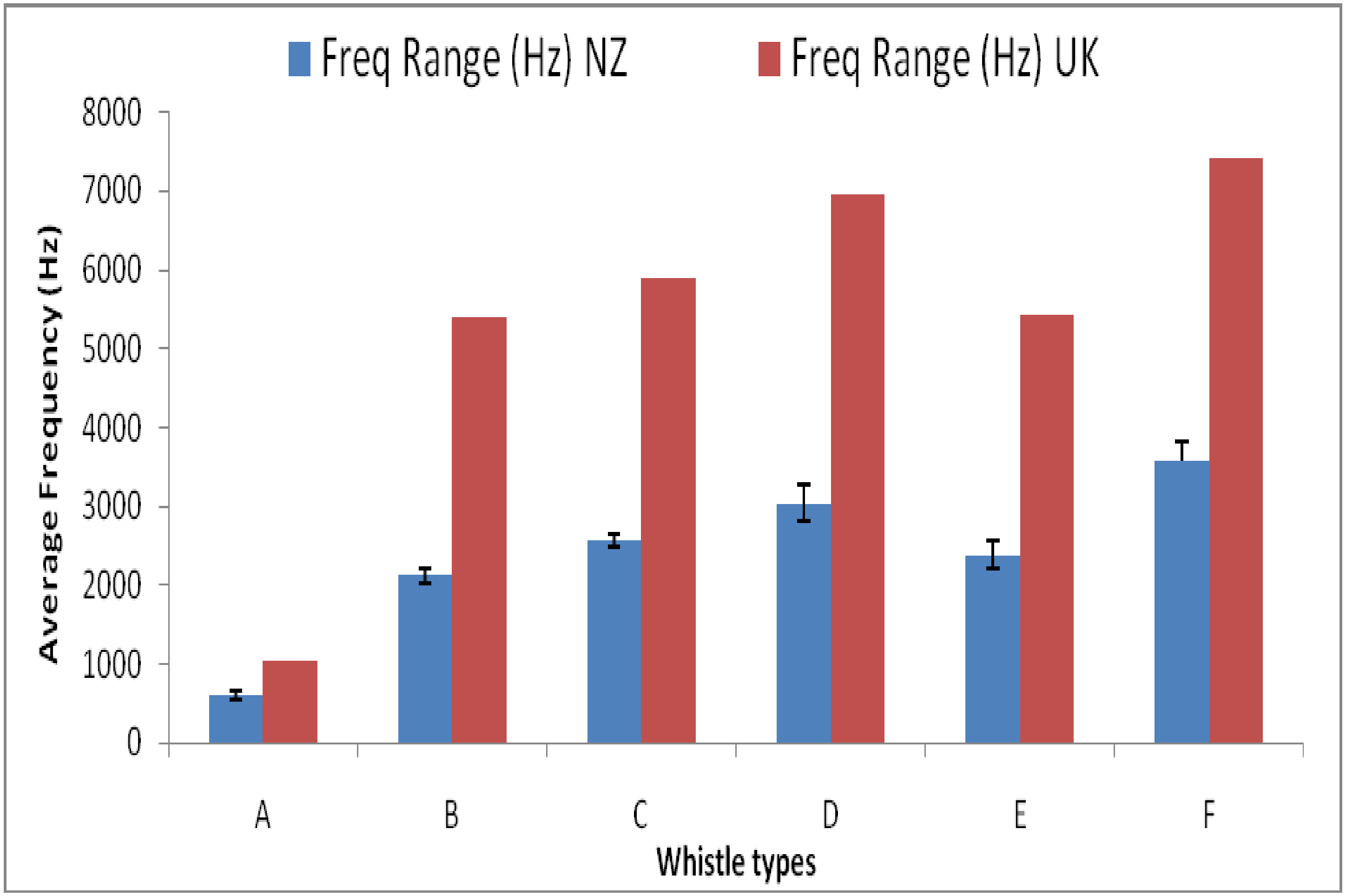

Fig. 3.22: Frequency range of vocalisations of common dolphins (*Delphinus* sp) in Hauraki Gulf, New Zealand between February 2008 and May 2009 compared with *Delphinus* in UK waters (Ansmann et. al. 2007). Note: A = constant frequency; B = upsweep; C = downsweep; D = convex; E = concave; and F = sine. Error Bars: Standard Errors.

