

Behaviour of Bottlenose Dolphins: Inference for Dolphin Tourism off Durban, South Africa

By

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Submitted in fulfillment of the academic requirements for the degree of Master of Science in the
School of Conservation and Biological Sciences,
University of KwaZulu-Natal
Durban

March 2008

Preface

The experimental work described in this dissertation was carried out in the School of Biological and Conservation Sciences, University of KwaZulu-Natal, Durban-Westville, from June 2004 to February 2005, under the supervision of Prof. V. M. Peddemors and Dr. A. J. Smit.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others it is duly acknowledged in the text.

Acknowledgements

“I feel a very unusual sensation - if it is not indigestion, I think it must be gratitude”. Benjamin Disraeli.

I would like to deeply thank various people, who during my research provided me with helpful assistance. Without their care and consideration, this dissertation would likely not have matured.

First, my gratitude is extended to my supervisor, Prof. Vic Peddemors, and my friend and colleague J. Ryan Peter for allowing me to pursue this research, and providing me an invaluable amount of guidance, dedication and interest. To Vic, you have exposed me to various branches of cetacean studies, from sampling out at sea to dolphin dissections and whale strandings. I am extremely grateful for all those experiences to help with my future career. To Ryan, I will never forget those long blistering days on the ‘roof’ and our hyperactive speckled egg days.

Second, I would like to thank and commend the interest and great job done by Santosh Bachoo, for sacrificing his sleep and being a great skipper; Prof. Rob Harcourt, Dr. Luciana Möller, Mr. Francisco Viddi from the Graduate School of the Environment, McQuarie University, Sydney and the level 3 Conservation Biology class (2003 - UDW) for assisting me with dolphin tracings and scorings.

Third, a special thanks to those who helped and discussed valuable ways of analysing my data. To Sean O’ Donoghue and Frank Sokolic for their open-handed assistance with Arc GIS. Dr. A. J. Smit for affording me invaluable amount of co-operation with categorical data analysis; Glen Gailey for allowing me to use his personal random permutation software; and Deena Pillay for guiding me with the boat experiment analysis.

Fourth, I thank the support of our institutions, the Department of Conservation Biology, the UKZN Research Grant and the National Research Foundation. Grateful thanks to Prof. Maurice Ndege and Steven Meth for generously loaning us the digital theodolite. I would also like to thank the Body Corporate of Maldonado beachfront apartments for the use of their rooftop for the duration of the study. Your generosity is greatly appreciated.

Most important, to my parents, brothers, fiancé and friends, who put up with my complaints, lost weekends and moods. Thanks for continually supporting me – Finally, It’s done!

Abstract

During long-term studies of dolphins, the number of individuals in the population being studied are constantly monitored using the technique of photo-identification. This constant monitoring makes use of different researchers over time. Therefore, measurement of photographic quality and individual distinctiveness for photo-identification analyses was incorporated in this dissertation to provide an additional data set for analysis. Researchers with differing levels of experiences did not obtain the same information from the same photograph and were unable to reliably quantify variables of photo quality and individual distinctiveness, but experienced researchers were found to be more adept than inexperienced researchers in counting notches on the dorsal fin of bottlenose dolphins. These results highlight the necessity for researchers to be trained in photo-identification techniques prior to carrying out their study. This study theodolite tracked dolphins off Durban from June 2004 to Feb 2005 to assess habitat utilization of bottlenose dolphins (*Tursiops aduncus*) in the Durban bay region. Dolphins were seen in all months surveyed and throughout the survey area. Temporal distribution of dolphins was skewed with 91% of dolphins seen before midday and 98% of sightings observed in water depths less than 30m. Six behavioural categories were recorded, including: social, fast travel, slow travel, feeding, resting and milling. The most dominant behaviour exhibited by dolphins was slow travel (46%) followed by feeding (27%). Resting was not observed at all. Of the feeding behaviour 88% occurred in the southern end of the bay whereas other behaviours occurred randomly throughout the survey area. Additional theodolite tracks were conducted during experimental boat approaches (before, during and after boat approaches) to determine potential short-term reactions of dolphins to dolphin watching boats. Two speeds of approach (slow ~ < 5 km/hr and fast ~ > 40 km/hr) and two distances of approach (20m and 80 m) were tested. The bottlenose dolphin groups did not change their behaviour in response to boat approaches during any of the periods of experimentation. Short-term changes in group speed, group size and spread were not statistically significant. Dolphin groups continued with their 'normal' behaviour and spent the same amount of time in the bay when compared to their distribution and behaviour in the absence of the experimental boat. These findings indicate that the experimental boat did not affect the behaviour of dolphins at either a slow or fast approach and even at a close distance. This is interpreted as being as a result of habituation of the dolphins due to their residency in a busy port. This work is crucial in developing guidelines for the development of a sustainable dolphin watching industry off Durban.

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Chapter 1
Literature Review

Introduction

All species of whales, dolphins and porpoises belong to the order Cetacea. Members of this order exhibit an extensive array of distributional ranges, social structures, foraging techniques and life history strategies (Carwadine 1999; Reeves *et al.* 2003). Over 30 species of dolphins (family Delphinidae) are found world-wide, with only a fraction of these species being currently studied in any detail e.g., dusky dolphins, *Lagenorhynchus obscurus*, (Würsig & Würsig 1977; Würsig and Harris 1990; Cipriano 1992), Hawaiian spinner dolphins, *Stenella longirostris* (Norris *et al.* 1994), bottlenose dolphins, *Tursiops* sp, (Wells *et al.* 1987; Ballance 1990; 1992; Connor *et al.* 1992; Smolker *et al.* 1992; Peddemors 1995) and killer whales, *Orcinus orca*, (Bigg *et al.* 1990; Connor *et al.* 2000). As marine mammals are exclusively aquatic, difficulty in access and the inability to see these animals are the most important limiting factors for understanding cetacean social structure and behaviour. Therefore, the majority of researchers have concentrated their efforts on documenting and observing a few of the coastal dolphin species.

Bottlenose dolphin taxonomy

The bottlenose dolphin (*Tursiops* spp.) are one of the most commonly studied cetaceans globally. This species is cosmopolitan and found in almost all oceans except at very high latitudes (Corkeron 1999; Reeves *et al.* 2003), yet its speciation is still under scrutiny (Natoli *et al.* 2004; Charlton *et al.* 2006). However, throughout the range of bottlenose dolphins, researchers have discovered two morphological types based on inshore-offshore partitioning (Hoelzel *et al.* 1998). These two types can be separated by blood characteristics, the offshore form containing a higher percentage of myoglobin (Duffield *et al.* 1983). The coastal form has been the focus of most studies, yet there is still substantial confusion regarding this animal as there appear to be specialist populations either inhabiting enclosed bays and estuarine waters (considered as an inshore eco-type in these discussions), or animals in coastal open waters (considered as a nearshore eco-type in these discussion). Inshore coastal bottlenose dolphins typically inhabit an area within the 18 meter depth contour and often enter harbours, inlets, bays, lagoons, estuaries and rivers (Leatherwood and Reeves 1983), while the nearshore coastal eco-type is typically found in waters less than 50m deep (Ross *et al.* 1987). Several studies have illustrated that these coastal bottlenose dolphins have restricted home ranges (Connor and Smolker 1985; Scott *et al.* 1990; Balance 1990; 1992; Hammond and Thompson 1991; Peddemors 1995; Defran and Weller 1999; Gubbins 2002b; Zolman 2002). The offshore form, however, is less constrained in its range and movements (Leatherwood and Reeves 1983; Leatherwood and Reeves 1988; Scott and Chivers 1990;

Rossbach and Herzing 1999). Owing to their distribution and difference in external and osteological characters, many species and subspecies were originally described, the consequence of which has been a long period of taxonomic uncertainty. Until recently only a single species of bottlenose dolphin *Tursiops truncatus* has been recognised in the scientific literature and by CITES.

During the late 1970s, Ross (1977) presented evidence for the existence of two species, *T. truncatus* and *T. aduncus* off South Africa on the basis of size and morphological characters, but after examining specimens from Australia Ross and Cockcroft (1990) concluded that specimens from the two countries should be assigned to a single species *T. truncatus* after latitudinal variation was found in both east and west coast Australian bottlenose dolphins. They also suggested that a subspecies of *T. truncatus* should be considered wherein adults have ventral pigmentation. However, during the late 1990's Wang and colleagues (Wang *et al.* 1999; Wang *et al.* 2000 a, b) showed that *T. aduncus* is a distinct species from *T. truncatus* in Chinese waters using genetic, osteological and external morphology data. This was further supported by recent phylogenetic studies (Hoelzel *et al.* 1998; LeDuc *et al.* 1999; Möller and Beheregaray 2001; Kemper 2004; Natoli *et al.* 2004). The differences between *T. truncatus* and *T. aduncus* are briefly summarised below:

(1) External Morphology - The rostrum length as a proportion of the length from the tip of the snout to the eye (taken perpendicular to the longitudinal axis of the body) is greater in *T. aduncus* than in *T. truncatus*. Ventral spotting may also be useful in distinguishing the two species. Ventral spotting seems to be common in most *T. aduncus* throughout their range (Wang *et al.* 2000b). Additionally, Wang *et al.* (2000a) showed clear osteological separation between these two species using four characters. The numbers of vertebrae in the two species are non-overlapping at least in Chinese waters where the two species are sympatric (Wang *et al.* 2000a).

(2) Genetic - All recent analyses of mitochondrial DNA sequences (mt DNA) support the above characters in differentiating between the two forms as separate species (Curry and Smith 1997; Wang *et al.* 1999; Möller and Beheregaray 2001; Natoli *et al.* 2004). Hoelzel *et al.* (1998) also using mt DNA found genetic separation between the two forms from South Africa, except for one specimen. Based on the cytochrome b gene, LeDuc *et al.* (1999) suggested *Tursiops aduncus* may not even belong to the genus *Tursiops* but the authors recommended that, until a taxonomic revision of the subfamily Delphinidae clarifies generic names, *T. aduncus* should be accepted as a valid species.

Therefore, at present there are two species that are recognised, *Tursiops truncatus* and *Tursiops aduncus*. *T. truncatus* occurs in all tropical and temperate waters, including bays, lagoons, estuaries, open coasts and offshore waters (Wells *et al.* 1987; Bearzi *et al.* 1997; Defran and Weller 1999; Wells

et al. 1999; Reeves *et al.* 2003), while *T. aduncus* appears to be confined to coastal environments of the Indo-Pacific oceans (Ross and Cockcroft 1990; Wang *et al.* 1999; Möller and Beheregaray 2001; Reeves *et al.* 2003; Natoli *et al.* 2004).

Photo-identification of bottlenose dolphins

From a conservation point of view, not only is it necessary to know what species is being researched, but it is also often necessary to identify any stock structure within the population in question. This can either be done through genetic techniques, or via the ability to individually identify animals and record their movements and distribution. The study of a species' ecology, behaviour and life history parameters also necessitates the need to identify individuals within a population (Payne 1983; Scott *et al.* 1990b; Whitehead *et al.* 2000). Individual identification of the animals studied provide insights into their population size, migratory routes, site fidelity, preferred habitat, life spans and reproductive histories. Studies of many cetaceans took a great leap forward with the introduction of photo-identification techniques in the 1970's. Payne (1983) was the first to document the ability to distinguish individual southern right whales, *Eubalaena australis* by comparing photographs of the callosity patterns found on their heads. At about the same time researchers of killer whales and dolphins were investigating the use of photo-identification to identify individuals. Bigg (1982) found that the distinctive saddle pattern colouration and unique shapes of fins of Killer whales (*Ocinus orca*) proved useful for the identification of specific individuals of this species. Würsig and colleagues (Würsig and Würsig 1977; Würsig and Jefferson 1990) further validated the use of photo-identification by determining that individual bottlenose dolphins can be identified and recognised over long periods of time by natural variation in pigmentation patterns, scars and notches, nicks and tears that occur on their dorsal fins.

Since Würsig and colleague's pioneering use of photo-identification techniques with bottlenose dolphins, a number of independent studies around the world have incorporated this methodology as a tool towards gaining insights into the lives of these animals (Whitehead 1982; Hammond 1986; Hammond 1990; Katona and Beard 1990; Würsig and Harris 1990; Balance 1990; 1992; Bräger *et al.* 1994; Peddemors 1995; Smolker *et al.* 1997; Defran and Weller 1999; Shirakihara *et al.* 2002; Mahomed 2003; Samuels and Bejder 2004). Using photo-identification as a tool it was determined that individual bottlenose dolphins in Galvestone Bay, Texas, showed strong site fidelity with seasonal fluctuations in habitat usage patterns (Bräger *et al.* 1994; Maze and Würsig 1999; Irwin and Würsig 2004). The study also concluded that the number of resident animals between 1990 and 2001 ranged

from 28-37, though transient animals were also found to pass through the area. In Shark Bay, Australia, photo-identification helped in understanding that several foraging techniques were unique to only a limited number of individual bottlenose dolphins at particular locations. One example included five animals that were the only ones documented to carry sponges and use them as a tool during feeding (Smolker *et al.* 1997). Additional studies in this area using photo-identification have recognised associations between preferred males, which subsequently allowed investigations into alliance strategies that contribute to their mating success (Krützen *et al.* 2003). Bottlenose dolphins have also been intensively studied off the coast of Sarasota, Florida since the 1970's. Photo-identification has been essential in many studies of this species in this area (Scott *et al.* 1990a; Wells 1991; Barros and Wells 1998; Nowacek *et al.* 2001). One of these studies (Nowacek *et al.* 2001) found that boat activity caused significant changes in behaviour and physiological response in identified individuals. This supported the need for better management plans of boating activity in the areas of importance to the animals.

Cetacean research is often challenging as animals surface only for a brief period to breathe, limiting the time available for researchers to sight them. This quick glimpse may not be long enough for a researcher to recognise the individual animal, although with the aid of a camera, researchers can photographically capture many of the dorsal fins to identify and re-identify a large number of individual animals seen at the time. The use of natural markings on animals has many advantages, but there are associated problems with the technique. For example, variation in natural markings does not ensure that each marked individual is regularly captured. This can present a problem in mark-recapture studies, since the analytical technique is not robust and any violations underlining the assumptions can result in large errors in the final analysis (Hammond 1986; Gailey 2002). Assumption of equal catchability can be violated in a variety of ways, two of which are: 1) capture-proneness or capture-shyness of individuals in the field and/or 2) photographic data gathering and analysis in the lab. The first assumption is beyond the scope of my study. In photographic database analysis, the probability of recognizing an individual is affected by the quality of the photograph and the distinctiveness of the animal. The aim of chapter two is to identify if independent researchers with differing levels of experiences obtained the same information from the same photograph and the objectives are:

Objective 1: to compare multiple researcher judgements of photographic quality.

Objective 2: to compare multiple researcher judgements of animal distinctiveness.

Objective 3: to compare multiple researcher judgements of notch counts on dorsal fins.

Objective 4: to assess the suitability of non-trained researchers in long-term identification studies and to derive the foundation of training and experience as a prerequisite in photo-identification analysis.

Bottlenose dolphin ecology

The best-studied bottlenose dolphins are those in coastal areas, and certain generalizations have been made about these populations. Residence patterns in coastal bottlenose dolphins range from transient, as in migratory dolphins along parts of the eastern United States (Barco *et al.* 1999), the open southern California coast (Hansen 1990; Defran and Weller 1999; Defran *et al.* 1999) and along the coast of South Africa (Peddemors 1995), to the stable resident communities reported in Sarasota Bay (Irvine *et al.* 1981; Wells *et al.* 1987; Scott *et al.* 1990a; Connor *et al.* 2000), Shark Bay (Connor and Smolker 1985; Smolker *et al.* 1997) and the Adriatic Sea (Bearzi *et al.* 1997). Social ecological studies have shown considerable variation in average group size, site fidelity, home range and the size of local populations in different coastal habitats. This has been related to differences in predation risk, food availability and dolphin foraging strategies (Shane *et al.* 1986; Ballance 1992; Defran and Weller 1999). In protected habitats, such as small, shallow bays and estuaries, bottlenose dolphins usually associate in small groups, show a high degree of site fidelity, feed primarily on scattered prey, and belong to relatively small local populations (Shane *et al.* 1986; Wells *et al.* 1987). In less protected habitats, such as deep bays, open coasts, and pelagic waters, individuals will aggregate in larger groups, show reduced levels of site fidelity, and belong to larger populations (e.g. Ballance 1992; Peddemors 1995; Defran and Weller 1999). While limited information is available on the social organisation of offshore *T. truncatus* populations, coastal populations of both *T. truncatus* and *T. aduncus* appear to exhibit fission-fusion grouping patterns, i.e. they associate in groups that change frequently in size and composition (Wells *et al.* 1987; Smolker *et al.* 1992). Habitat structure and activity patterns are reportedly the main factors influencing group size, while group composition is primarily based on age, sex, reproductive condition and kinship (Shane *et al.* 1986; Wells *et al.* 1987; Duffield and Wells 1991; Smolker *et al.* 1992; Connor *et al.* 2000; Möller *et al.* 2002).

Little is known about the behaviour or ranging patterns of offshore dolphin populations. They are found in large groups, incorporating up to thousands of individuals, and are believed to be less restricted in their home ranges and movements (Scott and Chivers 1990; Rossbach and Herzing 1999). Kenney (1990) reported that the offshore population off the east coast of the USA ranges primarily between 200 and 2000 m deep but Wells *et al.* (1999) using satellite linked transmitters on two

rehabilitated stranded dolphins showed that one particular dolphin (Gulliver) moved to water depths of more than 5000 m, i.e. 300km offshore of the northern Caribbean islands. “Gulliver” travelled 4200 km in 47 days while the other dolphin “Rudy” covered 2050 km in 43 days. These records expand the range and habitat previously reported for the offshore stock of bottlenose dolphins inhabiting the waters off the south-eastern United States and illustrates the difficulties of defining offshore stocks. Additionally, Würsig (1978) reported a 600 km round-trip for several identifiable dolphins in Argentina. Tanaka (1987) reported that a satellite-tracked dolphin off Japan apparently travelled 604 km in 18 days along the Kuroshio Current.