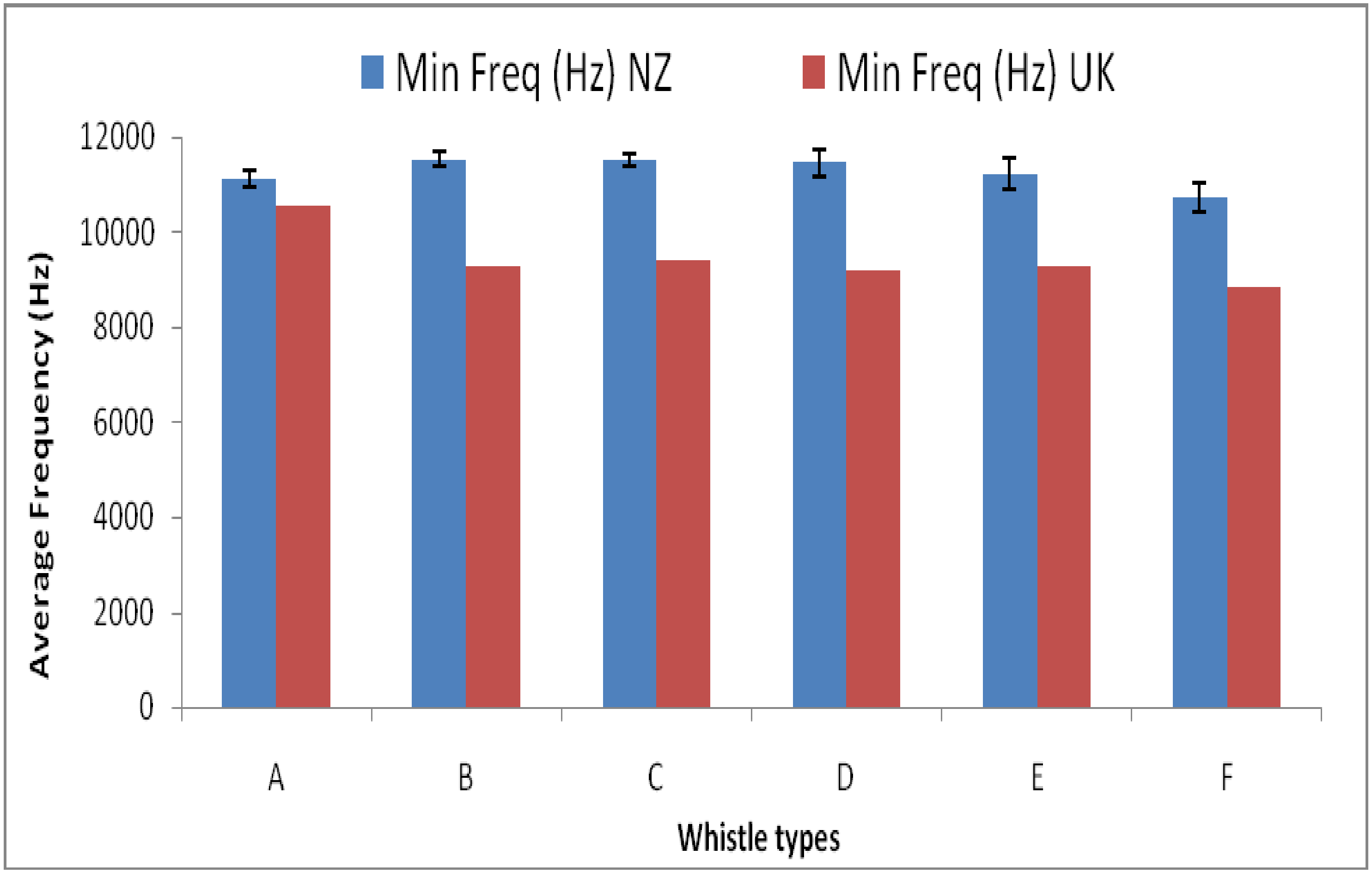

Fig. 3.23: Minimum frequency of vocalisations in common dolphins (*Delphinus* sp) from the Hauraki Gulf, New Zealand between February 2008 and May 2009 compared with *Delphinus* in UK waters (Ansmann et. al. 2007). Note: A = constant frequency; B = upsweep; C = downsweep; D = convex; E = concave; and F = sine. Error Bars: Standard Errors.

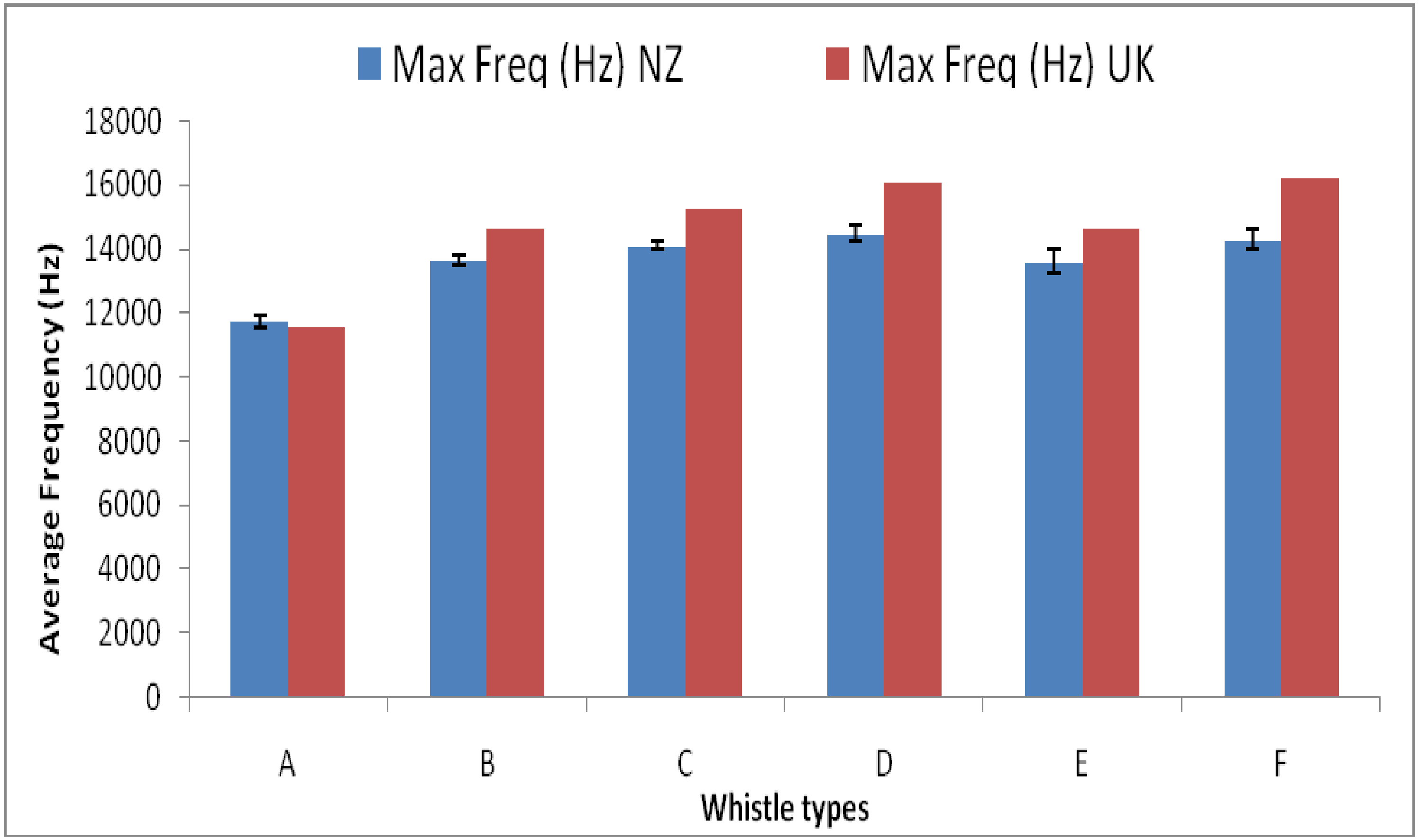

Fig. 3.24: Maximum frequency of vocalisations in common dolphins (*Delphinus* sp) from the Hauraki Gulf, New Zealand between February 2008 and May 2009 compared with *Delphinus* in UK waters (Ansmann et. al. 2007). Note: A = constant frequency; B = upsweep; C = downsweep; D = convex; E = concave; and F = sine. Error Bars: Standard Errors.

Chapter 4

Common dolphins (*Delphinus* sp.) travelling in the Hauraki Gulf, Auckland, New Zealand (photo by Author)

Discussion

4.1 Study Limitations

Quantification of the vocal repertoire of a species is critical for subsequent analysis of signal functionality, geographical variation, social relevance and transmission (Boisseau, 2005). While signal repertoires have been documented for numerous species, detailed descriptions for cetaceans remain rare. This is true of common dolphins (*Delphinus* sp.) and particularly so of the New Zealand population. This study describes the vocalisations of free-ranging common dolphins in the Hauraki Gulf, New Zealand. Data presented here represent the first account of whistle characteristics for this species within New Zealand waters. Nonetheless, analyses presented here are not without limitation. The following discussion focuses on some of the apparent biases and limitations of the present study.

Firstly, all acoustic recordings analysed as part of the present study were collected from the commercial tour vessel, *Dolphin Explorer*. While whale-watch vessels are frequently accessed for research purposes as a *Platform of Opportunity* (Wiseman 2008, Stockin et al. 2008,a,b), their use is limited. For example, methods used to find dolphin groups can induce bias. This was especially true in the present study where sections of the Hauraki Gulf would be sampled repetitively over consecutive days by the tour boat. Additionally, the use of associated species (e.g. Australasian gannets, *Morus serrator*) to locate dolphins groups can cause behavioural biases (Wiseman, 2008). Once with a group of dolphins, the technique used to approach and record whistles was consistent, although in the case of travelling animals, the tour boat often had to restart its engines and track ahead of the group in order to lower the hydrophone. This resulted on occasion, in multiple rather than single approaches to the same dolphins, a factor which may have affected the whistle parameters being monitored. While static arrays or passive acoustic devices (e.g. TPODS) have proven useful for coastal species such as Hector's dolphins (Rayment et al. 2009), their use within the present study was not practical since dolphins are distributed throughout most parts of the Hauraki Gulf (Stockin et al. 2008a).

Unfortunately due to the obligatory schedule of the tour vessel, most interactions with dolphins were kept to a minimal since multiple dolphin and whale encounters were likely within one survey (Stockin et al. 2008a). As such, in most cases the duration of recordings collected from each focal group was relatively short (mean = 4.31 min). Nonetheless, fixed sampling methods, as used in this study, have several benefits. The most important aspect about this method is that it allows vocalisations of animals to be recorded and correlated with a direct physical observation. This allowed species confirmation, group size and behaviour to be assessed in relation to whistles characteristics. One limitation was that this procedure required recordings to only be undertaken when the engine and the sonar of the boat were switched off.

Background noise from other vessels can also be problem in acoustic studies. Fortunately, despite the maritime traffic within the Hauraki Gulf, it was always possible, to find groups of dolphins in absence of any other vessel traffic. These conditions allowed the vocalisations of animals to be recorded in a clear manner. However, any change in whistles as a result of the approaching tour boat could not be determined in the scope of the present study since no recordings of vocalisations prior to the arrival of *Dolphin Explorer* were possible.

Another issue when recording the vocal behaviour of wild dolphins is that it can be hard to discern between the vocalisations of the focal group (i.e., near the boat) *versus* others dolphins that compose the wider group. With equipment of a higher grade, it is possible to measure the intensity of the whistles and use this to resolve this issue. Using whistle intensity, it is possible to assess the distance from the hydrophone and thus to facilitate analysis of the spectrometer. Generally, it is thought that dolphin vocalisations can be picked up from a distance of no more than 1 km (Richardson et al. 1995). Therefore, when able to directly compare the intensity with the distance, it is possible isolate the vocalisations of the focal group from other dolphins with the surrounding area. During the present study, this could only be achieved qualitatively owing to the quality of the hydrophone used.

Another limitation with acoustic studies involving wild cetaceans, and possibly the main source of variance between encounters, is the non-independence of the data collected. During the present study, it was not possible to determine which individual within a group produced the vocalisations. Therefore, it is likely that recordings often included more than one whistle from each individual, thus it cannot be guaranteed that each whistle used in the analysis is from a different dolphin (Oswald et al. 2003). This should be kept in mind when examining the results of this and other acoustic studies featuring free-ranging cetaceans.

4.2 Field Effort

During the present study, a total of 22 acoustic surveys were conducted in the Hauraki Gulf between February 2008 and May 2009. While data could not be recorded during all months owing to field logistics (e.g. bad weather), survey effort was spread across the entire year. This ensured that sampling occurred throughout all austral seasons, and therefore included any temporal variance within the whistle characteristics of common dolphins using Hauraki Gulf waters.

Survey effort was also spatially representative of common dolphin occurrence within the study site (Stockin et al. 2008a), with acoustic recordings collected in various water depths (14 – 48 m), thus covering a range of habitats. As such, any variance in vocalisations as a result of habitat usage (Stockin et al. 2008a; 2009a) was reflected within the analysed dataset.

4.3 Whistle Density

Whistle densities calculated within the present study should be considered as best estimates of whistle numbers only. Inaccuracies in these counts are likely especially during times of high vocal activity, as whistles often overlap each other and can not always be clearly distinguished. Significant differences in the whistle density (T: 012 w/s – F: 1.61 w/s) between travelling and feeding groups also likely influenced the whistle parameters, as detailed in Section 4.4.

Previous studies suggest parameters such as duration or number of inflections or steps are usually, within the same population, more variable than other parameters (Rendell et al. 1999; Morisaka et al. 2005).

4.4 Whistle Parameters

When comparing the Hauraki Gulf data with published data for the Celtic Sea and English Channel populations, notable differences were found in almost all descriptive parameters analysed. Based on a comparable number of analysed whistles, frequency ranged from 3.20 to 23.0 kHz in the Hauraki Gulf population, with most whistles detected between 10 an 14 kHz. This compared with a frequency span of 3.56 to 23.51 kHz for UK waters, with most whistles occurring at between 9 and 15 kHz (Ansmann et al. 2007). The maximum and minimum frequencies in Hauraki Gulf animals were notably lower and higher, respectively than those recorded within English waters. Consequently, this resulted in a smaller frequency range than that previously reported by Ansmann et al. (2007) for UK *Delphinus*.

In the Hauraki Gulf, the mean recorded whistle duration was 0.27 s (range = 0.01 – 4.00) compared with 0.65 s (range = 0.05 - 2.02) for UK waters. Reasons why whistles appear shorter in the Hauraki Gulf population remain unclear. Perhaps the extensive geographical separation between the compared common dolphin populations may offer some explanation. This rationale is based on the similar whistle durations reported for two neighbouring UK populations (i.e. Celtic Sea and English Channel) examined by Ansmann et al. (2007). Nonetheless, this remains surprising given parameters of modulation (e.g. duration, number of inflections and steps) are typically more diverse within rather than between populations (Morisaka et al. 2005).

Whistle types identified in the present study were in many cases similar to those previously described by Ansmann et al. (2007). However, the proportion to which each contour featured within the vocal repertoire differed significantly between Hauraki Gulf and UK common dolphins. For example, whistle types A and C appeared more frequently in the repertoire of the Hauraki Gulf population. This resulted in common dolphins displaying less modulation in their whistles when compared with previously studied populations. This trend was consistent through out whistle types.