In contrast, coastal dolphins exhibit a full spectrum of movements including year-round home ranges, seasonal migrations, periodic residency and a combination of occasional long range movements and repeated local residency (Würsig and Würsig 1977; Shane *et al.* 1986; Ballance 1990; Shane 1990; Würsig and Harris 1990; Peddemors 1995; Bearzi *et al.* 1997; Boonman 1998; Shirakihara *et al.* 2002; Mahomed 2003). Long term residency may be structured as a relatively permanent home range, or as a repeated occurrence in a specific area over many years. For example, the residents of several dolphin communities along Florida’s west coast have maintained relatively stable home ranges during more than 25 years of observations (Wells *et al.* 1987). Similarly, Connor and Smolker (1985) reported that bottlenose dolphins in Western Australia frequented the same coastal region for over 20 years. In other areas, residency is long term but more variable. Dolphins seen frequently during 1974 - 1976 in Golfo San Jose, Argentina, showed a subsequent decline in frequency of occurrence, but were still occasionally identified in the area 8 -12 years later (Würsig and Harris, 1990). Similarly, Mahomed (2003) noticed a decline in the rate of occurrence of residents off Durban, on the South African east coast, where only 16 individuals were re-identified from an estimated resident population of 200 animals (Boonman 1998). These individuals were found to inhabit the Durban bay region for over 17yrs (Peddemors 1995; Boonman 1998) and were identified again 5-8 years after previous research (Mahomed 2003).

These identified home ranges of bottlenose dolphins are not exclusive. Along the central west coast of Florida, communities of resident dolphins appear to inhabit a variety of overlapping home ranges. For example, the home range of the Sarasota dolphins encompasses an area of about 125 km² occupied by approximately 120 individuals (Scott *et al.* 1990a, Wells 1991; Barros and Wells 1998). Most of the activities of the residents are concentrated within their home ranges, but occasional movement between ranges occurs also. The same applies to bottlenose dolphins off San Luis Pass, Texas (Maze

and Würsig 1999), in Jervis Bay and Port Stephens, Australia (Möller *et al.* 2002), and off KwaZulu-Natal, South Africa (Peddemors 1995). Within the home range, habitat use varies with season, with shallow estuarine waters frequented during the summer and coastal waters and passes used during the winter (Wells and Scott 1999). However, behaviour may also vary among animals within the same area.

Other populations of bottlenose dolphins have shown to migrate seasonally or display semi-permanent fidelity to a particular region. In addition, more than one type of residence pattern may occur for different groups in the same geographic area. Several studies have documented apparent site fidelity for bottlenose dolphins in a particular region but have also documented sightings of known individuals at significant distances from the original study area in which they were first identified. For example; a 4-month cycle of occurrence of dolphins was observed in Golfo San Jose, Argentina (Würsig and Harris 1990). In the coastal waters of Cornwall, UK, Wood (1998) investigated a group of bottlenose dolphins with a seasonal residency pattern, spending the winter in southern Cornwall and moving further north-eastward during spring and summer. Residency was flexible with a number of individual dolphins using the region periodically. The dolphins occupied a coastal extent of 650 km within which they repeatedly made long- distance journeys (Wood 1998). The longest journey recorded covered 1076 km and took 20 days. Similar observations were recently also published by other authors. Wilson *et al.* (1997) reported that members of a population of *T. truncatus* resident in the Moray Firth off north-eastern Scotland were seen in all months of the year, but there were consistent seasonal fluctuations in the number of individuals present. Numbers were low in winter and spring and peaked in summer and autumn. Individuals exhibited rapid movements across the population's range. For instance, one individual was sighted at locations 190 km apart within a 5-day period. Boat-based photo-identification surveys of bottlenose dolphins in three separate coastal study areas within the Southern California Bight (Santa Barbara, Orange County, and Ensenada (Mexico)) showed that a high proportion of dolphins photographed in Santa Barbara (88%), Orange County (92%), and Ensenada (88%) were also photographed in San Diego (Defran *et al.* 1999). Fifty- eight percent of this population repeatedly moved between study areas showing no evidence of site fidelity to any particular area. Three dolphins travelled together from Ensenada to Santa Barbara which lies 470km north. Defran *et al.* (1999) suggested that these long range back-and-forth movements within the Southern California Bight are presumably influenced by the distribution of food resources.

By and large, the complexity of a habitat and the biological requirements of a species interact to influence the size of an animal's home range, distributional patterns and habitat use (McNab 1963). The abundance, distribution and availability of resources within the habitat determines the size of an area which will satisfy the energy requirements of an animal. In Chapter 3, the aim is to document the distribution and habitat use patterns of bottlenose dolphins, *T. aduncus*, off Durban, KwaZulu-Natal, South Africa. This coastline is an open and fully exposed nearshore habitat which is quite dissimilar from regions where most long-term studies on this species have been conducted. Hence, the objectives of this study are:

Objective 1: to document the activity budget of undisturbed ('normal behaviour') bottlenose dolphins off Durban.

Objective 2: to provide the opportunity to further evaluate the influence of habitat on bottlenose dolphin behaviour.

Objective 3: to provide baseline data for future comparisons once dolphin-watching is established.

Dolphin tourism

Wildlife tourism has experienced a rapid world-wide growth in recent years with no exception to the marine environment. Numerous commercial dolphin and whale watching ventures are appearing around the world, often evolving from an industry of wildlife viewing in aquaria to viewing animals in their natural environment from shore, sea or air (Hoyt 2001). The dramatic rise in popularity of cetacean tourism has also created a market for interactive experiences such as dolphin feeding (Connor and Smolker 1985; Corkeron *et al.* 1990; Bryant 1994; Orams 1994; Wilson 1994; Samuels and Bejder 2004) and dolphin swimming programmes (Dudzinski *et al.* 1995; Samuels and Spradlin 1995; Constantine and Baker 1997; Constantine 2001; Bejder and Dawson 2001; Samuels and Bejder 2004; Valentine *et al.* 2004). The economic benefits of such growth are extensive. However, the impacts on wildlife can often be disturbing causing apparent changes in behavioural and social ecology leading to reduced fitness and higher levels of mortality (Bejder and Samuels 2003).

The issue of feed-the-dolphin programs received considerable attention in the USA (Texas, Florida and South Carolina) and Australia (Monkey Mia, Banbury and Tangalooma). All these areas have a history of human/dolphin interactions which have involved uncontrolled feeding of bottlenose dolphins (Corkeron *et al.* 1990; Orams 1994; Bryant 1994). In the USA individual dolphins have become dependent on hand-outs from humans and would beg for fish and often show aggressive

behaviour towards humans if not given any food (Bryant 1994), and on occasion, when not fed, they would apparently not resume hunting for themselves and suffered malnutrition (Constantine 1999). In Australia, Orams *et al.* (1996) observed “pushy” behaviour at people by the dolphins when receiving fish from tourists. Research by Mann *et al.* (2000) found the survival rate of calves of non-provisioned mothers to be higher than provisioned females. It is thought that the young dolphins of provisioned females did not learn to forage properly and that the mothers invested less time in their offspring, including protecting them from predators. This placed the offspring of provisioned females more at risk than the offspring of non-provisioned dolphins. Bryant (1994) concluded: “Feeding wild dolphins alter their natural behaviour and poses risks to the animals by changing their habitat use, calf rearing abilities and loss of wariness to humans.” For example, Samuels and Bejder (2004) documented dramatic changes in behaviour and ranging patterns of a juvenile dolphin near Panama City Beach, Florida. This individual was observed to interact with humans including swimmers during 74% of observations, was fed by humans at least once per hour, and had dangerous encounters involving humans or vessels once per 12 minutes. However, it could not be determined whether these behavioural differences were due to food provisioning, frequent in-water encounters or both.

“Swim-with” tourism in which humans interact with free-ranging whales and dolphins by entering the water, are another popular form of cetacean-based tourism. This activity targets at least 20 species of cetaceans world-wide and new programmes are initiated on a regular basis (Hoyt 2001). In a few locations, swim-with activities occur either as part of commercial dive tours (e.g. Great Barrier Reef, Australia), or swimmers try to swim with provisioned dolphins after feeding sessions (e.g. Monkey Mia, Australia; Panama City Beach, Florida), or when casual swimmers have easy access from the shore (e.g. Porpoise Bay, New Zealand; Kealake’kua Bay, Hawaii). In some boat-based programmes, tourists are permitted to swim freely in proximity to cetaceans (e.g. Bay of Islands and Kaikoura, New Zealand). At other locations operators use various methods to approach the animals, these include; holding onto a motorised underwater scooter (e.g. Rockingham and Port Phillip Bay, Australia) grasping onto ‘mermaid lines’ (e.g. Great Barrier Reef and Port Phillip Bay, Australia), or sitting in ‘boom nets’ (e.g. Bay of Islands, New Zealand and Port Stephens Bay, Australia) that are towed by boats.

In a bench-mark study, Constantine (2001) investigated the responses of wild, non-provisioned bottlenose dolphins to swim attempts from commercial tour boats in the Bay of Islands. The responses of the dolphins were influenced by the method of swimmer placement. Of the three swimmer

placements, 'line abreast' was the only one to show a decrease in avoidance response and it was suggested that this placement gives the dolphins the choice to approach and maintain their current behaviour and that it does not force uninterested dolphins to engage in an interaction with swimmers. The 'around boat' placement resulted in a significant increase in avoidance and a corresponding decrease in interactions over time, while the 'in path' placement had the highest rate of avoidance response because these placements only offered the dolphins two choices, stay and interact or change behaviour to avoid swimmers. When an interaction occurred, juveniles interacted more with swimmers than any other age group. This was interpreted as play activity which is important in the development of young mammals. Impacts of swimming with cetaceans have also included aggression towards humans (Shane *et al.* 1993), avoidance of swimmers in the short-term (Bejder *et al.* 1999), physical abuse, disruption of behaviour and risk of injury (Samuels *et al.* 2003; Samuels and Bejder 2004) and even the displacement of a population from their critical habitats (Forest 1998; Allen and Read 2000; Spradlin *et al.* 2001). Apart from the impacts of human interaction on dolphins, humans are also placed at risk to injury when entering the water (Connor and Smolker 1985; Lockyer 1990; Santos 1995). As such, this activity has been banned in countries including Argentina, Brazil, Mexico, Spain and South Africa (Marsh *et al.* 2003).

The most prevalent branch of cetacean-based tourism is viewing cetaceans from land, aircraft or boat platforms. Land-based cetacean watching does not cause any impact on cetaceans and there are no quantitative studies that relate the effects of aircraft on cetacean populations. However, several studies have shown that frequent interactions with boats resulted in short-term negative responses. Disturbance from boats may be considered from a number of different aspects. Examples of stimuli from boats which may be disturbing include: A boat which is too close or in danger of striking an animal, active pursuit or circling of animals, interfering with feeding or other activities, and vessel noise (Salvado *et al.* 1992; David 2002; Buckstaff 2004). For dolphin response, boat disturbance include changes in: surfacing, ventilation and dive patterns (Janik and Thompson 1996; Nowacek *et al.* 2001; Lusseau 2003; Lemon *et al.* 2006), swim speed, course and orientation (Bejder *et al.* 1999; Williams *et al.* 2002; Bejder 2005; Lemon *et al.* 2006), group dispersion/cohesion (Bejder *et al.* 1999; Nowacek *et al.* 2001; Bejder 2005), behavioural states/activity budgets (Constantine and Baker 1997; Samuels and Bejder 2004; Lusseau 2003; Bejder 2005), and ranging patterns and habitat use (Allen and Read 2000; Samuels and Bejder 2004; Bejder *et al.* 2006).

Land-based observations of bottlenose dolphins in the Moray Firth, Scotland showed a significant increase in the number of surfacings by dolphins after a boat had encountered them (Janik and Thompson 1996). In contrast, there was no significant effect of a research vessel on diving patterns in Doubtful Sound, New Zealand (Lusseau 2003). It was assumed that the dolphins were habituated given the boat had been used for eight years in compliance of guidelines, whereby all interactions with dolphins were terminated at any sign of avoidance. Consequently, there was a possibility that the dolphins did not associate the presence of the research boat with any potential danger. Lusseau (2003) unexpectedly identified that males and females had shorter dive intervals during winter, possibly reflecting the harsher environmental conditions (e.g. colder temperatures and decrease in prey availability). Additionally, males exhibited vertical avoidance earlier than females and females exhibited shorter dive intervals compared to males. This contradicted results by Nowacek *et al.* (2001) who showed no breathing discrepancy between the sexes, albeit in a warmer environment. These results highlight how dolphin groups may react differently depending on their location, previous experience and/or environmental conditions. Reactions to boats may also be related to the dolphins' surface behaviour at the time of the approach; and may differ between populations (Samuels and Bejder 2004; Bejder 2005). Shane (1990a) demonstrated that bottlenose dolphins in Florida exposed to boats change their behaviour less when dolphins were actively socializing. By contrast, Constantine and Baker (1997) showed that bottlenose dolphins in New Zealand were more prone to disturbance while socializing, but less likely during foraging.

There are concerns over impacts of this growing industry on both the animals (Beach & Weinrich 1989; Blane and Jaakson 1995; Corkeron 1995; Constantine & Baker 1997) and tourists (Orams 1995, Orams *et al.* 1996). In order to minimise these impacts, management strategies have been developed in several parts of the world. In South Africa, the 1998 Marine Living Resources Act was passed to protect all marine mammals in South African waters. Subsequently, in 2006 the Marine Living Resources Regulations were drafted to provide a series of guidelines for issuing permits and for regulating human behaviour around marine mammals; however, only minimum approach distances have been stipulated without regulating the number of boats allowed near marine mammals and the speed of those vessels.

The understanding of the vulnerability and responses of marine mammals to boat disturbance is yet in its infancy. More often than not, regulations and guidelines have been based on evidence that is anecdotal, scientific but insufficient, or entirely lacking (Bejder and Samuels 2003). Therefore,

Chapter 4 aims at investigating short-term responses of bottlenose dolphins *T. aduncus* to controlled boat approaches off Durban and the objectives are:

Objective 1: to assess short-term effects of a boat on the behaviour of bottlenose dolphins off Durban.

Objective 2: to compare their behavioural responses during boat approaches to 'normal' behaviour (Chapter 3).

Objective 3: to assess short-term effects of a boat on bottlenose dolphin habitat utilisation of the Durban bay.

Objective 4: to formulate guidelines for the boat-based dolphin watching industry.

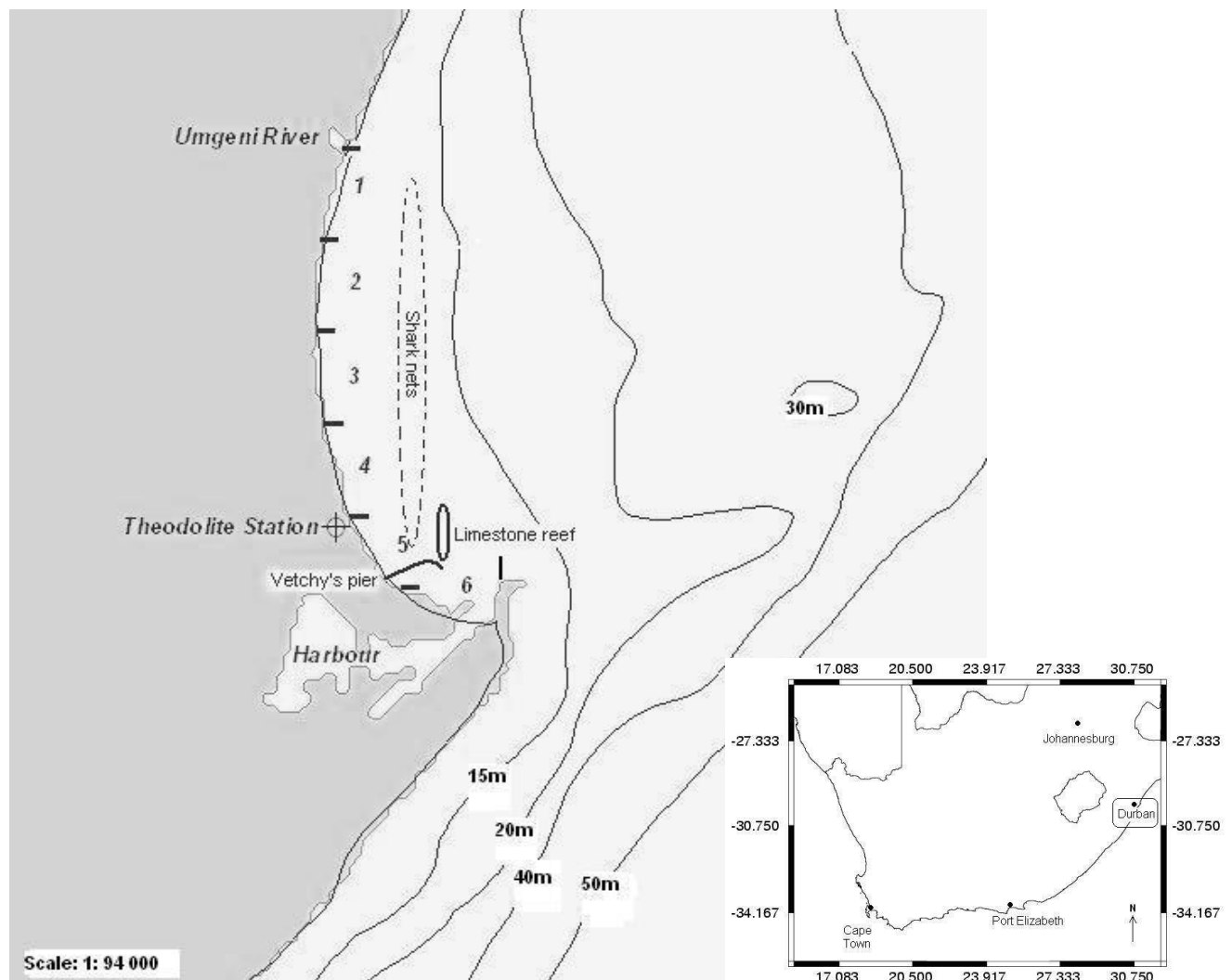


Figure 1.1: The study site off Durban, KwaZulu-Natal, South Africa, indicating the six long-shore zones (~1km in length) used to monitor bottlenose dolphin movements and behaviour.

Chapter 2

**Measurement of photographic quality and individual distinctiveness for photo-
identification analyses: An inter-observer test.**

Introduction

Identification of animals from natural markings is an important tool for the study of animal populations and is widely applied to diverse taxa (Bretagnolle *et al.* 1994; Kelly 2001). This technique has many advantages over the capture and placement of artificial tags, brands, implants or other objects on free-ranging animals (Würsig and Würsig 1977; Hammond *et al.* 1990). Animals no longer need to be physically captured and the behaviour of the animal is therefore less likely to be affected by the experiment (Hammond 1986). This technique of individually identifying animals is common in studies of marine mammals, particularly cetaceans (Connor *et al.* 2000). Capture-recapture studies using naturally marked animals are suitable for studying cetaceans because they are long-lived, fast moving animals that are encountered briefly at the surface. Extensive application of this technique to cetaceans has considerably increased our knowledge of population parameters, movement, behaviour, abundance and social structure in many populations (Würsig and Würsig 1977; Whitehead 1982; Hammond 1986; Hammond 1990; Katona and Beard, 1990; Würsig and Harris 1990; Würsig and Jefferson, 1990; Ballance 1990; 1992; Bragger *et al.* 1994; Peddemors 1995; Smolker *et al.* 1997; Defran and Weller 1999; Shirakihara *et al.* 2002; Mahomed 2003).

For dolphins, these brief surface encounters are used to photographically “capture” naturally occurring features on dorsal fins to recognise individuals in a population. This photo-identification technique has become a primary methodology for cetacean studies in the past few decades (Chapter 1). Although information acquired from photo-identification is extremely valuable, data processing is labour intensive, physically fatiguing and subject to human error (Katona and Beard 1990). For photo-identification of whales many computational programmes have been developed for their tail flukes, for example, humpback whales (Mizroch *et al.* 1990) and sperm whales (Whitehead 1990). Only recently has a computational program named *Finscan* (Hillman *et al.* 2002) for bottlenose dolphin dorsal fins been developed. It makes the processing time needed to identify individual dolphins more efficient. The program distinguishes distinct identifiable markings along the trailing edge of dorsal fin images of photographs collected in the field and it additionally has the potential to give access to large databases around the world to match individuals in various locations (Gailey 2001). Although one can use either manual or computational methods to identify the individual animal, the quality of the photographs used as acceptable samples and the distinctiveness of the animals sampled can affect the accuracy of results.

To evaluate the accuracy of photo-identification data, the effects of photo quality and individual distinctiveness must be determined. As the quality of photographs decrease, it becomes increasingly difficult to match new photographs of individuals to previously identified animals, resulting in an increase in the probability of known individuals being erroneously identified as new animals. Such errors in identification in abundance studies can positively bias estimates (Hammond 1986; Rugh *et al.* 1990). In addition, if dolphins vary in their distinctiveness, using poor quality photographs can create unequal probabilities of re-identification because the probability of matching animals from poor quality photographs may be greater for more distinctive dolphins. By determining an acceptable level of photographic quality for a photo to be considered a sampling event, errors in the matching process (due to poor quality photographs) can be reduced. The North Atlantic Humpback Whale catalogue has developed procedures for photo quality and individual distinctiveness analyses (Katona and Beard 1990; Friday *et al.* 2000), but this is lacking for most other multi-user catalogues.

Many studies on specific cetacean populations are carried out over decades (Chapter 1). Photo-identification is consistently carried out within these studies, thus allowing several researchers at different times to match animals or add to the existing catalogue. The accuracy of identifying individuals may be affected during this multi-user process, not only due to photo quality or individual distinctiveness but also through the complexity of the human visual system.

The purpose of this study was to determine the degree of observer reliability in processing photo-identification data between experienced and inexperienced researchers. Inter-observer reliability tests are a vital part of judgment-based research, such as behaviour and individual identification (Lehner 1996). To reliably identify individuals by subtle natural markings, a degree of learned experiences is necessary (Mahomed 2003). Gailey (2001) stated “reliability tests are a form of validity of one’s research. However, validity and reliability are not interchangeable terms. Validity (i.e. accuracy) tests compare results to the known truth, and reliability (i.e. precision) evaluates the consistence of judgments in the absence of the truth. Judgments can be precise without necessarily being accurate, but cannot be accurate without being precise.” In terms of individual identification using natural markings, the true identity of the individual is not known. Therefore, an evaluation is needed of the reproducibility of one’s judgments based on the data presented. The requirement of inter-observer tests is logical to show that different people can agree on the judgments, upon which the research is based (Carletta 1996). For example, if two experienced observers used the same set of data for their study and obtained two different results, then the results of both studies are subjected to doubt (Bateson

1977). A more practical example would be that two research studies are conducted in the same study area at different times. Discrepancies in results could be recognised as differences between the two observers. However, if both studies demonstrate that their judgments were reliable, then the question of inter-observer variation can be eliminated, and the results can be explained by other factors, such as environmental change (Gailey 2001). In other words, inter-observer reliability tests are simply the elimination of the possibility that research results are affected by differences between observers.

Lorenz (1935, reviewed in Gailey 2001) recognised that the greatest source of error in behavioural research was between observers' perception of the same thing. Despite numerous suggestions that observers' reliability should be tested periodically (for example, Martin and Bateson 1993; Lehner 1996; Friday *et al.* 2000), relatively few studies report observer reliability. In fact, Mann (1999) reported that out of seventy-four cetacean studies reviewed, none demonstrated the reliability of their judgments. This is probably due to the practical difficulty of having two experienced observers recording the same behaviour at the same time (Mann 2000). As Bateson (1977) states, "Failure in such a test does not necessarily detract from the value of a field study in which an observer claims to have identified individual animals. However, if the observer is successful in the test, even the most skeptical armchair critic must surely accept that at least part of the apparatus necessary for such a field study is in good working condition."

There are extensive studies carried out in the medical and psychological fields of inter-observer reliability tests. For example, Karkouti and Rose (1996) used inter-observer reliability tests for predicting difficult tracheal intubation and, Jager *et al.* (1995) evaluated reliability of observers to interpret radiographs of mammographs after breast-conserving treatment in cancer patients. There are few such studies reported in cetacean research, but several years ago the accuracy of group size estimates based on inter-observer agreements was analysed (Rugh *et al.* 1990). This chapter evaluates the reliability between experienced and inexperienced researchers to identify individual bottlenose dolphins based on photographic images, and to determine if training in lab analyses is required for cataloging individuals using photo-identification techniques.

Methods

Photographs from a previously analysed database of individual bottlenose dolphins (24 dorsal fins) were used for this study (Mahomed 2003). These animals were photographed off Durban using a Nikon D50 SLR camera with 70-210 mm zoom lens. Each photographic slide was rear projected and enlarged. The contour of the fin was then traced onto a sheet of A4 paper and each picture scored for photographic quality and individual distinctiveness. In analyzing photographic quality and individual distinctiveness, a modified version of the methodology proposed by Friday *et al.* (2000) was used (Table 2.1).

The evaluation of photographic quality was determined using three specific variables. These are: 1) clarity, 2) contrast, and 3) angle. Additionally, a general overall variable of photographic quality was used to encompass all the above specific variables and other variables that may have not been included. Individual distinctiveness of bottlenose dolphins were determined using two specific variables: 1) Leading edge serrations and/or scarring and/or pigmentation, and 2) Trailing edge serrations. An overall distinctiveness value was also incorporated in the analyses (Table 2.1). Furthermore, the total number of notches on the leading and trailing edge were also included and the Defran ration of each fin determined (Defran *et al.* 1990).

To evaluate if photo quality and individual distinctiveness can be measured reliably, a total of eleven researchers were asked to classify the 24 photographs. One researcher (R1) was considered to be trained with experience in both the field and tracing/cataloguing (lab analysis) of individual fins (> 5 yrs experience). A second researcher (R2) was considered to be untrained in both techniques but had experience (> 1 year). Additionally, three other researchers (R3 – R5) had field experience but limited untrained experience in tracing/cataloguing and a researcher (R6) who was trained in lab techniques but had no experience prior to this study. Furthermore, the last category consisted of five researchers (R7 – R11) who were introduced to dolphin studies for the first time and had no training or experience in this type of study. Due to the lack of researchers in each group, researchers were later divided into experienced and inexperienced researcher groups for sufficient replication and statistical purposes.

The level of agreement between researchers was evaluated with a standard weighted *kappa* statistic (Kw) (Friday *et al.* 2000). This agreement statistic is commonly used in educational, psychological and medical literature (Agresti 1990). The *Kappa* statistic estimates the observed pair-wise agreements

between two or more researchers corrected for chance alone. *Kappa* values usually range between one and zero, but can also be negative when agreement occurs less often than predicted by chance alone or it may be due to the chance corrected component of this statistic. A *kappa* value of one represents a high level of agreement and a *kappa* value near zero indicates a low level of agreement. The resulting *kappa* value will almost always be less than that of percent agreement due to the chance-corrected component. Landis and Koch (1977) recognised this aspect of *kappa* values and presented a qualitative basis for evaluating *kappa* statistics (Table 2.2). The terminology proposed by Landis and Koch (1977) has been adopted here.

There is concern that some researchers may be less adept in identifying certain variables due to certain factors, for example, differences in vision capability between researchers can affect their ability to categorise different variables. To quantitatively recognise less adept researchers, a conditional random permutation (Gailey 2001) was applied using all photographs. If a researcher's actual overall *kappa* value was found to be significantly different from that of other researchers, then the researcher was removed and the conditional random permutation was computed again until all researchers were not significantly different from each other. Each permutation was reanalyzed with different random subsets to ensure that the same researchers were consistently rejected as being less adept.

Results

The eleven researcher's pair-wise analysis showed considerably lower levels of agreement for all specific and overall variables than would be expected by chance alone. The level of agreement ranged from slight to moderate agreement according to Landis and Koch (1977) (Table 2.2), with no specific trends.

Researchers agreed on a fair level for overall photographic quality ($K_{overall} = 0.31$, 95% CI: 0.28-0.35) (Table 2.3) and photograph clarity ($K_{overall} = 0.32$, 95% CI: 0.28-0.35) (table 2.4). Individual pair-wise agreements for photograph clarity only showed researchers 3 (R3) and 4 (R4) ($K_w = 0.60$, $SE = 0.09$), plus researchers 7 (R7) and 8 (R8) ($K_w = 0.63$, $SE = 4.19$), as agreeing substantially (Table 2.4). There was only very slight agreement between researchers regarding the contrast of the photograph ($K_{overall} = 0.07$, 95% CI: 0.04-0.11) (table 2.5) and the angle at which it was taken ($K_{overall} = 0.11$, 95% CI: 0.06-0.15) (Table 2.6).

Table 2.1: Photographic quality and individual distinctiveness variables of dolphin dorsal fin images.

Variable	Definition	Scores
Clarity	Degree of separation between the boundary of the dorsal fin from an environmental back ground. Clarity may also include pixilation.	1 = excellent 3 = average 5 = poor
Contrast	Difference in colouration between the dorsal fin and the surrounding environment.	1 = excessive 3 = ideal 5 = insufficient
Angle	Deviation from a perpendicular camera to dorsal fin photograph	1 = perpendicular 3 = moderate (~30°) 5 = oblique (~ 60°)
Overall Quality	Broad category incorporating all specific aspects and other aspects that may not be accounted.	1 = good 3 = average 5 = poor
Leading edge/ scarring/ pigmentation	Scale of serrations or injuries on the leading edge. It also includes scarring and pigmentation on the animal's body.	1 = large scale 2 = average 3 = non-distinctive
Trailing edge	Scale of serrations or injuries on the trailing edge.	1 = large scale 2 = average 3 = indistinct
Overall distinctiveness	Broad category incorporating all specific aspects and other aspects that may not be accounted.	1 = very distinct 2 = average, with distinct features 3 = not distinctive, with little information content

Table 2.2: Qualitative evaluation of *kappa* statistics from Landis and Koch (1977).

<i>Kappa</i>	Qualitative Level of Agreement
0.00 - 0.20	Slight Agreement
0.20 - 0.40	Fair Agreement
0.40 - 0.60	Moderate Agreement
0.60 - 0.80	Substantial Agreement
0.80 - 1.00	Perfect Agreement

For all aspects of individual distinctiveness, researcher's agreed at only a fair level, including leading edge distinctiveness ($K_{overall} = 0.22$, 95% CI: 0.15-0.28) (Table 2.7); trailing edge distinctiveness ($K_{overall} = 0.34$, 95% CI: 0.30-0.39) (Table 2.8) and overall distinctiveness ($K_{overall} = 0.30$, 95% CI: 0.25-0.34) (Table 2.9). In evaluating pair-wise agreement levels within a category, some researcher's appear to be less reliable in identifying certain variables compared to other researchers. For example, researcher 6's overall distinctiveness $kappa$ value appeared lower ($K_{overall} = 0.09$, 95% CI: -0.5-0.23) than those of other researchers. Researcher 7 also experienced great difficulty in classifying the angle of the photograph ($K_{overall} = 0.00$, 95% CI: 0.00-0.00) compared to other researchers.

Less adept researchers were identified by evaluating their overall kappa agreement and conducting a random permutation test. The number of permutations for each variable were: OPQ = 3, clarity = 5, angle = 6, contrast = 12, LE = 7, TE = 10 and OD = 12. All variables for photographic quality were rejected by 3 or more researchers (Table 2.10) and 6 or more researchers for animal distinctiveness (Table 2.11). By rejecting less adept researchers, reliability increased for all variables of photographic quality and individual distinctiveness (Table 2.12). Researcher 1 (R1) who has the most experience and training was not rejected for any of the variables, while contrastingly, researcher 6 (R6) who had training but no experience was rejected by all variables. Overall, the results indicate that particularly classifying the photographic angle and the trailing edge distinctiveness were problematic for researchers with little or no experience.

Differences in the reliability of identifying individuals when relying exclusively on the distinctiveness of the dorsal fin, is a source of concern. To provide more insight into the problems with reliability of matching individuals with notch numbers and the use of the Defran ratio (a ratio computed by dividing the distance between the two largest notches by the distance of the larger lower notch to the top of the fin.), researchers were compared using a univariate general linear model. There was no significant differences between researchers for notch counts on the leading edge ($n = 264$, $p = 0.461$) (Figure 2.1), trailing edge ($n = 264$, $p = 0.440$) (Figure 2.2) and calculation of the Defran ratio ($n = 264$, $p = 0.437$) (Figure 2.3). Tukey's *post hoc* test for the number of notches on the trailing edge showed clear differences between researchers, where experienced researchers ($n = 5$) were significantly different to inexperienced researchers ($n = 6$) (Table: 2.13).

Table 2.3: Pair-wise kappa weighted agreement statistics for overall photographic quality (OPQ). For each variable the standard kappa statistic (Kw) for each researcher (R1 – R11) is shown along with the standard error (SE) and Z statistic (Z).

N = 24	OPQ	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
R1	Kw	0.53	0.24	0.47	0.19	0.18	0.18	0.16	0.39	0.39	0.36
	SE (Kw)	0.11	0.12	0.09	0.15	0.08	0.12	0.12	0.11	0.10	0.12
	Z	3.90	1.93	3.36	1.35	1.83	1.49	1.28	2.80	3.41	2.87
R2	Kw		0.26	0.49	0.39	0.10	0.29	0.16	0.44	0.61	0.44
	SE (Kw)		0.10	0.11	0.13	0.10	0.14	0.12	0.13	0.10	0.14
	Z		2.42	3.76	2.74	1.04	2.05	1.7	3.19	4.46	2.94
R3	Kw			0.59	0.22	0.15	0.17	0.27	0.33	0.18	0.19
	SE (Kw)			0.13	0.10	0.07	0.09	0.14	0.13	0.11	0.10
	Z			4.37	2.23	1.79	2.06	2.07	2.60	2.03	1.99
R4	Kw				0.31	0.15	0.36	0.29	0.58	0.33	0.35
	SE (Kw)				0.12	0.09	0.10	0.11	0.08	0.11	0.11
	Z				2.44	1.39	3.55	2.28	4.33	3.24	3.17
R5	Kw					0.17	0.56	0.36	0.38	0.32	0.71
	SE (Kw)					0.12	0.11	0.12	0.11	0.15	0.08
	Z					1.52	4.00	3.14	3.09	2.32	4.93
R6	Kw						0.08	0.15	0.11	0.12	0.06
	SE (Kw)						0.11	0.09	0.08	0.11	0.10
	Z						0.78	1.72	1.39	1.11	0.62
R7	Kw							0.41	0.35	0.41	0.54
	SE (Kw)							0.13	0.11	0.19	0.14
	Z							3.33	2.96	2.47	3.43
R8	Kw								0.23	0.10	0.27
	SE (Kw)								0.14	0.42	0.13
	Z								1.55	0.13	2.16
R9	Kw									0.30	0.38
	SE (Kw)									0.12	0.12
	Z									2.49	2.76
R10	Kw										0.48
	SE (Kw)										0.16
	Z										3.12

Table 2.4: Pair-wise kappa weighted agreement statistics for photograph clarity. For each variable the standard kappa statistic (Kw) for each researcher (R1 – R11) is shown along with the standard error (SE) and Z statistic (Z).

N = 24	Clarity	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
R1	Kw	0.33	0.48	0.48	0.34	0.11	0.44	0.44	0.26	0.27	0.32
	SE (Kw)	0.14	0.11	0.11	0.13	0.11	0.12	0.13	0.13	0.13	0.13
	Z	2.33	3.82	3.73	2.56	0.91	3.56	3.51	1.76	2.21	2.25
R2	Kw		0.35	0.35	0.27	0.19	0.43	0.43	0.27	0.45	0.32
	SE (Kw)		0.11	0.09	0.16	0.10	0.12	0.11	0.13	0.11	0.16
	Z		3.16	3.09	1.83	1.70	3.31	3.67	1.79	3.39	2.18
R3	Kw			0.60	0.26	0.52	0.33	0.40	0.26	0.25	0.25
	SE (Kw)			0.09	0.11	0.11	0.12	0.12	0.11	0.09	0.10
	Z			4.26	2.53	4.18	3.15	3.75	2.14	2.95	2.50
R4	Kw				0.38	0.33	0.26	0.34	0.38	0.15	0.16
	SE (Kw)				0.08	0.09	0.08	0.09	0.11	0.07	0.08
	Z				3.35	3.12	2.97	3.42	2.90	2.15	1.76
R5	Kw					0.07	0.52	0.54	0.40	0.01	0.55
	SE (Kw)					0.12	0.10	0.12	0.12	0.15	0.13
	Z					0.63	3.73	4.27	2.93	0.07	3.63
R6	Kw						0.16	0.54	0.24	0.18	0.13
	SE (Kw)						0.13	0.12	0.12	0.11	0.10
	Z						1.33	4.10	2.15	1.67	1.22
R7	Kw							0.63	0.36	0.10	0.35
	SE (Kw)							0.14	0.12	0.10	0.14
	Z							4.19	2.74	0.62	2.41
R8	Kw								0.40	0.21	0.44
	SE (Kw)								0.12	0.16	0.13
	Z								3.05	1.50	3.37
R9	Kw									0.05	0.03
	SE (Kw)									0.11	0.14
	Z									0.38	0.17
R10	Kw										0.24
	SE (Kw)										0.19
	Z										1.49

Table 2.5: Pair-wise kappa weighted agreement statistics for contrast within the photograph. For each variable the standard kappa statistic (Kw) for each researcher (R1 – R11) is shown along with the standard error (SE) and Z statistic (Z).