Before examining potential reasons to explain the outlined differences between the Hauraki Gulf and UK populations, it is first necessary to consider the methodologies used in both the present and previously published study. Of significant importance is the different manners in which acoustic data were collected. For example, Ansmann and colleagues used a towed hydrophone array during systematic transect surveys. This differs considerably to the non-systematic surveys and static hydrophones used in the present study. Arguably, parameters may vary purely as a result of these sampling differences. For example, towed arrays used by Ansmann et al. (2007) have a number of inherent limitations which may influence comparisons drawn here. Firstly, only in a proportion of UK recordings did the authors manage to confirm species identity via visual observations. As such, the acoustic presence of similar delphinids, namely white-sided (*Lagenorhynchus acutus*), white-beaked (*L. albirostris*) and striped dolphin (*Stenella coeruleoalba*) can not be completely discounted. Secondly, the mobile nature of towed hydrophones likely biased certain behaviours (e.g. travel). The impact such differences may have had on the present comparisons remain unclear. Nonetheless, during the remainder of the discussion, focus is placed on potential ideas to further explain the New Zealand dataset.

The present study examined a southern hemisphere population of common dolphins inhabiting inshore, shallow coastal waters. Data presented by Ansmann et al. (2007) represent northern hemisphere *Delphinus* inhabiting deep open oceanic waters. Clearly, these two environments not only differ by hemisphere but also by local environmental conditions, especially depth and oceanography. The way in which common dolphins use differing environments may contribute, at least in part, to some of the differences outlined during the present study. For example, the Hauraki Gulf is an important feeding area for common dolphins (Stockin et al. 2009a). The associated impact this may have on whistle density and parameters measured here are important factors to consider. Furthermore, the use of inshore Hauraki Gulf waters as a calving and nursery area (Stockin et al. 2008a) may also have some bearing on the results presented, especially since differences in whistle parameters between the sexes have been identified in other delphinids (Sayigh et al. 1995).

Many studies of acoustic communication have revealed that acoustic signals of animals, especially the frequency and temporal structure of signals, change in response to the acoustic environment. Characteristics of acoustic signals are affected by the acoustic environments among habitats (Sugiura et al. 1999), and geographical variation in animal acoustic signals can result from differences in acoustic environments (Morton, 1975). However, ambient noise, especially in shallow seas (ca 60 m deep) can be extremely high. Noisy environments may induce marine animals to produce sounds that transmit efficiently in their habitats. For instance, a beluga whale (*Delphinapterus leucas*) shifted its biosonar signals to higher frequencies and intensities after it was experimentally moved to a noisier environment (Au et al. 1985). In the present study, busy northern hemisphere waters may explain why *Delphinus* in the Celtic Sea and English Channel communicate over a wider frequency range than those studied presently in the Hauraki Gulf. While Auckland waters remain busy for recreational craft, the level of commercial shipping within UK waters is considerably higher. Thus, ambient noise levels experienced by those populations are likely to be considerably higher than experienced by common dolphins within Hauraki Gulf waters.

4.5 Signature Whistles

Signature whistles are particular vocalisations that give personal information about the individual identity. In the same way humans develop names to facilitate identification, bottlenose dolphins (*Tursiops truncatus*) have been shown to use a similar system based on the inter-individual variability in their signature whistles (Janik et al. 2005). Janik and Colleagues et al. 2005 found that the frequency modulation pattern of signature whistles carries sufficient information for individual discrimination and that this information is used by the receiver to identify individuals. Their results also suggest that animals recognise each other's whistles individually rather than just discriminate between them.

In the present study there was no conclusive way to determine if whistles repetitions identified within the Hauraki Gulf population were indeed signature whistles. This was because these whistles were recorded incidentally and no experimental protocol was carried out to synthesize and test whether a particular animal emitted the same whistle over time. Nonetheless, of the 20 whistle repetitions identified in the present study, 8 appeared in at least two different independent encounters (up to 15 months apart). These data allow us to suppose there is a good possibility that during the field work that either (1) the same pod was encountered more than once or (2) some of the same dolphins occurred within different pods. The first explanation is plausible since previous research has indicated that common dolphins in the Hauraki Gulf show high site fidelity (Stockin, 2008). The second hypothesis is also possible since common dolphins are known to live in fission-fusion societies (Bruno et al. 2004). A third and more alternative hypothesis is that these types of vocalisation maybe created by different individuals but within the same pod. While this is not reported within the literature, whistle imitation by other delphinids has previously been recorded in bottlenose dolphins (Miksis et al. 2002). Regardless of the explanation, signature whistles can facilitate continued contact between individuals both within and between groups.

4.6 Behaviour

Assessing acoustic recordings in relation to observed behaviour is problematic when dealing with a wild population of mobile dolphins. The analyses presented here for the Hauraki Gulf population are no exception. While captive studies often involve a single animal whose behaviour can be directly correlated vocalisations produced (e.g. Caldwell and Caldwell, 1968), the same can not be said for studies examining free-ranging populations. As such, this study attempted to understand whistle communication at the group level, since individual recognition was not possible. Nonetheless, common dolphins can form large groups (e.g. Oswald et al. 2003) and are typically structured into several subgroups (Stockin et al. 2008a,b). These subgroups often engage in distinct behaviours (Stockin et al. 2009a) which is why during the present study only recordings of these smaller (*ca* 20–30 animals) subunits were made. This enabled to be focus on the specific behaviours for which all the subgroup members were engaged. As travel and forage states were recorded in isolation of other behaviours in the Hauraki Gulf population, only these states were compared in relation to recorded vocalisations.

The first notable difference between foraging and travelling groups related to whistle density. Typically common dolphins in the Hauraki Gulf emitted far fewer whistles per minute when travelling. Conversely, feeding dolphins exhibited a much higher whistle density. Since whistle density is likely affected by the number of dolphins (assuming that more whistles per unit time can be emitted from a larger group), only dolphin groups of comparable size were assessed. Results of the present study showed that during foraging, whistle density was around 13 times higher than during travelling activity. This finding appears logical, since it is appropriate to suggest that the level of coordination required between foraging individuals would be higher than that necessary in travelling dolphins. This is supported by recent studies which indicate New Zealand common dolphins employ a number of foraging behaviours, several of which include coordinated group strategies (Burgess, 2006; Neumann and Orams 2003). Presumably, less coordination (and communication) is required by travelling groups, since by definition, travelling implies animals in a uniform speed and direction. Possibly, the few whistles that are emitted by travelling individuals act as signals to maintain group cohesion only. Alternatively, perhaps the multiple approaches made towards travelling groups during recordings may in part also explain differences in whistle density detected. However, since *Dolphin Explorer* was able to track ahead of travelling groups and cut engines prior to secondary sampling, it seems unlikely that disturbance as a result of secondary sampling would alone explain the differences reported here.

Another significant finding between the behaviours related to whistle duration. Presumably, to be coordinated during cooperative feeding strategies, individuals within a group need to communicate efficiently i.e. within the shortest lapse of time possible. This fits with the findings of the present study, which showed feeding common dolphins display a shorter whistle duration than groups engaged in travelling behaviour only.