N = 24		R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
R1	Kw	0.13	- 0.02	0.20	0.24	0.26	0.32	0.22	0.12	0.00	0.05
	SE (Kw)	0.10	0.07	0.13	0.14	0.13	0.16	0.13	0.06	0.67	0.64
	Z	1.61	0.07	1.48	1.75	2.26	3.00	2.56	1.91	- 0.04	0.83
R2	Kw		- 0.17	0.07	0.08	0.18	0.01	0.05	0.02	0.02	0.16
	SE (Kw)		0.12	0.08	0.11	0.12	0.08	0.13	0.11	0.08	0.13
	Z		- 1.26	0.86	0.10	1.62	0.12	0.44	0.18	0.28	1.16
R3	Kw			0.18	0.02	- 0.09	0.19	0.13	0.03	0.03	- 0.18
	SE (Kw)			0.11	0.12	0.11	0.12	0.12	0.11	0.10	0.13
	Z			1.93	0.17	- 0.79	2.59	1.26	0.20	0.24	- 1.40
R4	Kw				0.32	0.02	0.20	0.20	0.13	0.08	0.14
	SE (Kw)				0.17	0.11	0.17	0.13	0.10	0.12	0.09
	Z				2.16	0.14	2.37	2.29	1.26	0.63	1.95
R5	Kw					- 0.15	0.36	0.32	0.21	0.10	0.13
	SE (Kw)					0.11	0.17	0.14	0.08	0.10	0.10
	Z					- 0.15	4.12	3.36	2.19	1.00	1.69
R6	Kw						0.04	- 0.05	0.01	- 0.02	- 0.03
	SE (Kw)						0.07	0.07	0.10	0.09	0.08
	Z						0.47	- 0.55	0.15	- 0.17	- 0.35
R7	Kw							0.47	0.05	0.07	0.05
	SE (Kw)							0.22	0.07	0.07	0.11
	Z							3.81	0.63	0.87	0.59
R8	Kw								0.06	- 0.02	0.04
	SE (Kw)								0.08	0.09	0.13
	Z								0.61	- 0.17	0.34
R9	Kw									0.11	0.20
	SE (Kw)									0.20	0.12
	Z									0.68	1.64
R10	Kw										0.19
	SE (Kw)										0.11
	Z										1.82

Table 2.6: Pair-wise kappa weighted agreement statistics for the angle at which the photograph was taken. For each variable the standard kappa statistic (Kw) for each researcher (R1 – R11) is shown along with the standard error (SE) and Z statistic (Z).

N = 24	Angle	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
R1	Kw	0.50	0.38	0.41	0.31	0.09	0.00	0.09	0.07	0.06	0.32
	SE (Kw)	0.13	0.15	0.22	0.14	0.05	-	0.14	0.21	0.12	0.23
	Z	3.39	2.32	2.48	2.22	1.49	-	0.68	0.43	0.45	2.62
R2	Kw		0.35	0.37	0.33	0.07	0.00	0.15	0.19	0.22	0.27
	SE (Kw)		0.15	0.16	0.18	0.07	-	0.14	0.70	.22	0.17
	Z		2.37	2.63	2.26	1.05	-	1.02	1.18	1.75	2.39
R3	Kw			0.26	0.31	0.01	0.00	0.05	0.10	0.15	0.21
	SE (Kw)			0.18	0.14	0.06	-	0.15	0.18	0.18	0.18
	Z			1.77	1.87	0.21	-	0.38	0.60	1.25	1.95
R4	Kw				0.18	0.04	0.00	0.18	0.33	-0.11	0.47
	SE (Kw)				0.14	0.03	-	0.13	0.21	0.06	0.27
	Z				1.48	1.01	-	1.66	2.10	-0.72	3.44
R5	Kw					0.03	0.00	0.17	0.11	0.20	0.14
	SE (Kw)					0.10	-	0.16	0.18	0.13	0.12
	Z					0.29	-	1.02	0.68	1.89	1.41
R6	Kw						0.00	-0.05	-0.01	-0.02	0.02
	SE (Kw)						-	0.08	0.03	0.03	0.02
	Z						-	-0.53	-0.14	-0.68	0.73
R7	Kw							0.00	0.00	0.00	0.00
	SE (Kw)							-	-	-	-
	Z							-	-	-	-
R8	Kw								0.29	0.19	0.13
	SE (Kw)								0.14	0.12	0.12
	Z								1.94	1.97	1.44
R9	Kw									0.10	0.36
	SE (Kw)									0.16	0.27
	Z									0.62	2.28
R10	Kw										-0.05
	SE (Kw)										0.04
	Z										-0.29

Table 2.7: Pair-wise kappa weighted agreement statistics for leading edge serrations, pigmentation and scars (LE). For each variable the standard kappa statistic (Kw) for each researcher (R1 – R11) is shown along with the standard error (SE) and Z statistic (Z).

N = 24	LE	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
R1	Kw	0.43	0.50	0.44	0.34	- 0.09	0.22	0.59	0.10	0.52	- 0.10
	SE (Kw)	0.16	0.16	0.17	0.16	0.17	0.16	0.13	0.14	0.16	0.17
	Z	2.52	2.81	2.91	2.12	- 0.57	1.35	3.59	0.63	2.82	- 0.15
R2	Kw		0.63	0.41	0.37	0.09	0.21	0.37	0.41	0.38	0.22
	SE (Kw)		0.13	0.16	0.16	0.19	0.14	0.16	0.12	0.17	0.16
	Z		3.78	3.03	2.27	0.59	1.44	2.27	2.58	2.30	1.33
R3	Kw			0.36	0.50	0.00	0.33	0.23	0.38	0.68	0.35
	SE (Kw)			0.16	0.13	0.17	0.16	0.16	0.15	0.13	0.18
	Z			2.45	3.05	0.03	2.05	1.41	2.43	3.67	1.95
R4	Kw				0.14	0.22	0.12	0.33	0.15	0.52	0.17
	SE (Kw)				0.11	0.18	0.09	0.14	0.09	0.19	0.18
	Z				1.16	1.80	1.21	2.70	1.10	2.89	0.98
R5	Kw					0.17	0.50	0.13	0.29	0.46	0.50
	SE (Kw)					0.17	0.14	0.17	0.15	0.13	0.14
	Z					1.12	3.27	0.80	1.88	2.90	3.16
R6	Kw						0.05	0.28	- 0.04	0.03	0.05
	SE (Kw)						0.14	0.18	0.14	0.17	0.18
	Z						0.36	1.79	- 0.24	0.22	0.31
R7	Kw							- 0.04	0.35	0.25	0.44
	SE (Kw)							0.15	0.13	0.14	0.13
	Z							- 0.24	2.63	1.69	3.12
R8	Kw								0.06	0.28	- 0.15
	SE (Kw)								0.14	0.17	0.15
	Z								0.37	1.78	- 0.92
R9	Kw									0.19	0.42
	SE (Kw)									0.15	0.17
	Z									1.23	2.67
R10	Kw										0.33
	SE (Kw)										0.20
	Z										1.67

Table 2.8: Pair-wise kappa weighted agreement statistics for trailing edge serrations, pigmentation and scars (TE). For each variable the standard kappa statistic (Kw) for each researcher (R1 – R11) is shown along with the standard error (SE) and Z statistic (Z).

N = 24	TE	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
R1	Kw	0.51	0.51	0.63	0.22	0.09	0.37	0.56	0.48	0.39	0.64
	SE (Kw)	0.15	0.15	0.13	0.18	0.14	0.16	0.13	0.15	0.15	0.12
	Z	3.10	3.13	4.01	1.37	0.55	2.49	3.74	3.05	2.45	4.00
R2	Kw		0.47	0.48	0.31	0.26	0.08	0.48	0.35	0.37	0.52
	SE (Kw)		0.17	0.15	0.18	0.16	0.16	0.15	0.18	0.16	0.14
	Z		2.80	3.02	1.93	1.64	0.55	3.02	2.21	2.37	3.39
R3	Kw			0.49	0.13	0.15	0.34	0.49	0.48	0.26	0.41
	SE (Kw)			0.14	0.19	0.12	0.12	0.14	0.13	0.14	0.13
	Z			3.35	0.83	1.00	2.61	3.35	3.19	1.75	2.69
R4	Kw				0.16	0.33	0.17	0.54	0.41	0.21	0.52
	SE (Kw)				0.17	0.15	0.19	0.18	0.16	0.15	0.11
	Z				1.05	2.15	1.10	3.06	2.54	1.36	3.76
R5	Kw					0.30	0.33	0.28	0.47	0.30	0.45
	SE (Kw)					0.16	0.16	0.16	0.12	0.15	0.17
	Z					1.89	2.27	1.84	3.33	1.89	2.76
R6	Kw						0.03	0.21	0.10	0.03	0.30
	SE (Kw)						0.17	0.14	0.16	0.17	0.17
	Z						0.22	1.36	0.65	0.20	1.89
R7	Kw							0.31	0.21	0.03	0.35
	SE (Kw)							0.18	0.16	0.12	0.14
	Z							1.98	1.36	0.22	2.47
R8	Kw								0.41	0.21	0.41
	SE (Kw)								0.16	0.14	0.12
	Z								2.54	1.36	2.99
R9	Kw									0.44	0.49
	SE (Kw)									0.16	0.14
	Z									2.77	3.20
R10	Kw										0.50
	SE (Kw)										0.14
	Z										3.13

Table 2.9: Pair-wise kappa weighted agreement statistics for overall distinctiveness (OD). For each variable the standard kappa statistic (Kw) for each researcher (R1 – R11) is shown along with the standard error (SE) and Z statistic (Z).

N = 24	OD	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
R1	Kw	0.62	0.39	0.49	0.48	0.23	0.54	0.28	0.49	0.39	0.65
	SE (Kw)	0.13	0.17	0.15	0.15	0.16	0.14	0.14	0.18	0.16	0.12
	Z	3.71	2.60	2.94	3.03	1.47	3.58	2.09	2.97	2.49	4.21
R2	Kw		0.49	0.67	0.45	0.31	0.33	0.43	0.38	0.29	0.56
	SE (Kw)		0.17	0.12	0.16	0.15	0.14	0.14	0.16	0.17	0.16
	Z		3.07	3.98	2.79	2.24	2.31	3.31	2.34	1.93	3.40
R3	Kw			0.55	0.11	0.18	0.09	0.13	0.31	0.13	0.42
	SE (Kw)			0.18	0.14	0.14	0.09	0.12	0.16	0.12	0.17
	Z			3.34	0.76	1.38	0.76	1.24	2.19	1.01	2.59
R4	Kw				0.15	0.19	0.18	0.19	0.22	0.13	0.48
	SE (Kw)				0.15	0.16	0.11	0.13	0.16	0.14	0.16
	Z				0.94	1.31	1.30	1.50	1.42	0.88	2.91
R5	Kw					- 0.19	0.39	0.15	0.33	0.59	0.42
	SE (Kw)					0.15	0.15	0.14	0.18	0.15	0.17
	Z					- 1.19	2.56	1.05	2.07	3.78	2.65
R6	Kw						0.08	0.24	0.04	- 0.04	0.11
	SE (Kw)						0.16	0.15	0.16	0.14	0.18
	Z						0.54	1.67	0.29	- 0.26	0.72
R7	Kw							0.37	0.40	0.41	0.43
	SE (Kw)							0.16	0.15	0.16	0.14
	Z							2.44	2.60	2.65	3.13
R8	Kw								0.21	0.13	0.23
	SE (Kw)								0.15	0.15	0.14
	Z								1.49	0.89	1.85
R9	Kw									0.00	0.36
	SE (Kw)									0.19	0.17
	Z									0.00	2.41
R10	Kw										0.40
	SE (Kw)										0.16
	Z										2.76

Table 2.10: Overall kappa weighted agreement statistics identifying adept judges for variables of photographic quality. For each variable the overall *kappa* statistic (Kwo) for each researcher is shown along with the significance probability for the conditional random permutation.

		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
Clarity	Kwo	0.55	0.48	0.60	0.57	0.47	0.41	0.49	0.60	0.49	0.38	0.44
	P	1.00	0.61	1.00	1.00	0.11	0.00	0.58	1.00	0.44	0.00	0.06
	Kwo	0.56	0.51	0.57	0.54	0.52		0.50	0.61	0.48		0.44
	P	1.00	0.78	1.00	0.97	0.83		0.64	1.00	0.28		0.00
	Kwo	0.58	0.52	0.60	0.57	0.50		0.51	0.61	0.51		
	P	1.00	0.43	1.00	1.00	0.18		0.39	1.00	0.43		
Contrast	Kwo	0.16	0.08	0.01	0.25	0.28	0.05	0.18	0.22	0.12	0.15	0.18
	P	0.97	0.22	0.00	1.00	1.00	0.03	1.00	1.00	0.75	0.33	0.83
	Kwo	0.20	0.11		0.26	0.30	0.07	0.16	0.22	0.13	0.08	0.21
	P	1.00	0.07		1.00	1.00	0.00	0.71	1.00	0.46	0.00	1.00
	Kwo	0.18	0.09		0.28	0.35		0.18	0.27	0.14		0.21
	P	0.76	0.00		1.00	1.00		0.71	1.00	0.29		0.93
	Kwo	0.18			0.28	0.37		0.19	0.27	0.17		0.19
	P	0.14			1.00	1.00		0.29	0.95	0.04		0.10
Angle	Kwo	0.18	0.11	0.08	0.06	0.04	0.00	0.00	0.01	0.13	0.04	0.03
	P	0.89	0.31	0.06	0.03	0.00	0.00	0.00	0.00	0.31	0.00	0.00
	Kwo	0.59	0.60	0.40	0.42					0.24		
	P	1.00	1.00	0.40	0.80					0.00		
	Kwo	0.63	0.62	0.46	0.43							
	P	1.00	1.00	0.00	0.00							
	Kwo	0.69	0.69									
	P	1.00	1.00									
OPQ	Kwo	0.55	0.49	0.35	0.67	0.51	0.27	0.48	0.37	0.60	0.63	0.59
	P	1.00	0.92	0.00	1.00	0.97	0.00	0.72	0.00	1.00	1.00	1.00
	Kwo	0.63	0.60		0.72	0.60		0.55		0.68	0.68	0.71
	P	1.00	0.93		1.00	0.93		0.33		1.00	1.00	1.00

Table 2.11: Overall kappa weighted agreement statistics identifying adept judges for variables of individual distinctiveness. For each variable the overall *kappa* statistic (Kw_O) for each researcher is shown along with the significance probability for the conditional random permutation.

		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
LE	Kw_O	0.50	0.51	0.47	0.28	0.34	0.10	0.22	0.44	0.33	0.54	0.16
	P	1.00	1.00	1.00	0.28	0.86	0.00	0.00	1.00	0.75	1.00	0.00
	Kw_O	0.57	0.56	0.53	0.32	0.31			0.51	0.36	0.57	
	P	1.00	1.00	1.00	0.00	0.00			1.00	0.04	0.90	
	Kw_O	0.61	0.60	0.54					0.57	0.41	0.52	
	P	1.00	1.00	1.00					1.00	0.00	1.00	
	Kw_O	0.68	0.60	0.58					0.64		0.57	
	P	1.00	1.00	0.83					1.00		1.00	
TE	Kw_O	0.53	0.47	0.50	0.52	0.43	0.25	0.37	0.50	0.51	0.35	0.63
	P	1.00	0.94	1.00	1.00	0.67	0.00	0.14	0.97	0.97	0.00	1.00
	Kw_O	0.57	0.48	0.54	0.54	0.43		0.40	0.53	0.53		0.64
	P	1.00	0.36	1.00	0.96	0.00		0.00	0.93	0.93		1.00
	Kw_O	0.66	0.55	0.57	0.61				0.56	0.58		0.64
	P	1.00	0.00	0.19	0.71				0.10	0.14		1.00
	Kw_O	0.67		0.58	0.61				0.56	0.59		0.65
	P	1.00		0.07	0.67				0.00	0.27		1.00
	Kw_O	0.69		0.58	0.62					0.60		0.67
	P	1.00		0.00	0.50					0.10		1.00
	Kw_O	0.71			0.63					0.60		0.69
	P	1.00			0.00					0.00		1.00
	Kw_O	0.76										0.76
	P	1.00										1.00
OD	Kw_O	0.55	0.57	0.32	0.48	0.30	0.12	0.38	0.28	0.43	0.28	0.58
	P	1.00	1.00	0.39	1.00	0.36	0.00	0.91	0.08	1.00	0.00	1.00
	Kw_O	0.58	0.61	0.34	0.50	0.36		0.41	0.28	0.46		0.57
	P	1.00	1.00	0.04	1.00	0.07		0.29	0.00	0.75		1.00
	Kw_O	0.61	0.62	0.37	0.53	0.39		0.41		0.49		0.61
	P	1.00	1.00	0.00	1.00	0.00		0.00		0.57		1.00
	Kw_O	0.66	0.68		0.66					0.51		0.65
	P	1.00	1.00		1.00					0.00		1.00
	Kw_O	0.71	0.71		0.68							0.69
	P	1.00	1.00		0.33							0.50

Table 2.12: Overall kappa agreement statistics after less adept judges were removed using a random permutation test.

Variable	Kw _O	95% CI	Kw _O	95% CI
Clarity	0.50	0.38 – 0.61	0.55	0.49 – 0.63
Contrast	0.15	0.10 – 0.30	0.24	0.19 – 0.39
Angle	0.06	0.00 – 0.18	0.69	0.68 – 0.70
Overall Quality	0.50	0.37 – 0.65	0.65	0.29 – 0.53
LE distinctiveness	0.35	0.21 – 0.55	0.61	0.55 – 0.70
TE distinctiveness	0.46	0.29 – 0.53	0.76	0.75 – 0.77
Overall distinctiveness	0.39	0.33 – 0.58	0.70	0.66 – 0.72

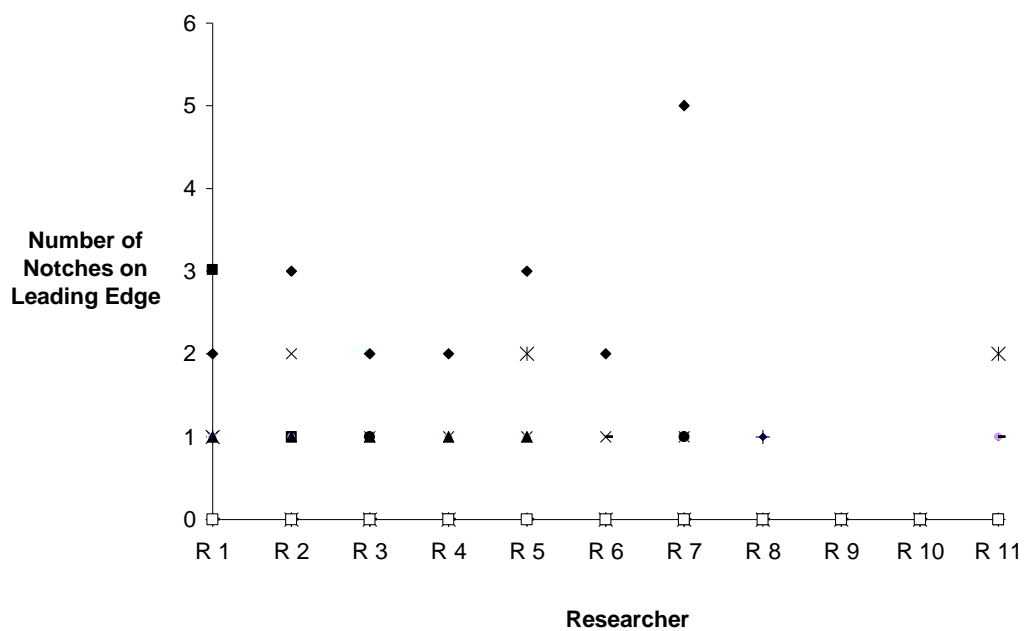


Figure 2.1: Notch counts on the leading edge of each dolphin dorsal fin tracing by each researcher. Each identical symbol represents the same photographic slide.

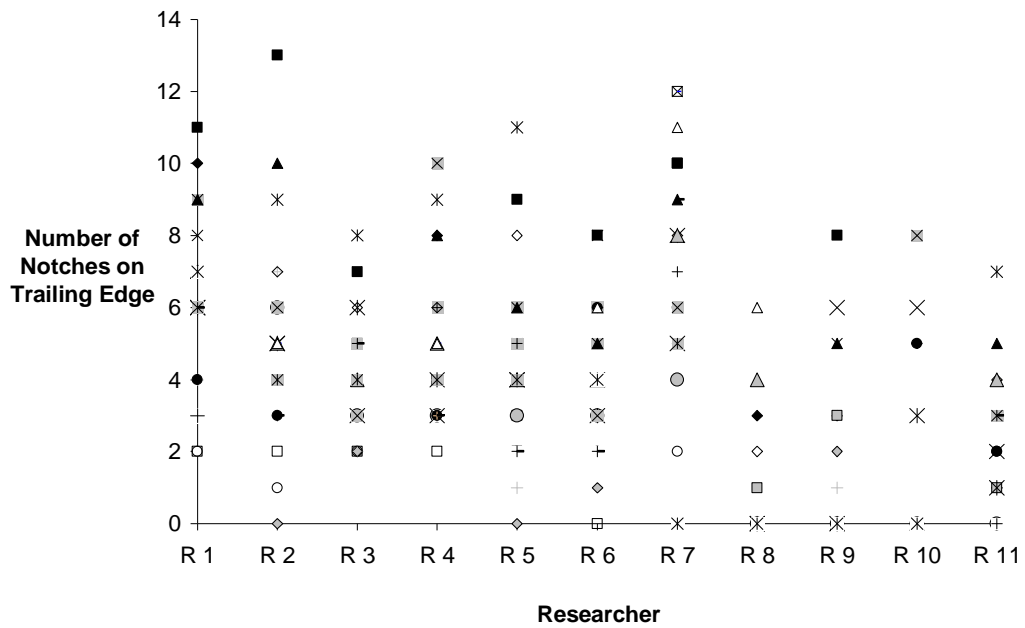


Figure 2.2: Notch counts on the trailing edge of each dolphin dorsal fin tracing by each researcher. Each identical symbol represents the same photographic slide.

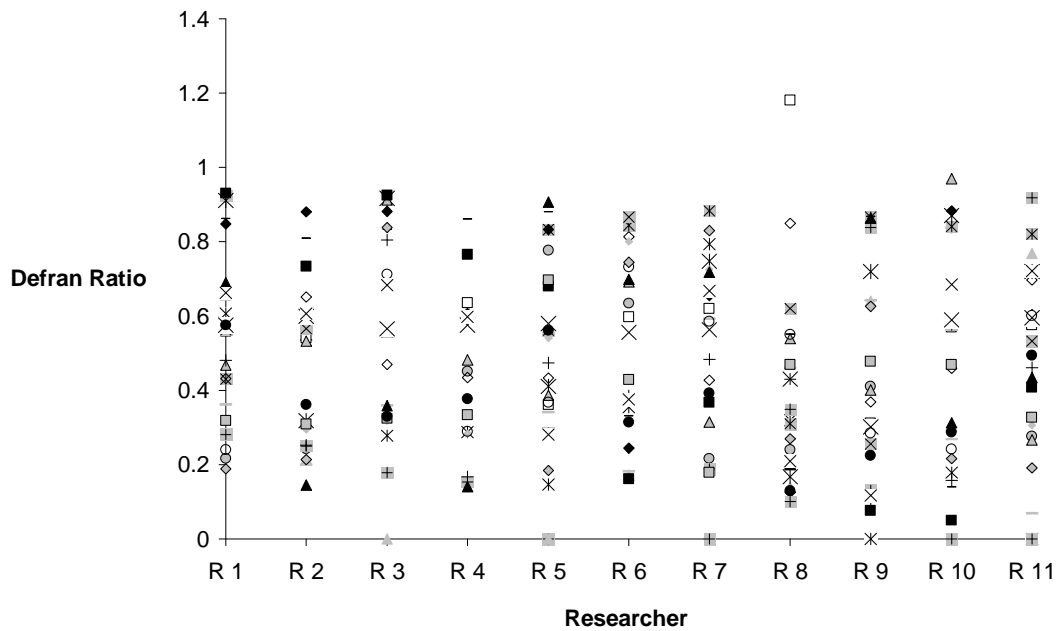


Figure 2.3: Defran Ratio of each dolphin dorsal fin tracing by each researcher. Each identical symbol represents the same photographic slide.

Table 2.13: Tukey's *post hoc* results for number of notches on the trailing edge.

Experienced Researcher	Inexperienced Researcher	Std. Error	Significance
R1	R6	0.24417	0.011
	R7	0.24332	0.985
	R8	0.24332	0.000
	R9	0.25637	0.000
	R10	0.25883	0.000
	R11	0.24332	0.000
R2	R6	0.24590	0.465
	R7	0.24505	0.260
	R8	0.24505	< 0.001
	R9	0.25801	< 0.001
	R10	0.26046	< 0.001
	R11	0.24505	0.001
R3	R6	0.24679	0.995
	R7	0.24595	0.007
	R8	0.24595	< 0.001
	R9	0.25887	< 0.001
	R10	0.26130	0.006
	R11	0.24595	0.077
R4	R6	0.24771	0.683
	R7	0.24687	0.141
	R8	0.24687	< 0.001
	R9	0.25974	< 0.001
	R10	0.26217	< 0.001
	R11	0.24687	0.003
R5	R6	0.24417	1.000
	R7	0.24332	0.002
	R8	0.24332	< 0.001
	R9	0.25637	< 0.001
	R10	0.25883	0.016
	R11	0.24332	0.165

Discussion

The results of this study provide multiple judgment-based scores of specific aspects of photographic quality and individual distinctiveness that can be used for future objective performance evaluation for manual methods of photo-identification. One of the major disadvantages in subjectively evaluating image quality and individual distinctiveness based on multiple subjective measurements is the time, and therefore expense, associated with such a task. In this study, researchers were unable to agree reliably on all aspects of photo quality and individual distinctiveness. By Contrast, Gailey (2001) using digital images and the *Finscan* program found that observers agreed reliably on various aspects of image quality and individual distinctiveness, but angle could still not be measured reliably. A photographic reliability study on humpback whales by Friday *et al.* (2000) found that judges agreed moderately for overall quality and substantially for overall distinctiveness. Similar results were found by Rugh *et al.* (1998) using marginal homogeneity assumptions. When analysing their results in more depth, Gailey (2001) found that clarity, contrast and visibility are important parameters in explaining the quality of an image. Both Gailey (2001) and Friday *et al.* (2000) found some observers to be less adept in identifying different variables of image quality and individual distinctiveness and that some observers appeared to be affected in judging distinctiveness independent of image quality. The researchers used in the current study displayed similar differences between observers. The specific variable of angle was found to be only slightly reliably measured for small cetacean dorsal fins in this study and that of Gailey (2001), while it appears to be more readily reliably measured in large whales (Friday *et al.* 2000). This suggests that there may be interspecific differences in how reliably researchers can differentiate particular differentiating components when conducting individual identification studies.

Notch counts between experienced researchers were similar to that of inexperienced researchers. Researcher 6 although inexperienced in lab analyses had limited field experience and was trained in dolphin tracings. Therefore, when he was compared to inexperienced researchers he differed. Furthermore, while carrying out the experiment it was noticed that inexperienced researchers counted splash caused by dolphins and sun glare as notches. This most certainly is already a source of incorrect identification in many studies and highlights the importance of training observers to take these potential biases into consideration when tracing and/or identifying dolphin fins. Incorrect identification may involve falsely identifying two sightings of different individuals as the same (a false positive error) or two sightings of the same individual as different (false negative error), which can

present a problem in mark-recapture studies since most models cannot deal with this problem. This highlights that researchers should be trained with experience in the field and photo-identification techniques prior to commencing any photographic matching tasks.

One of the easiest ways to incur errors in individual identification may be the result of poor quality photographs. For photo-identification mark-recapture analysis, high quality photographs have always been recommended to minimise violations in assumptions of equal catchability (Hammond 1986, Würsig and Jefferson 1990). Therefore, the distribution of photo quality should be in favour of higher photo quality estimates. In this study only 58% of the photographs analysed were found to be higher than the quality estimate of 3 (i.e. 1 = good, 3 = average, 5 = poor). These lower quality images could have affected the ability of some researchers to categorise photo quality and distinctiveness which, in turn, may have led to the low levels of agreement. This hypothesis could not be statistically analysed due to the small sample size but should be considered when conducting similar analyses in future studies.

The importance of photographic resolution required for individual identification has previously been recognised by researchers. Würsig and Jefferson (1990) recommend chemical emulsion film to have small grain size and maximal resolution to identify the small and subtle notches on a dorsal fin that may only be represented on a fraction of the film. The resolution of film is significantly dependent on the amount of light present, since the light-sensitive salt crystals in the chemical emulsion of film will fixate more, resulting in finer grain size, than in poorer lighting conditions. Therefore, the resolution will vary throughout the photograph. With the recent advent and widespread use of digital photography in photo-identification studies, these resolution difficulties are reduced as digitally capturing photographs results in a linear resolution, which may decrease contrast differences between lighting areas (Gailey 2001).

The advent of the digital era and concomitant synergy with computers and the use of computer based identification software have many advantages when compared to manual techniques. Data management and analysis can be achieved at a more efficient rate. Moreover, such a system could increase the efficiency of collecting data using digital photography, eliminating the necessity to develop film. Data can be managed and processed immediately after returning from the field survey, even in remote locations where processing of photographic material would not be possible. Although computer based systems are highly efficient there are concerns about the reproducibility of research

results compared to traditional photographic identification. Experienced researchers were found to be more reliable in identifying individuals with photographs than either experienced or inexperienced researchers with digital images (Gailey 2001). Whether traditional manual methods or a computer-assisted approach is used, to reliably identify individuals using natural markings, learned experience is necessary.

Chapter 3

Effects of habitat on the distribution, movement patterns and behaviour of bottlenose dolphins

Introduction

Animals generally use space disproportionately within the boundaries of their home range (Samuel *et al.* 1985). Areas receiving concentrated use by resident animals can be termed preferred habitats. Studying cetacean habitat selection can be extremely difficult. These environments are challenging due to the diving ability of cetaceans and the lack of knowledge of what they do beneath the surface. However, these animals must return to the surface to breathe; hence habitat use can be interpreted from their distribution at the surface (Hastie *et al.* 2003b) and their distribution can be closely linked to habitat features (Ross *et al.* 1987; Gowans and Whitehead 1995; Wilson *et al.* 1997; Davis *et al.* 1998; Karczmarski *et al.* 2000; Hastie *et al.* 2004). However, the primary function of the preferred habitats often remains vague. Only when behavioural observations are made can a complete representation of the ecological function of those areas be revealed (Hastie *et al.* 2004).

The density and distribution of groups and sub-groups is a function of the size and area of any wild population's home range (Karczmarski *et al.* 2000). An adequate identification of habitat use within a population's home range and core areas where biological and social behaviours concentrate is a fundamental part of understanding the species ecology and crucial for the conservation and management of any wild population (Karczmarski *et al.* 2000).

Bottlenose dolphins have been the most researched cetacean species (Shane *et al.* 1986; Ross *et al.* 1987; Ballance 1990; Acevedo 1991; Cockcroft *et al.* 1991; 1992; Smolker *et al.* 1992; Peddemors 1995; Bearzi *et al.* 1997; Wilson *et al.* 1997; Defran *et al.* 1999; Shirakihara *et al.* 2002; Hastie *et al.* 2004) due to their schooling behaviour, coastal habits and display in aquaria. Distribution patterns of cetaceans have often been correlated with underwater topography, such as abiotic features (Watts and Gaskin 1986; Ross *et al.* 1987; Gowans and Whitehead 1995; Davis *et al.* 1998; Karczmarski *et al.* 2000; Hastie *et al.* 2003) and seabed gradient (Watts and Gaskin 1986; Gowans and Whitehead 1995; Davis *et al.* 1998; Karczmarski *et al.* 2000; Hastie *et al.* 2003b). These patterns have been studied over large spatial scales. However, relatively little is known about habitat utilization at fine scales off an open coastline, i.e. tens of kilometers (Allen and Read 2000).

Numerous aerial and boat based surveys have been conducted in an attempt to estimate the bottlenose dolphin population for KwaZulu-Natal (Ross 1982; Cockcroft *et al.* 1991; 1992;

Peddemors 1993; Ross *et al.* 1997) and Durban (Booman 1998). The population estimate for bottlenose dolphins stands at 520 for the north coast (Cockcroft *et al.* 1992) and 350 for the south coast (Cockcroft *et al.* 1991). Subsequently, photo-identification and behavioural studies have suggested less discreteness of these groups than previously reported (Peddemors 1995; Booman 1998). One area of substantial over-lap of home ranges and subsequent mixing of dolphin groups is Durban (29° 50'S; 31° 2'E) (Figure 1.1). Booman (1998) estimated the number of bottlenose dolphins using Durban bay at approximately 200 individuals. A proportion of these enter the harbour apparently primarily to feed (Dix 1998). It appears that the dolphins off Durban spend most of their time feeding and travelling (Peddemors 1995; Dix 1998), however no detailed behavioural study of the bottlenose dolphins using the Durban environs has been conducted.

This study therefore investigates the movement patterns and distribution of bottlenose dolphins occurring in the open and fully exposed nearshore habitat of Durban to determine habitat utilization within this area. This coastline is quite dissimilar from regions where most other long-term studies on this species have been conducted (Chapter 1) and provides the opportunity to further evaluate the influence of habitat on bottlenose dolphin behaviour. Such data are important to understand potential impacts, including tourism activities.

Human disturbance may result in short-term changes in ranging patterns and habitat use (Constantine and Baker 1997; Barr & Slooten 1998; Samuels and Bejder 2004; Allen and Read 2000; Constantine 2001) or long-term displacement of cetaceans from preferred areas (Norris and Dohl 1980; Bryant 1984). These factors underline the importance of collecting pre-tourism data. Consequently, this work is crucial in allowing future comparisons with dolphin use of these areas following the anticipated introduction of permitted swim-with-the-dolphins eco-tourism and the booming boat-based whale and dolphin watching industry.

Methods

This study was conducted in the bay of the city Durban, primarily as this is the region most likely to be heavily impacted by any future tourism activities. The bay consists of an open stretch of coastline bordered in the north by the Umgeni River and in the south by a sandstone bluff demarcating the harbour entrance (Figure 1.1). The study area extended over 10km² with an average water depth of 25 m.

Preliminary observations were conducted between April and June 2004 to determine the feasibility of the study. Theodolite data were subsequently collected from June through to December 2004. Observations of dolphin group movements through the study area were made from an elevated land-based observation site (29° 51' 31"S and 31° 02' 23"E) situated on the south beach of Durban bay (Figure 1.1). Observations were initiated at dawn with two observers scanning the study area for dolphins using binoculars and naked eye. A Sokkisha ® DT5 30X telescope was used in this study which was located approximately 65,6m above sea level.

Once a group of dolphins was sighted, the group was then tracked for as long as possible within the study area using focal group sampling method (Altman 1975, Hanson and Defran 1993; Barco *et al.* 1999; Acevedo and Parker 2000). A group was defined as any school of dolphins observed in apparent association, moving in the same direction and often but not always, engaged in the same behaviour. The tracking team consisted of a theodolite operator and a scribe. The theodolite operator located the position of dolphins during each surfacing, while the scribe recorded the time, group size, position, and behaviour of the dolphin group. Environmental conditions were also recorded on an hourly basis.