4.7 Conclusions

Few published data worldwide detail the vocal repertoire of free-ranging common dolphins. For the first time, I examined the whistle characteristics of New Zealand common dolphins using various quantitative analyses. Findings suggest that the majority of whistle parameters examined in New Zealand common dolphins differ to those previously published for UK populations. Furthermore, unlike other populations, behaviour does appear to affect the whistle characteristics of New Zealand common dolphins. However, preliminary findings presented here are restrictive to the Hauraki Gulf and therefore, further research is recommended in order to expand our current knowledge.

4.8 Future Research

Future studies should be conducted from an independent boat in order to (1) facilitate focal group follows and (2) extend the period of sampling recordings for individual groups. The use of additional methods such as photo-identification should also be considered to improve the chances of tracking individuals during fission-fusion events. With a larger sample size, further analyses should take into consideration the role of group composition, associated species (e.g. Bryde's whales) and boat traffic on common dolphin vocalisations.

Additional field effort should be undertaken throughout all austral seasons to assess temporal variation within Hauraki Gulf common dolphins. Since differences in the vocal repertoire of delphinids have been identified between year (Morisaka et al. 2005) and sex (Sayigh et al. 1995), future research should aim to span multiple years and target nursery and bachelor pods independently. Additional acoustic data from outside the Hauraki Gulf should also be collected in order to assess the similarity of common dolphin vocalisations between neighbouring waters within New Zealand. This will establish how representative the Hauraki Gulf recordings collected during the present study are in relation to the larger New Zealand population.

Finally, future effort should be made to (1) obtain recordings from milling, resting and socialising groups and (2) collect vocalisations of foraging animals engaged within different strategies (e.g. line abreast, wall formation, etc). This would allow us to examine different behaviours and assess the degree of communication between individuals involved within specific foraging strategies.

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APPENDICES

Appendix 1 (Field Sheet)

TAB HG

1) General Data

Observer(s) _____ **R. Vessel** ___________________ **Date**________________________ **Survey No** _______ **Encounter No** _______

Survey Period _________________________ **Encounter S.T.** _____________ **Encounter E.T.** ______________ **Species** ________

Associated Species ______________________ **Latitude** ___________________________ **Longitude** ___________________________

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2) Vessel Data

Interaction Score _______ **Encounter Status** ______________________________________ **No Vessels Present** _______________

Closest V. Distance _______ **V. Type(s)** ____________________ **V. Movement** ________________________ **V. Speed** ___________

Arrival Status ____ **Departure Status** ____

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3) Environmental Data

Depth _______ **Sea State** _______ **Sea Swell** ______ **S.S.T.** ________ **Weather** _____________ **Visibility** _____________________

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4) Group Data

Pod Size _________ **Group Size** _________ **No Subgroup(s)** _____________ **D. Travel** _________

Adults	Juvs	Calves	New

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5) Behavioral Data

States	Feeding	Milling	Socializing	Resting	Travelling
Pre-Approach					
Approach					
Post-approach					
Departure					

6) Audio

Tape #	S.T.	E.T.	Depth	Start dist.	End dist.	Animals #	Comments

FIELD KEY

Visibility

Excellent—Surface water calm (Beaufort 0-1) with no sun glare or other environmental factors impeding ability to sight animals (visibility >5km)

Very Good—May be slightly uneven lighting or light chop (Beaufort 0-2) but still relatively easy to sight animals (visibility >5km)

Good—Light chop w/ scattered whitecaps (Beaufort 0-3), swell (2-4m) or some sun glare or other impediment (e.g. haze) in < or equal to 10% of the study area, dolphins can still be detected fairly easily

Fair—Choppy waves with fairly frequent whitecaps, low-light conditions (e.g. heavy overcast, dawn, dusk), swell 4-6m or sun glare in, or equal to 50% of study area, some animals likely to be missed

Poor—Numerous whitecaps (Beaufort 5), sun glare or haze in >or equal to 50% of study area, or swell >6m, impeding ability to sight dolphins, many animals likely to be missed

Unacceptable—Beaufort > or equal to 6, or glare, haze, or other visibility impediment in >75% of study area, detection of animals unlikely unless observer is looking directly at place of surfacing

Beaufort Sea State

0—Smooth and mirror-like, wind calm (0-1 knts)
1—Light ripple, light air (1-3 knts)
2—Small wavelets, not breaking, light breeze (4-6 knts)
3—Scattered whitecaps, gentle breeze (7-10 knts)
4—Small waves, frequent whitecaps, moderate breeze (11-16 knts)
5—Moderate waves, many whitecaps, fresh breeze (17-21 knts)
6—All whitecaps, some spray, strong breeze (22-27 knts)
7—Breaking waves, spindrift begins, near gale (28-33 knts)
8—Medium high waves, foamy, gale (34-40 knts)

Tide

Please refer to tide table (Waitemata Harbour)

High - Sighting occurred 30min either side of high tide
Ebb - Sighting occurred on > 30min after high tide
Low - Sighting occurred 30min either side of low tide
Flood - Sighting occurred > 30min after low tide

Weather

Sunny - Predominantly sunny, no/few clouds
Overcast - Cloudy/grey with no visible sunshine
Showers - Light rain on and off with limited visibility
Rain - Heavy/continuous rain with dark skies
Hail - Hail showers/storms
Fog - Fog

SST (Sea Surface Temperature)

Please refer to hand-held digital thermomoter for temp in degrees centigrade

GPS (Global Positioning System)

Please refer to the onboard GPS monitor or the hand-held GPS

Vessel

DE - Dolphin Explorer
A - Aihe
O - Other (Please specify)

Observer

Please state initials of each volunteer observer

Behaviour States
Feeding - Often during in a work-up with prey species at sea surface visibly being taken by dolphins
Resting - Swimming slowly in same direction, synchronous breathing
Socialising - Movement with no particular speed or direction, often in very close association with boat and /or other animals
Travelling - Swimming rapidly at a constant speed in a unidirectional manner
Milling - Slow swimming/bobbing on surface in different directions, asynchronous breathing

Behaviour Events
Back Slap - Emerge from water as far as mid body and slap back against water
Bow Ride - Riding the bow wave of a moving vessel
Chin Slap - Emerge from water as far as mid body and slap anterior belly against water
Fluke Out - Surface vertically, tail first, thrusting tail stock and flukes into air, may wriggle tail
Head Butt - Fast head to head contact between animals
Herding - Co-ordinated foraging behaviour amongst animals, often with no prey species visible
Porpoising - Repetative leaps clean of waters surface, usually in fast moving pod
Sexual - Observed copulation, petting and/or suckling (please specify)
Side Slap - Emerge from water as far as mid body and slap side against water
Surfing - Swimming just below surface of a rolling/breaking wave
Synchronous - Any synchronised behaviour involving 2+ animals
Tail Slap - Slaps of tail flukes in normal or inverted position
Vocalisations - Vocalising heard above the waters surface
Zig Zag - Repetative crossing of the bow or stern of a vessel