To standardise and allow comparison with published research (Norris and Dohl 1980; Bryant 1984; Shane *et al.* 1986; Ballance 1990; Acevedo 1991; Smolker *et al.* 1992; Peddemors 1995; Bearzi *et al.* 1997; Constantine and Baker 1997; Wilson *et al.* 1997; Barco *et al.* 1999; Defran and Weller 1999; Samuels and Bejder 2004), behaviours were categorised when more than 50% of the group were engaged in the same activity i.e. the dominant behaviour in the group. The behavioural categories recorded follow those defined by Shane *et al.* (1986) and are defined as follows:

(1) Fast Travel: School moves in a constant direction, swimming with short, relatively constant dive intervals.

(2) Slow travel: Very slow movement or drifting in one direction and by a slower respiratory roll through the air / water interface, while maintaining a fixed course of direction. The dolphins are engaged in slow movements generally lacking components of other types of described behaviour.

(3) Resting: Dolphins do not move or swim, but float on the surface for extended periods while breathing more shallow and frequently. Respirations are usually synchronous between individuals

within a group. Movement in various directions in one location, but showing no surface behaviours and no apparent physical contact between individuals, usually staying close to the surface.

(4) Milling/Undetermined: Dolphins do not move in any particular direction, individuals within a group continuously change their direction, school often changes direction, dive intervals variable but short; group spacings vary.

(5) Socializing: Some or all group members in almost constant physical contact with one another, oriented towards one another, and often displaying surface behaviour, socially directed swimming, coughing and tail slapping. Includes periods when the majority of the school appear to be in play behaviour, incorporating leaping, tail or pectoral fin slapping, chasing spy-hopping and bow-riding of boats, plus mating behaviour.

(6) Feeding/foraging:

(i) Repeated diving in varying directions in one location and often making tail-stock dives or flukes-up dive.

(ii) Swimming at high burst speeds along erratic courses, often including hair-pin turns.

Following the methods used by Karczmarski *et al.* (2000), the stretch of coastline was divided into 6 sectors, each approximately 1km in length. A coefficient of Area Use (AU), which ranges from 0 to 1, was calculated. This represents the time engaged by dolphins in a particular sector as a proportion of the total observation time in that day. This was expressed as $AU = D/T$, where D is the time spent by dolphins in a particular sector, and T, the total observation time in any one day. Dolphin behavioural activity associated with each fixed point was expressed as a frequency. Results were then analysed for significant variations within and between sectors, as well as within and between behaviours using Kruskal-Wallis ANOVA and test for correlations by Pearson correlation tests.

Results

Three hundred and forty one hours were spent surveying the study area for bottlenose dolphin groups between April and November 2004. Of this, one hundred and forty hours were conducted during the preliminary study between April and June 2004. These initial data indicated that bottlenose dolphins primarily used the Durban bay between sunrise and midday. Subsequently, this was the focal period of search effort, leading to only data from June to November 2004 being presented in this chapter to ensure comparable data were used.

Searches were conducted over 201 hours on 43 days during the six month period (17, 33, 34, 64.5, 57.5 and 5 hours in June, July, August, September, October and November, respectively). Bottlenose dolphins were encountered on 72% of all surveys and dolphins were only absent on 12 occasions on days that weather conditions allowed observer effort. A total of 37 groups were encountered and in most cases only one group was sighted per survey. Dolphin groups were successfully tracked for 26.8 hrs. Each group remained in the bay for an average of 43.5 minutes. A total of 3196 theodolite readings were made while tracking dolphins.

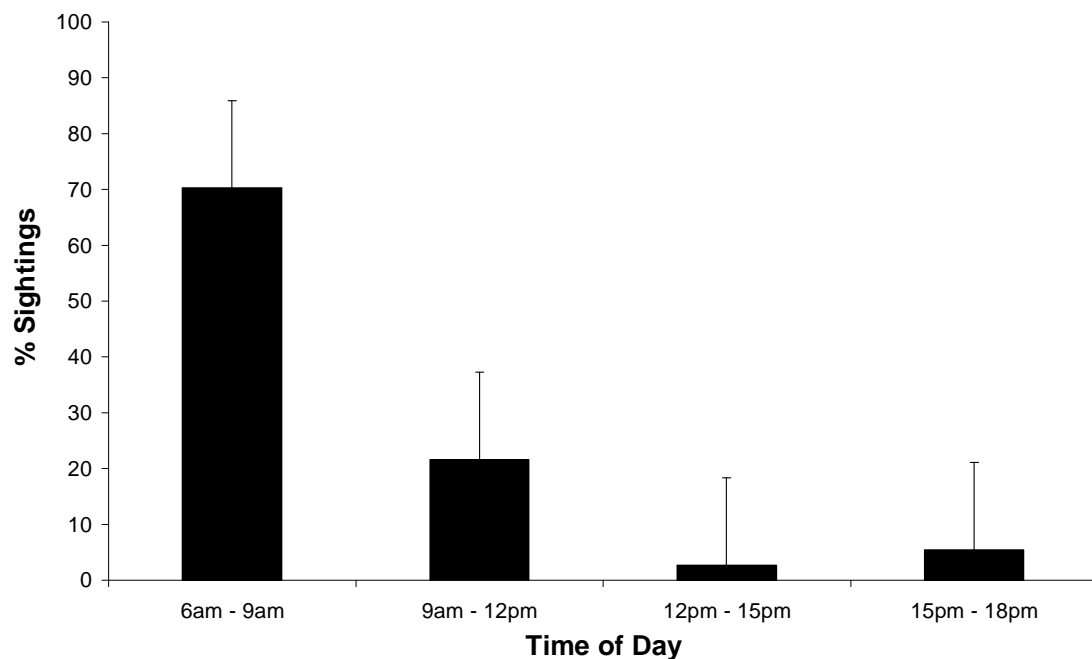


Figure 3.1: Average distribution of bottlenose dolphin sightings in the Durban bay region over the day. Error bars indicate 95% CI of the mean.

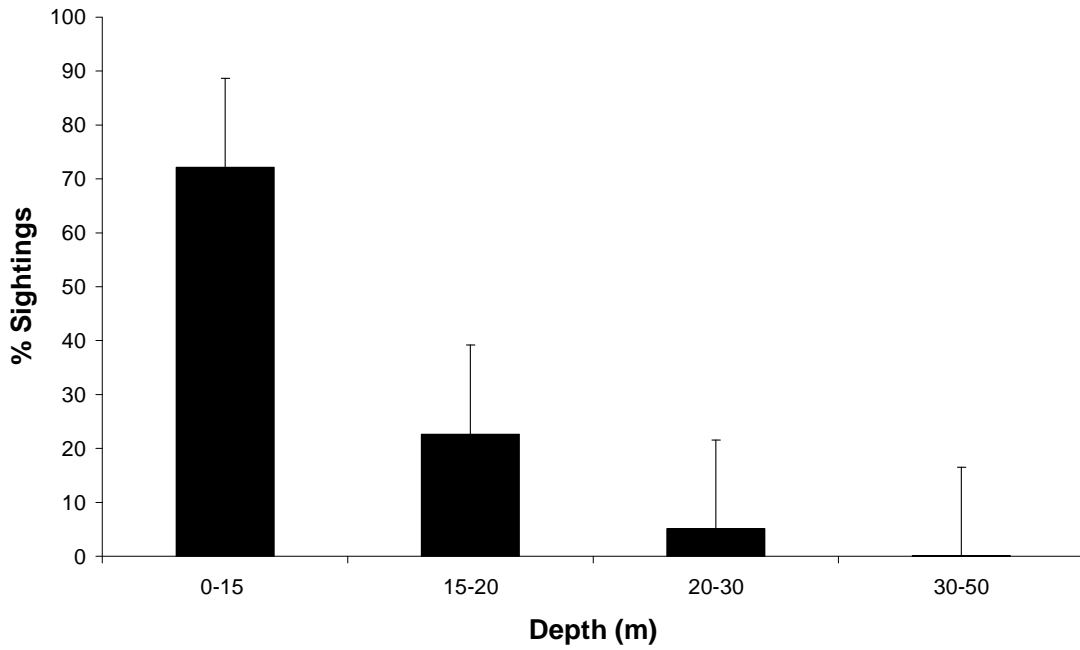


Figure 3.2: Average distribution of bottlenose dolphin sightings relative to water depth within the Durban bay region. Error bars indicate 95% CI of the mean.

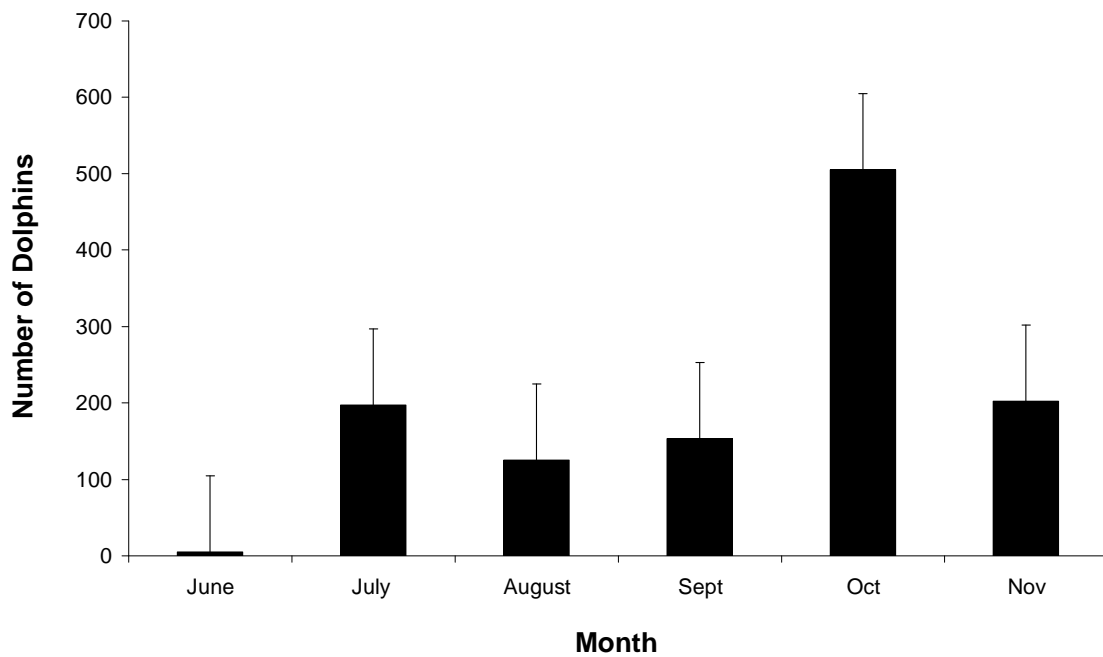


Figure 3.3: Mean monthly bottlenose dolphin group sightings off Durban between June and December 2004. Error bars indicate 95% CI of the mean.

Dolphins were seen in all months surveyed and throughout the survey area. Temporal distribution of sightings was skewed with 91% of dolphins seen before midday (Figure 3.1) and 98% of sightings were observed in water depths less than 30m (Figure 3.2). Land-based tracks revealed peak bottlenose dolphin abundance during October, with October also corresponding to a higher searching effort (Jun: $n = 2$, Jul: $n = 6$, Aug: $n = 7$, Sept: $n = 12$, Oct: $n = 17$, Nov: $n = 13$) (Figure 3.3).

The mean group size of bottlenose dolphins off Durban Bay is approximately 40 individuals (SD ± 28.32). There was no variation in group size relative to the time of day they were seen (Pearson's correlation, $r = 0.118$, $n = 35$, $p = 0.25$) (Figure 3.4), but monthly variations showed that group sizes increased during spring towards summer, i.e. September – November ($r = 0.364$, $n = 35$, $p = 0.031$) (Figure 3.5). Group size was also significantly correlated to depth, with larger group sizes found further from shore ($r = 0.063$, $n = 3100$, $p < 0.001$) (Figure 3.6), but not correlated with tidal data ($r = 0.014$, $p = 0.48$).

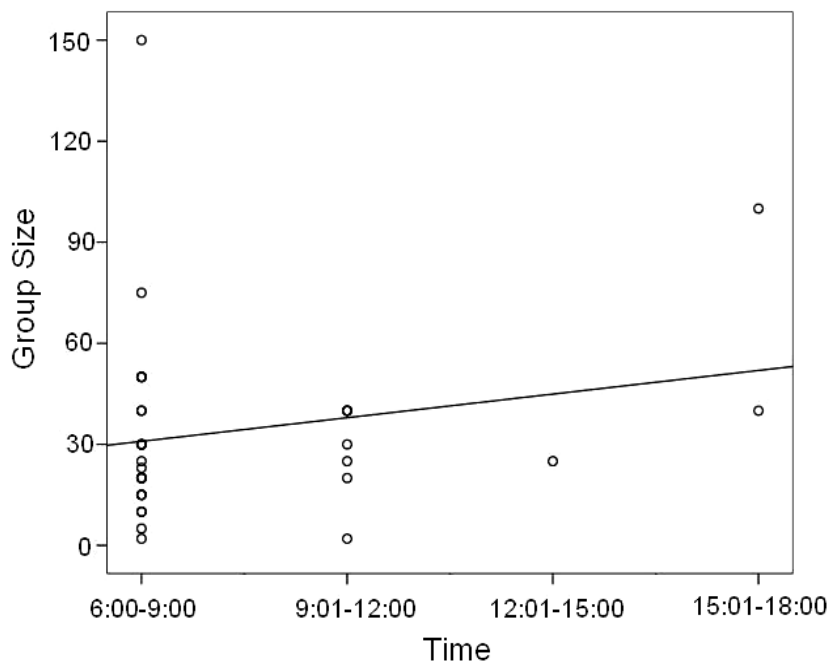


Figure 3.4: Variation in bottlenose dolphin group sizes off Durban relative to the time of day.

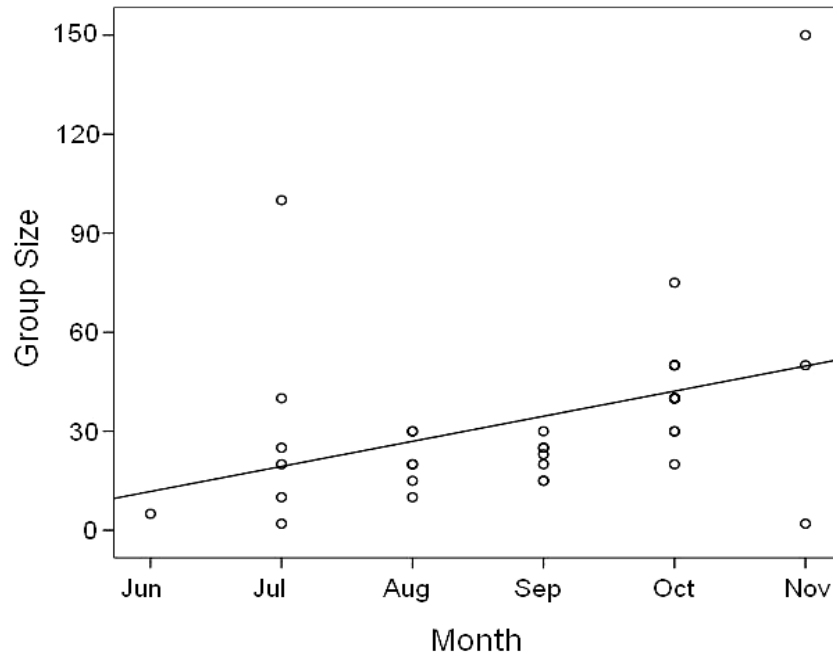


Figure 3.5: Monthly variation in bottlenose dolphin group size off Durban.

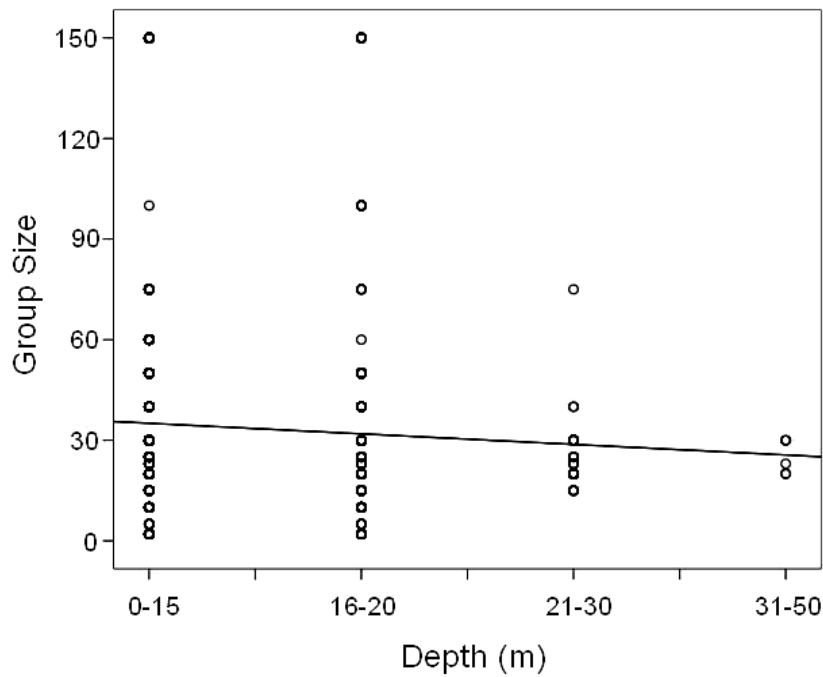


Figure 3.6: Variation in bottlenose dolphin group size according to depth.

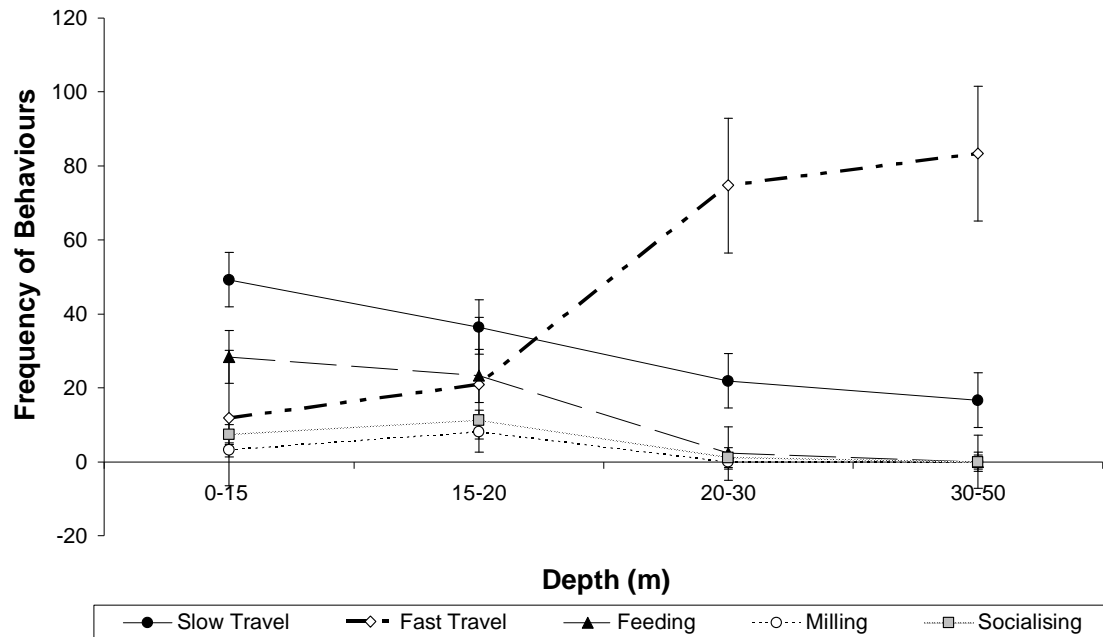


Figure 3.7: Observed bottlenose dolphin behavioural frequencies according to water depth. Error bars indicate 95% CI of the mean.

When dolphins were seen venturing in water depths greater than 30m (i.e. > 1.5 – 2 km offshore) the behavioural state was always travelling (Figure 3.7). Of the six behavioural categories only one, resting, was not observed at all within the study area. The most dominant behaviour overall exhibited by dolphins was slow travel (44%) followed by feeding (27%) (Figure 3.8).

Dolphin activity was not evenly distributed over the six sectors in the Durban bay region. When the study area was divided into northern (Sector 1 - 3) and southern (sector 4 - 6) regions there were highly significant variations in area use (AU) between these areas, with dolphin use of the southern region of Durban Bay being significantly higher ($t = 8.133$, $n = 250$, $p = < 0.001$) (Figure 3.9).

There was a very high significant correlation between behaviour and depth ($t = 1.51$, $n = 3123$, $p < 0.001$) (Figure 3.7). The frequency of fast travel increased with the increase in depth ($p < 0.001$) and slow travel decreased with a decrease in depth ($p < 0.001$). There were significant differences between behaviours displayed by the dolphins for both their frequency ($t = 2.772$, $n = 250$, $p = 0.050$) (Figure 3.8) and duration ($KW = 47.91$, $n = 121$, $p < 0.0001$) (Figure 3.10). The

average group speed for each of the behaviours was not fairly constant (Figure 3.11). Milling (ANOVA, $n = 116$, $p = 0.001$) and socializing ($n = 235$, $p = 0.007$) are substantially slower than fast travel. As expected there was a significant difference between slow travel and fast travel (ANOVA, $n = 1491$, $p = 0.018$) but speed of movement between fast travel and feeding were not significantly different ($n = 1491$, $p = 0.074$).

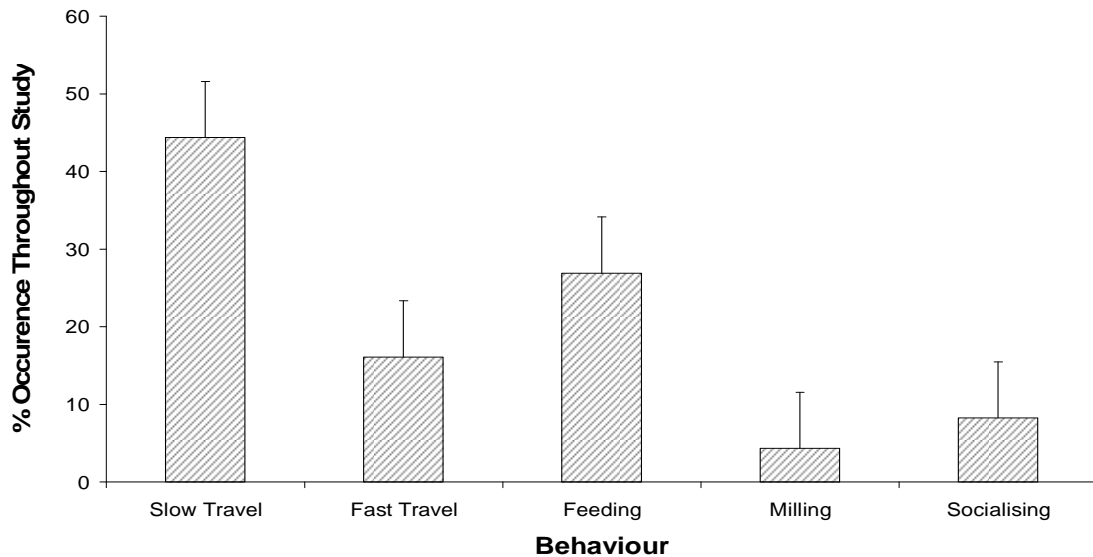


Figure 3.8: Observed Behavioural frequency of occurrence as a percentage of the total activity repertoire of bottlenose dolphins. Error bars indicate 95% CI of the mean.

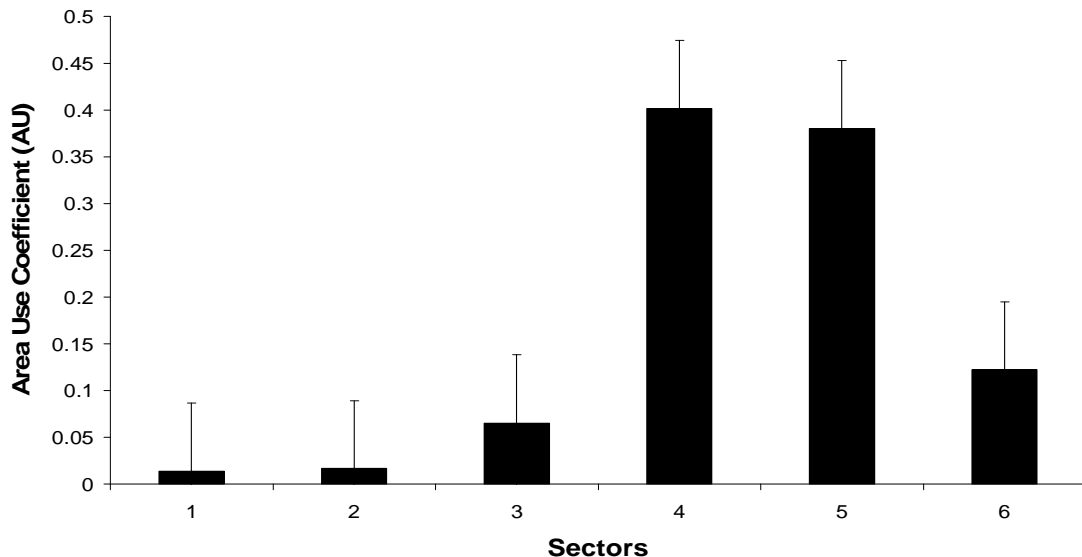


Figure 3.9: Mean coefficient of area use displayed by bottlenose dolphins over the Durban bay study site. Error bars indicate 95% CI of the mean.

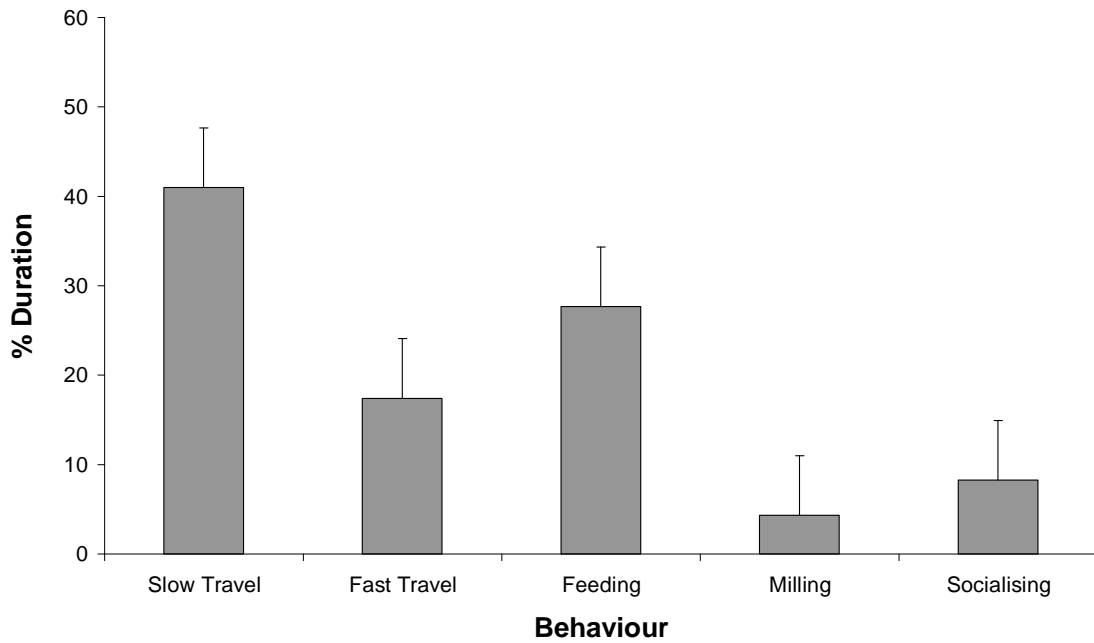


Figure 3.10: Average time spent by bottlenose dolphins in each observed behavioural category, as the percent duration of the total time spent observing dolphins. Error bars indicate 95% CI of the mean.

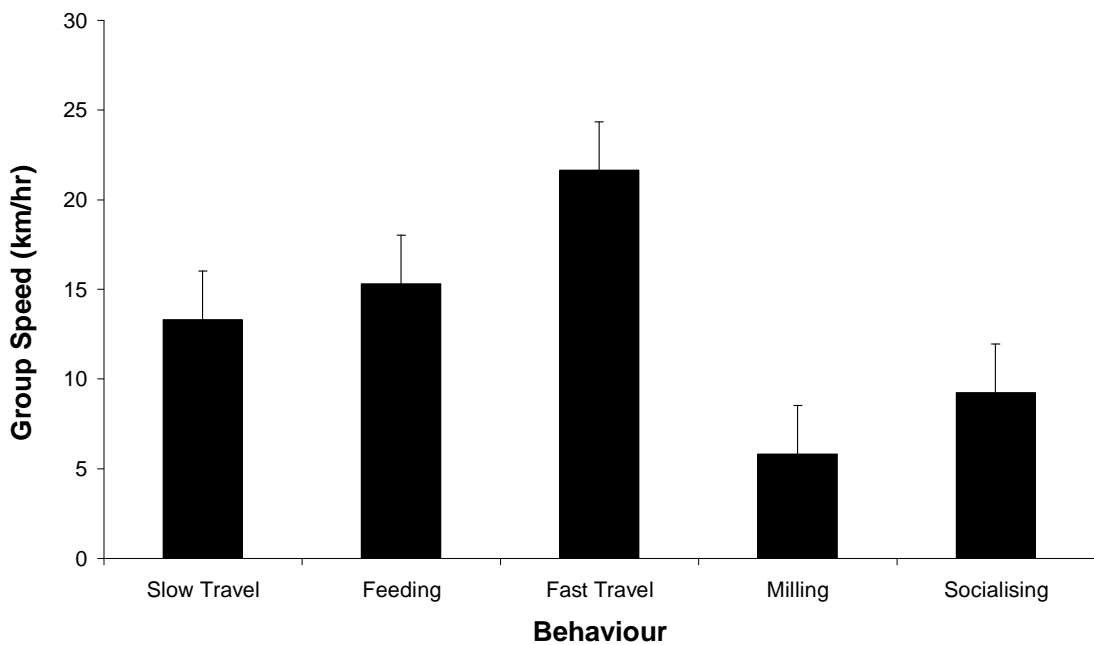


Figure 3.11: Average group speed of bottlenose dolphin movement during each observed behavioural category. Error bars indicate 95% CI of the mean.

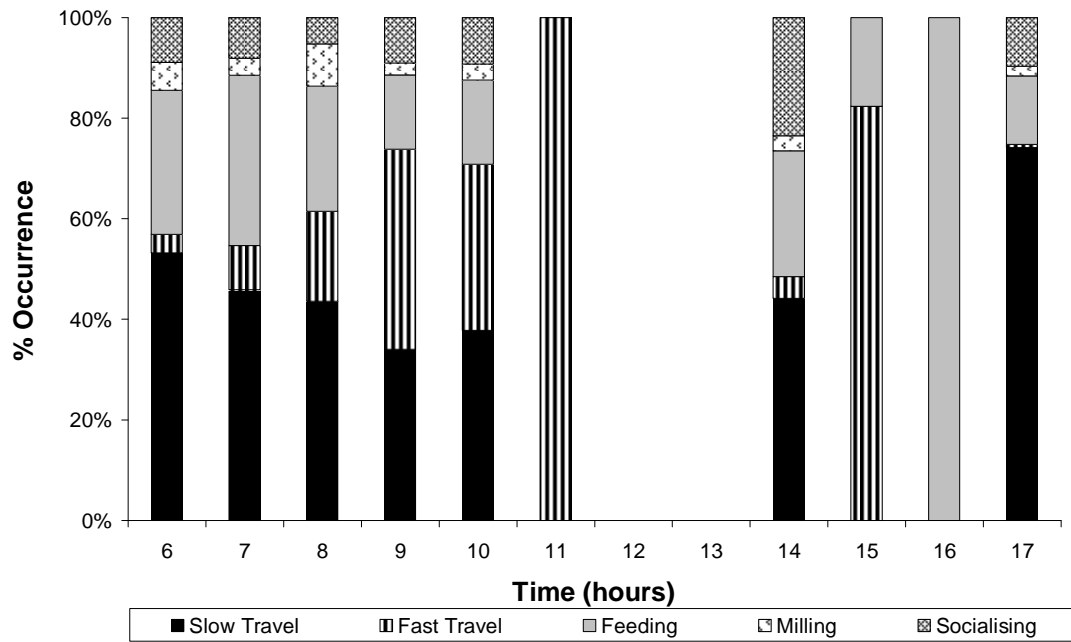


Figure 3.12: Frequency of behaviours within the daily activity budget of bottlenose dolphins within the study area.

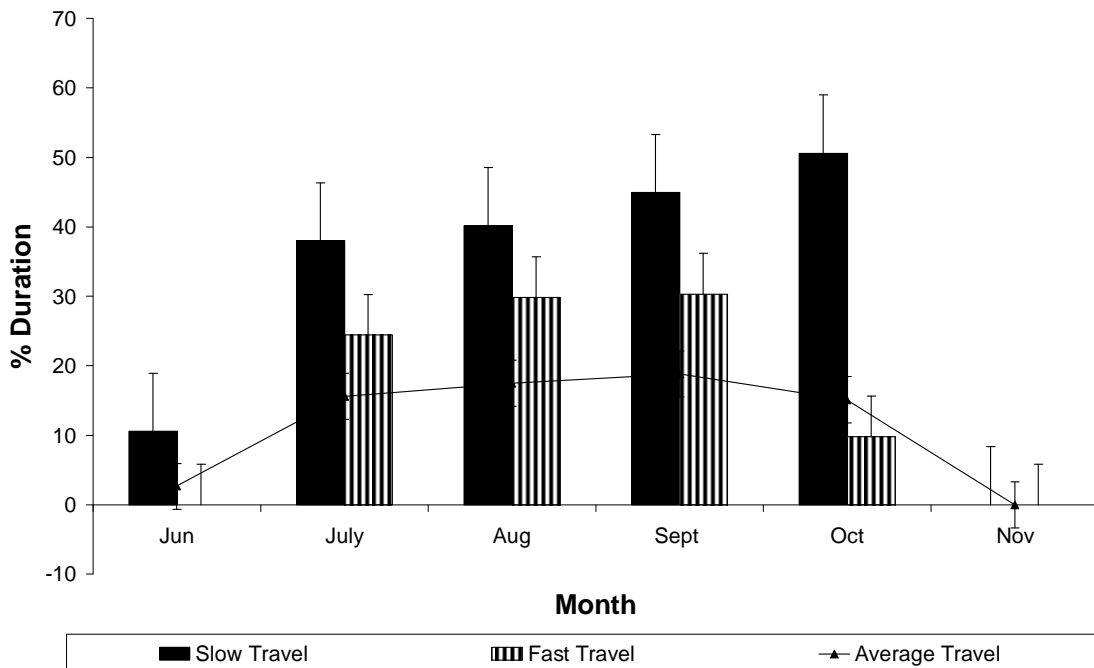


Figure 3.13: Monthly variation in the occurrence of all forms of travel behaviour exhibited by bottlenose dolphins. Error bars indicate 95% CI of the mean.