Encounter Status
Neutral - Animals and vessel both terminated encounter simultaneously
Animals - Animals terminated encounter by moving away from boat
Vessel - Vessel terminated encounter by moving away from animals

Vessel Movement
Stationary - Moored/anchored
Drifting - Drifting towards dolphins
Toward - Head-on movement towards dolphins
Parallel - Movement alongside dolphins
Away - Movement away from dolphins
Behind - Movement from back from dolphins

Vessel Speed
Stationary - No movement
Slow - Movement without wake
Fast - Movement with wake

Vessel Types
Research Vessel (Aihe)
Tour Vessel (Dolphin Explorer)
Tour Vessel (AN OTHER)
Passenger Ferry
Cargo/Tanker Vessel
Commercial Fishing Vessel
Recreactional Fishing Vessel
Sailing Yacht/Ketch
Match Racing Yacht
Jet Ski
Kayak/Canoe
Military Vessel
Cruise Liner
Other

Closest Vessel Distance
0-10m from pod centre
>10-50m from pod centre
>50-100m from pod centre
>100-200m from pod centre
>200m from pod centre

Interaction Score
0— Dolphins avoided the vessel entirely (>200m)
1— Dolphins neither approached nor avoided the vessel (100m)
2— Dolphins briefly approached the vessel but departed within < 5min
3— Dolphins approached the vessel but departed within < 10min
4— Dolphins approached the vessel but departed within < 20min
5— Dolphins approached the vessel and remained for > 20 min
6— Dolphins immediately approached the vessel and remained indefinately

Swim Score
0— Dolphins departed >50m from vessel before swimmers entered water
1— Dolphins departed >50m from vessel immediately after swimmers entered water
2— Dolphins avoided swimmers but remained within 50m of the vessel
3— Dolphins briefly (< 2 min) inspected swimmers before swimming > 50m from vessel
4— Dolphins briefly(< 2 min) inspected swimmers and remained within 50m of vessel
5— Dolphins interacted with swimmers for < 5 min
6— Dolphins interacted with swimmers for > 5 min
7— Dolphins closely interacted with swimmers for > 5 min
8— Dolphins closely interacted with swimmers for > 10 min
9— Dolphins closely interacted with swimmers for > 10 min, following swimmers on retreat
10— Dolphins closely interacted with swimmers for > 15 min, following swimmers with mimic behaviour

Arrival Status
Simultaneous - Research and tour/other vessels arrived simultaneously
Before - Research vessel arrived BEFORE all other vessels
After - Research vessel arrived AFTER all other vessels
Intermediate 1 - Research vessel arrived BEFORE the tour vessel but AFTER other vessels
Intermediate 2 - Research vessel arrived AFTER the tour vessel but BEFORE other vessels

Departure Status
Simultaneous - Research and tour/other vessels departed simultaneously
Before - Research vessel departed BEFORE all other vessels
After - Research vessel departed AFTER all other vessels
Intermediate 1 - Research vessel departed BEFORE the tour vessel but AFTER other vessels
Intermediate 2 - Research vessel departed AFTER the tour vessel but BEFORE other vessels

Swim With Programme
Yes
No

Number of Swimmers
1— Single swimmer
2— Two swimmers
3— Three swimmers
4— Four swimmers
5— Five swimmers
6— Six swimmers
7— Six plus swimmers

Species

CD - Common Dolphin
BD - Bottlenose Dolphin
BW - Brydes Whale
KW - Killer Whale
FK - False Killer Whale
SW - Sei Whale
FW - Fin Whale
MW - Minke Whale
BS - Beaked Whale Sp.
ID -Unidentified Sp.

Associated Species

None - No Associated Sp.
Gannets - Gannet Sp.
Terns -Tern Sp.
Shearwaters - Shearwater Sp.
Gulls - Gull Sp.
Birds - Other Bird Sp.
Seals - Pinniped Sp.
Sharks - Shark Sp.
Other - Other Sp.

Sub-Groups

1— One pod only, no separate sub-groups
2— 1 pod but animals split into 2 separate sub-groups
3— 1 pod but animals split into 3 separate sub-groups
4— 1 pod but animals split into 4/4+ separate sub-groups

Group Composition

Adult - Fully grown independent animal
Sub-adult - Partially grown independent animal
Juvenile - Partially grown animal, not yet fully independant
Calf - Dependant animal < than half the size of accompanying adult
New Calf - Recent calf with visible fetal folds and/or attached placenta

Direction of Travel

N— North
NE— North East
E— East
SE— South East
S— South
SW— South West
W— West
NW— North West

Dispersion Score

1—One dolphin length apart	(CONDENSED)
2—Two dolphin lengths apart	(TIGHT)
3—Three dolphin lengths apart	(TIGHT MIX)
4—Four dolphin lengths apart	(LOOSE MIX)
5—Five dolphin lengths apart	(LOOSE)
6—More than five dolphin lengths apart	(SCATTERED)

Group Size

1-10 animals
>**10-20** animals
>**20-30** animals
>**30-50** animals
>**50-100** animals
>**100-200** animals
>**200** animals

NOTES

Behavioural data is to be taken on 5 occasions; Pre-approach, Approach, Post Approach, Departure and during Swim-With sessions. These occasions are defined as follows;

Pre-approach - Upon initial sighting of the dolphins, >400m away from the peripheral animals
Approach - Upon the initial approach of the core/central animals of the pod
Post-approach - 15 minutes after the initial approach has taken place
Departure - Upon vessel and/or animals departure
Swim - Upon entrance of the swimmers into the water. Notes on beaviour after 10 mins should be taken if deemed necessary

Appendix 2 (Data Tables)

Table A.1.1: Parameters describing whole of whistle detect in the population of New Zealand common dolphin in Hauraki Gulf, between February 2008 and May 2009. Note: L.= intervalls leght; N.W. = number of the whistles; D = density.

Survey	**I.1(S)**	**N.W.1**	**D.1 (w/s)**	**I.2(S)**	**N.W.2**	**D.2 (w/s)**	**I.3(S)**	**N.W.3**	**D.3 (w/s)**	**I.4(S)**	**N.W.4**	**D.4(w/s)**	**I.5(S)**	**N.W.5**	**D.5 (w/s)**
8-Feb-08	60	49	0.817	60	683	11.383	60	419	6.98333	60	294	4.9	53	167	3.1509
19-Feb-08	60	15	0.25	66	1	0.0152	60	10	0.16667	60	2	0.033333	60	4	0.0667
27-Feb-08	71	202	2.845	60	49	0.8167	60	42	0.7	41	87	2.121951	68	0	0
27-Feb-08	88	2	0.023	25	1	0.04									
12-Mar-08	60	26	0.433	60	7	0.1167	60	9	0.15	60	13	0.216667	65	0	0
1-Apr-08	96	4	0.042												
11-Apr-08	60	0	0	72	4	0.0556									
11-Apr-08	60	3	0.05	60	1	0.0167	77	0	0						
15-May-08	60	0	0	60	0	0	48	0	0	60	57	0.95	60	69	1.15
15-May-08	60	48	0.8	60	84	1.4	60	50	0.83333	60	25	0.416667	60	16	0.2667
23-Aug-08	60	70	1.167	60	184	3.0667	60	274	4.56667	60	409	6.816667	10	67	6.7
23-Aug-08	60	3	0.05	60	1	0.0167	4	0	0						
29-Aug-08	60	27	0.45	60	9	0.15	60	38	0.63333	60	51	0.85			
29-Aug-08	60	0	0	5	5	1									
12-Nov-08	60	6	0.1	60	21	0.35	49	2	0.04082						
21-Nov-08	58	0	0												
25-Nov-08	91	730	8.022												
25-Nov-08	60	609	10.15	60	506	8.4333									
30-Dec-08	60	0	0	70	3	0.0429	60	9	0.15	60	12	0.2			
31-Dec-08	60	19	0.317	77	8	0.1039	60	2	0.03333	60	7	0.116667	60	10	0.1667
7-Jan-09	28	81	2.893	60	251	4.1833	42	109	2.59524						
7-Jan-09	60	326	5.433	60	162	2.7									
15-Jan-09	60	82	1.367	60	166	2.7667	60	115	1.91667	60	108	1.8	60	31	0.5167
30-Mar-09	60	123	2.05	60	66	1.1	60	47	0.78333	60	65	1.083333	60	19	0.3167
28-May-09	60	433	7.217	60	577	9.6167	60	640	10.6667	60	345	5.75	60	608	10.133
	1572	2858		1275	2789		940	1766		761	1475		616	991	

Table A.1.2: Parameters describing all whistle detections in the population of New Zealand common dolphin (*Delphinus* sp) in Hauraki Gulf, between February 2008 and May 2009. Note: L.= interval lenght; N.W. = number of the whistles; D = density.

Survey	I.6(S)	N.W.6	D.6 (w/s)	I.7(S)	N.W.7	D.7 (w/s)	I.8(S)	N.W.8	D.8 (w/s)	I.9(S)	N.W.9	D.9 (w/s)	I.10(S)	N.W.10	D.10 (w/s)
8-Feb-08															
19-Feb-08	60	0	0	60	0	0	60	10	0.16667	60	2	0.033333	60	0	0
27-Feb-08															
27-Feb-08															
12-Mar-08															
1-Apr-08															
11-Apr-08															
11-Apr-08															
15-May-08	40	19	0.475												
15-May-08	50	8	0.16												
23-Aug-08															
23-Aug-08															
29-Aug-08															
29-Aug-08															
12-Nov-08															
21-Nov-08															
25-Nov-08															
25-Nov-08															
30-Dec-08															
31-Dec-08	67	28	0.418												
7-Jan-09															
7-Jan-09															
15-Jan-09	60	16	0.267	60	20	0.3333	60	39	0.65	60	74	1.233333	60	60	1
30-Mar-09															
28-May-09	60	911	15.18	60	526	8.7667									
	337	982		180	546		120	49		120	76		120	60	

Table A.1.3: Parameters describing all whistle detections in the population of New Zealand common dolphin (*Delphinus* sp) in Hauraki Gulf, between February 2008 and May 2009. Note: L.= interval lenght; N.W. = number of the whistles; D = density.

Survey	I.11(S)	N.W.11	D.11 (w/s)	I.12(S)	N.W.12	D.12 (w/s)	I.13(S)	N.W.13	D.13 (w/s)	Total duration	Total n.Whistles	Total Density(w/s)
8-Feb-08										293	1612	5.501706
19-Feb-08	60	0	0	60	1	0.0167	29	0	0	755	45	0.059603
27-Feb-08										300	380	1.266667
27-Feb-08										113	3	0.026549
12-Mar-08										305	55	0.180328
1-Apr-08										96	4	0.041667
11-Apr-08										132	4	0.030303
11-Apr-08										197	4	0.020305
15-May-08										328	145	0.442073
15-May-08										350	231	0.66
23-Aug-08										250	1004	4.016
23-Aug-08										124	4	0.032258
29-Aug-08										240	125	0.520833
29-Aug-08										65	5	0.076923
12-Nov-08										169	29	0.171598
21-Nov-08										58	0	0
25-Nov-08										91	730	8.021978
25-Nov-08										120	1115	9.291667
30-Dec-08										250	24	0.096
31-Dec-08										384	74	0.192708
7-Jan-09										130	441	3.392308
7-Jan-09										120	488	4.066667
15-Jan-09	60	92	1.533	60	30	0.5				720	833	1.156944
30-Mar-09										300	320	1.066667
28-May-09										420	4040	9.619048
	120	92		120	31		29	0		**6310**	**11715**	**1.8566**

Table A.2: Statistical analyses on the data detected in Hauraki Gulf between February 2008 and May 2009. Note: X = significant - $p < 0.05$

Kruskal -Wallis statistics for whistle parameters by **encounter** -**DURATION**

	A	B	C	D	E	F	G	H	I
A		X	*	X	X	X	X	X	X
B			*	*	*	*	X	X	X
C				*	*	*	*	*	*
D					*	*	X	X	X
E						*	X	X	X
F							X	X	X
G								X	X
H									*
I									

Kruskal -Wallis statistics for whistle parameters by **encounter** - **START FREQUENCY**

	A	B	C	D	E	F	G	H	I
A		*	*	X	*	*	*	*	*
B			*	X	*	*	*	*	*
C				*	*	*	*	*	*
D					X	X	X	X	X
E						*	*	*	*
F							*	*	*
G								*	*
H									*
I									

Kruskal -Wallis statistics for whistle parameters by **encounter** - **END FREQUENCY**

	A	B	C	D	E	F	G	H	I
A		X	*	*	*	X	*	*	
B			*	X	X	*	X	*	X
C				*	*	*	*	*	
D					X	X	X	X	X
E						X	*	*	*
F							X	*	*
G								*	*
H									*
I									

Kruskal -Wallis statistics for whistle parameters by **encounter** - **FREQUENCY RANGE**

	A	B	C	D	E	F	G	H	I
A		X	*	X	X	X	X	X	X
B			*	*	X	X	X	X	X
C				*	*	*	X	*	*
D					X	X	X	X	X
E						*	X	*	*
F							X	*	*
G								X	X
H									*
I									

Kruskal -Wallis statistics for whistle parameters by **encounter** - **MINIMUM FREQUENCY**

	A	B	C	D	E	F	G	H	I
A		X	*	X	*	X	*	X	*
B			*	*	X	*	X	*	*
C				*	*	*	*	*	*
D					*	*	X	*	*
E						*	X	*	*
F							X	*	*
G								X	X
H									*
I									

Kruskal -Wallis statistics for whistle parameters by **encounter** - **MAXIMUM FREQUENCY**

	A	B	C	D	E	F	G	H	I
A		*	*	*	*	*	X	*	*
B			*	*	*	*	X	*	*
C				*	*	*		*	*
D					*	*	X	*	*
E						*	X	*	*
F							*	*	*
G								X	*
H									*
I									

Kruskal -Wallis statistics for whistle parameters by **encounter** - **MEAN FREQUENCY**

	A	B	C	D	E	F	G	H	I
A		*	*	*	*	*	*	*	*
B			*	*	*	*	*	*	*
C				*	*	*	*	*	*
D					*	*	*	*	*
E						*	*	*	*
F							*	*	*
G								*	*
H									*
I									

Kruskal -Wallis statistics for whistle parameters by **encounter** - **GRADIENT OF FREQUENCY**

	A	B	C	D	E	F	G	H	I
A		*	*	X	*	X	*	*	*
B			*	X	*	*	X	*	*
C				*	*	*	*	*	*
D					X	X	X	X	X
E						X	*	*	*
F							X	*	*
G								X	X
H									*
I									

Kruskal -Wallis statistics for whistle parameters by **encounter** - **NUMBER OF INFLECTIONS**

	A	B	C	D	E	F	G	H	I
A		*	*	X	*	X	*	*	*
B			*	X	*	*	X	*	*
C				*	*	*	*	*	*
D					X	X	X	X	X
E						X	*	*	*
F							X	*	*
G								X	X
H									*
I									

Kruskal -Wallis statistics for whistle parameters by **encounter** - **NUMBER OF STEPS**

	A	B	C	D	E	F	G	H	I
A		*	*	*	*	*	*	*	*
B			*	*	*	*	*	*	*
C				*	*	*	*	*	*
D					*	*	*	*	*
E						*	*	*	*
F							*	*	*
G								*	*
H									*
I									

Table A.3: Statistical analyses on the data detected in Hauraki Gulf between February 2008 and May 2009. Note: X = significant - $p < 0.05$

Kruskal -Wallis statistics for whistle parameters by **group size -DURATION**

	A	**B**	**C**	**D**	**E**
A		X	X	X	X
B			X	X	X
C				*	X
D					X
E					

Kruskal -Wallis statistics for whistle parameters by **group size - START FREQUENCY**

	A	**B**	**C**	**D**	**E**
A		*	*	*	*
B			*	X	X
C				X	X
D					*
E					

Kruskal -Wallis statistics for whistle parameters by **group size - END FREQUENCY**

	A	**B**	**C**	**D**	**E**
A		*	*	*	*
B			*	X	*
C				X	*
D					X
E					

Kruskal -Wallis statistics for whistle parameters by **group size - FREQUENCY RANGE**

	A	**B**	**C**	**D**	**E**
A		*	X	X	X
B			*	*	X
C				*	X
D					X
E					

Kruskal -Wallis statistics for whistle parameters by **group size - MINIMUM FREQUENCY**

	A	**B**	**C**	**D**	**E**
A		*	*	*	*
B			X	*	X
C				*	*
D					*
E					

Kruskal -Wallis statistics for whistle parameters by **group size - MAXIMUM FREQUENCY**

	A	**B**	**C**	**D**	**E**
A		*	*	*	*
B			*	*	X
C				*	X
D					X
E					

Kruskal -Wallis statistics for whistle parameters by **group size - MEAN FREQUENCY**

	A	**B**	**C**	**D**	**E**
A		*	*	*	*
B			*	*	*
C				*	X
D					X
E					

Kruskal -Wallis statistics for whistle parameters by **group size - GRADIENT OF FREQUENCY**

	A	**B**	**C**	**D**	**E**
A		*	*	X	*
B			X	X	X
C				X	X
D					X
E					

Kruskal -Wallis statistics for whistle parameters by **group size - NUMBER OF INFLECTIONS**

	A	**B**	**C**	**D**	**E**
A		X	X	X	X
B			X	X	X
C				X	X
D					X
E					

Kruskal -Wallis statistics for whistle parameters by **group size - NUMBER OF STEPS**

	A	**B**	**C**	**D**	**E**
A		*	*	*	*
B			*	*	X
C				*	*
D					*
E					

Table A.4: Statistical analyses on the data detected in Hauraki Gulf between February 2008 and May 2009. Note: X = significant - $p < 0.05$

Kruskal -Wallis statistics for whistle parameters by **whistle type -DURATION**

	A	B	C	D	E	F
A		*	X	X	X	X
B			X	X	X	X
C				X	X	X
D					*	*
E						X
F						

Kruskal -Wallis statistics for whistle parameters by **whistle type** - **START OF FREQUENCY**

	A	B	C	D	E	F
A		*	X	*	X	*
B			X	*	X	X
C				X	*	X
D					*	*
E						*
F						

Kruskal -Wallis statistics for whistle parameters by **whistle type** - **END OF FREQUENCY**

	A	B	C	D	E	F
A		X	*	*	X	*
B			X	X	*	X
C				*	X	*
D					*	*
E						*
F						

Kruskal -Wallis statistics for whistle parameters by **whistle type** - **FREQUENCY RANGE**

	A	B	C	D	E	F
A		X	X	X	X	X
B			X	X	X	X
C				*	*	*
D					*	*
E						*
F						

Kruskal -Wallis statistics for whistle parameters by **whistle type -MINIMUM FREQUENCY**

	A	B	C	D	E	F
A		*	*	*	*	*
B			*	*	*	X
C				*	*	X
D					*	*
E						*
F						

Kruskal -Wallis statistics for whistle parameters by **whistle type** - **MAXIMUM FREQUENCY**

	A	B	C	D	E	F
A		X	X	X	X	X
B			*	X	*	*
C				*	*	*
D					*	*
E						*
F						

Kruskal -Wallis statistics for whistle parameters by **whistle type** - **MEAN FREQUENCY**

	A	B	C	D	E	F
A		X	X	X	*	*
B			*	*	*	*
C				*	*	*
D					*	*
E						*
F						

Kruskal -Wallis statistics for whistle parameters by **whistle type -FREQUENCY GRADIENT**

	A	B	C	D	E	F
A		X	X	X	*	*
B			X	X	X	X
C				X	X	X
D					*	*
E						*
F						

Kruskal -Wallis statistics for whistle parameters by **whistle type** - **NUMBER OF INFLECTIONS**

	A	B	C	D	E	F
A		X	X	X	X	X
B			X	X	X	X
C				X	X	X
D					*	X
E						X
F						

Kruskal -Wallis statistics for whistle parameters by **whistle type -NUMBER OF STEPS**

	A	B	C	D	E	F
A		X	X	X	X	X
B			*	*	X	*
C				*	*	*
D					*	*
E						*
F						