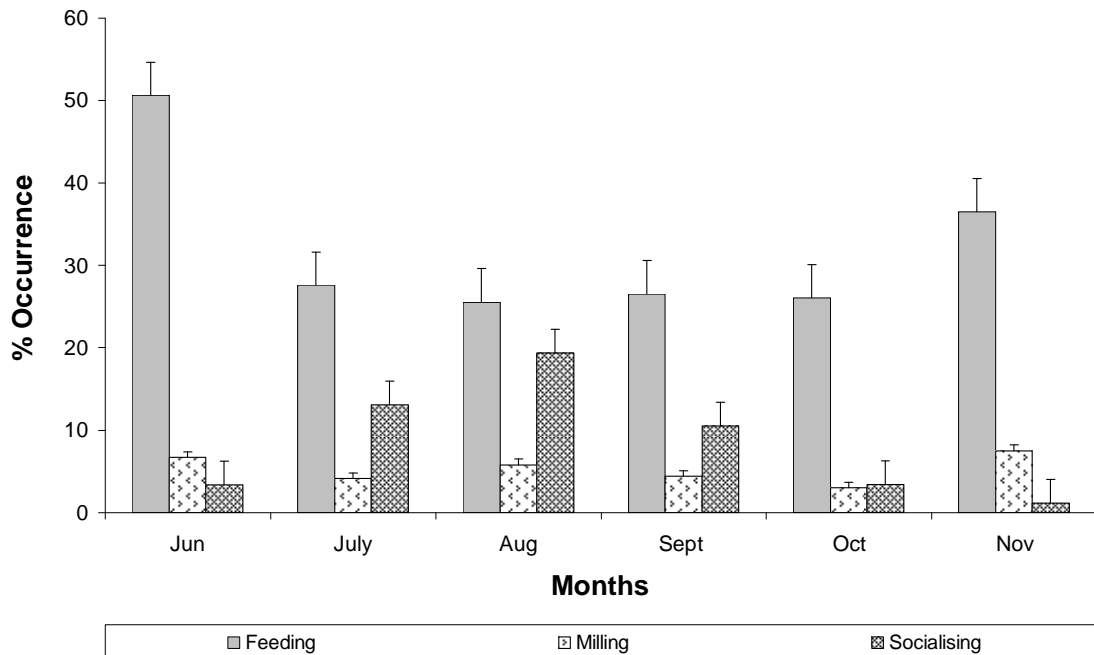


Figure 3.14: Monthly variation in the occurrence of the remaining three behaviours (feeding, milling and socialising) exhibited by bottlenose dolphins. Error bars indicate 95% CI of the mean.

Travelling (Fast/Slow):

Almost 62% of all observed behaviours consisted of travelling (46% slow and 16% fast) (Figure 3.8). Travelling occupied 59% of the time that dolphins were followed (Figure 3.10). There was no consistent overall direction observed in the travel, however, 73% of the surveys observed dolphins groups moving from north to south. There was a sharp increase in travel behaviour during mid winter (July and August) to early spring (Sept) that sharply decreased thereafter (Figure 3.13). This is inversely correlated to feeding (Pearson’s correlation, $n = 37$, $p = 0.001$) (Figure 3.14). Although travelling behaviour occurred throughout the study area (Figures 3.16 & 3.17), more time was spent slow travelling in sectors 2, 3 and 6 (Figure 3.15a), whereas fast travel was greatest in sector 4 (Figure 3.15b). Travel was the only behavioural category recorded in deeper water further from shore. The greater percentage of offshore movements consisted of fast travel and it appears that slow travel tends to be more inshore and perpendicular to the coast (Figure 3.16). The movement of dolphin groups towards shore were ‘fast’ (Figure 3.17) whilst movement offshore was at variable speeds.

Feeding:

Feeding was the second most dominant behaviour exhibited by bottlenose dolphins in Durban Bay, comprising 27% of both the frequency of occurrence and the time (Figures 3.10 and 3.12). There appeared to be a diurnal pattern to feeding behaviour, with increased activity concentrated in the early morning (48%) (Figure 3.12). Although the percent frequency of feeding averaged around 16% of all behaviours throughout the study period, feeding behaviour exhibited a decrease in occurrence from July to October (i.e. Mid-winter to early spring) (Figure 3.14). Feeding occurred throughout the study region (Figure 3.18), however the time spent feeding was greatest within sector 4 and 5 (Figure 3.15 b). These sectors coincide with reef bottoms (Vetchy's Pier and Limestone Reef) (Figure 1.1).

Milling:

Dolphins milled occasionally, mostly during or immediately after feeding and around mid morning (Figure 3.12). Milling behaviour was fairly constant throughout the study period varying between 5 and 8% (Figure 3.14). This behaviour occurred throughout the study area (Figures 3.15d and 3.19) but was the least displayed behaviour of the five recorded for dolphins off Durban (Figure 3.8).

Socialising:

Within the daily activity budget, social activities peaked at 7 am, but generally decreased in frequency during the day (Figure 3.12). Socialising occurred fairly constantly during the study period (Figure 3.14) but was inversely proportional to feeding. Social behaviour was not evenly distributed throughout the study area, with a significant decrease ($n = 34, p < 0.001$) recorded in the northern half of Durban Bay (Figures 3.15e and 3.20).

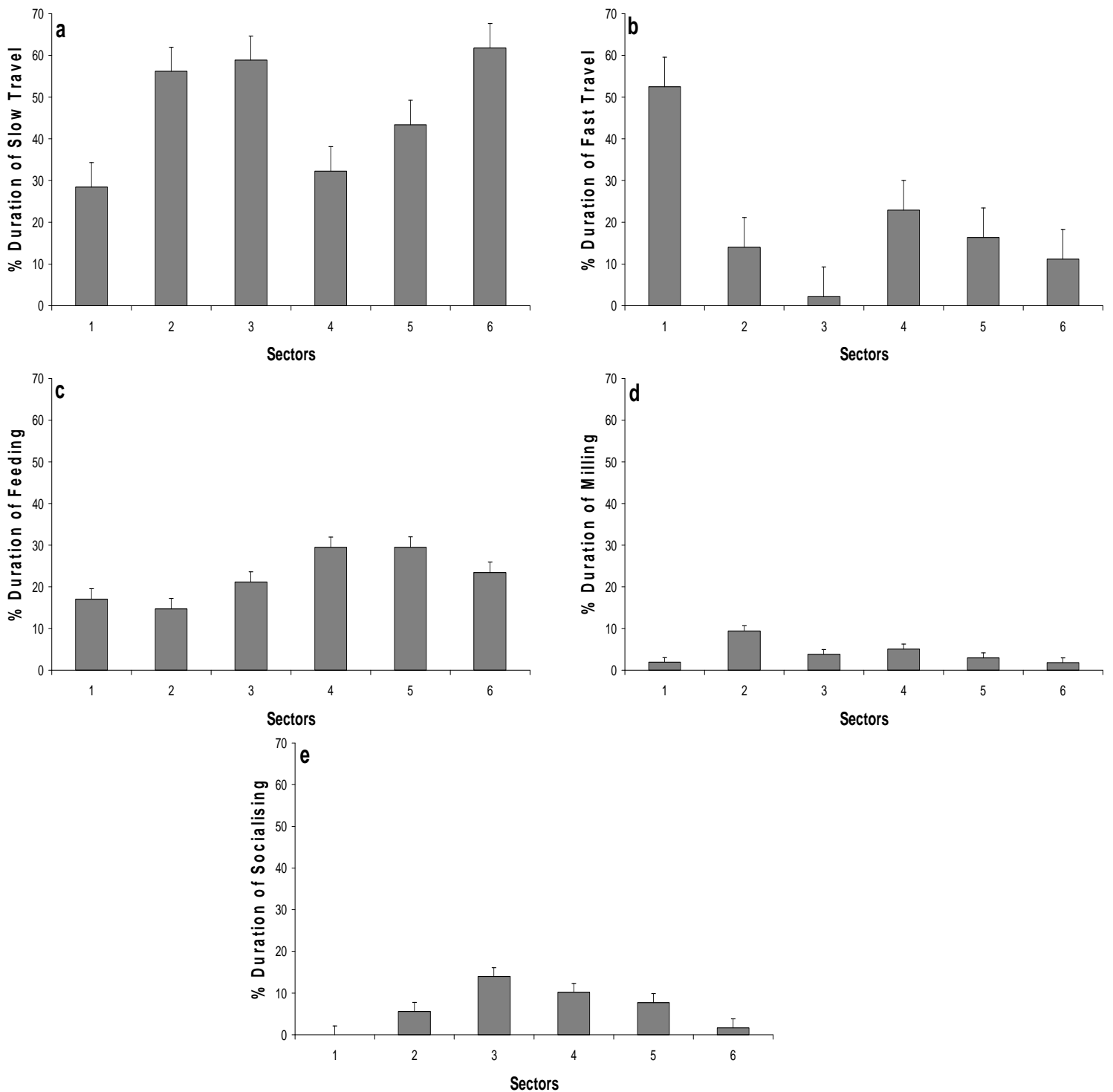


Figure 3.15: Average time spent by dolphins in each observed behavioural category (a) slow travel, (b) fast travel, (c) feeding, (d) milling, and (e) socialising; in each sector in the Durban bay. Error bars indicate 95% CI of the mean.

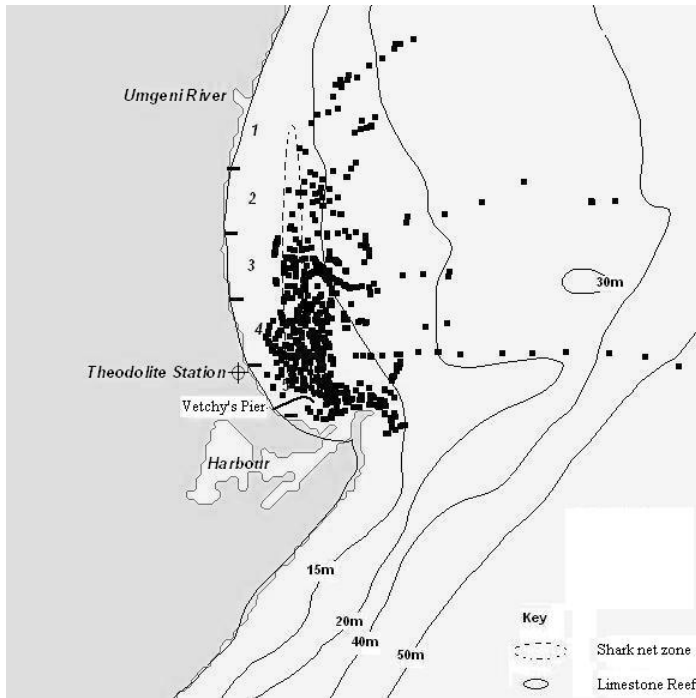


Figure 3.16: Visual representation of the distribution of slow travelling bottlenose dolphin groups off Durban throughout the study period.

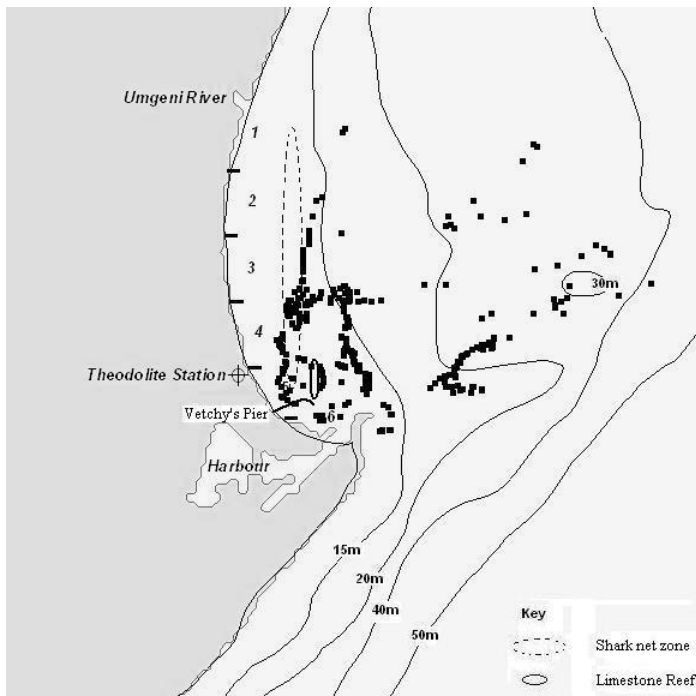


Figure 3.17: Visual representation of the distribution of fast travelling bottlenose dolphin groups off Durban throughout the study period.

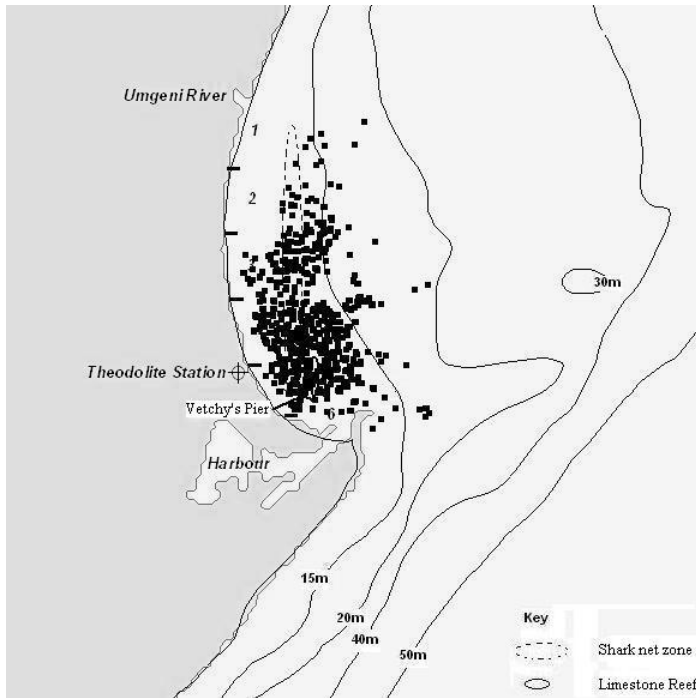


Figure 3.18: Visual representation of the distribution of feeding bottlenose dolphin groups off Durban throughout the study period.

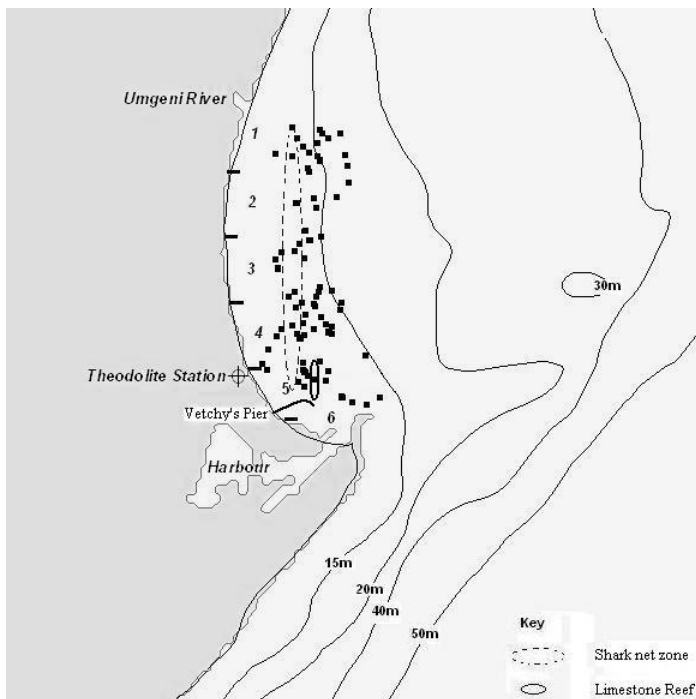


Figure 3.19: Visual representation of the distribution of milling bottlenose dolphin groups off Durban throughout the study period.

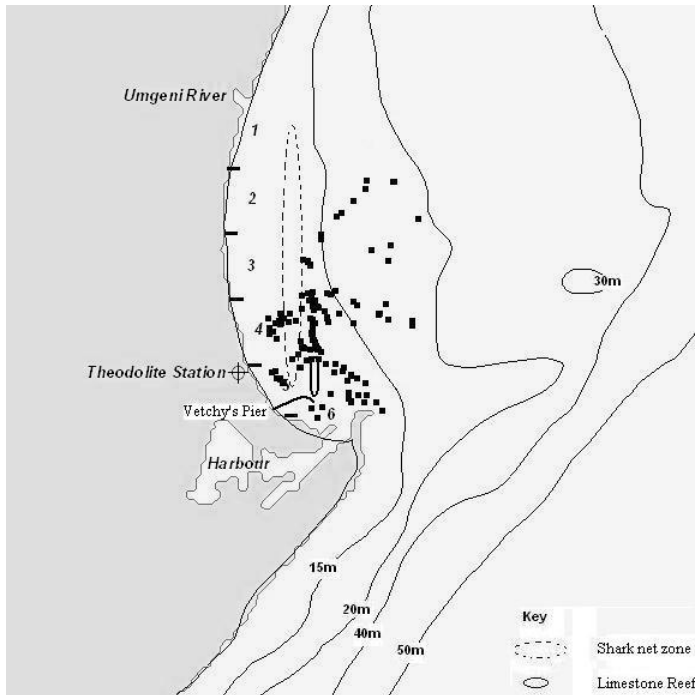


Figure 3.20 Visual representation of the distribution of socialising bottlenose dolphin groups off Durban throughout the study period.

Discussion

Bottlenose dolphins were observed throughout the Durban bay with the animals primarily using water depths of less than 30 m (within 1km of shore). All offshore occurrences were of travelling dolphin groups. Similarly, aerial surveys off the KwaZulu-Natal coast have indicated that bottlenose dolphins preferentially stay within the 30 m isobath (Ross *et al.* 1987), but that they may be seen in deeper water en route to offshore reefs (Cockcroft *et al.* 1991). Elsewhere in the world the coastal form of bottlenose dolphin also appears to favour waters less than 30m in depth, e.g. off Argentina (Würsig and Würsig 1979) and off San Diego (Defran and Weller 1999).

Group sizes for bottlenose dolphins reportedly range from 1 to over 100 individuals (Corkeron 1999; Connor *et al.* 2000) but Shane *et al.* (1986), dos Santos and Lacerda (1987), Smolker *et al.* (1992) and Allen (2005) reported most commonly smaller groups of 2-15, 1-20, 2-5 and 2-7 dolphins respectively in enclosed waters. The mean group size for bottlenose dolphins off Durban was larger than for most other inshore bottlenose dolphin populations. Coastal nearshore dolphins off San Jose, Argentina (Würsig and Würsig 1978), the Gulf of California (Ballance 1990),

Esenada De La Paz, Mexico (Acevedo 1991), San Diego, California (Defran and Weller 1999) and Amakusa, Japan (Shirakihara *et al.* 2002) assemble in schools similar in size to those observed in Durban and off the east coast of South Africa (Peddemors 1995). In contrast, considerably smaller mean group sizes have been reported for study areas in Texas (Shane 1980; Fertl 1994), the northern Adriatic Sea (Bearzi *et al.* 1997), Florida (Irvine *et al.* 1981; Wells 1986; Wells *et al.* 1987; Shane 1990; Ester and Wells 2001;), Shark Bay, Australia (Smolker *et al.* 1992; Mann *et al.* 1999) and New South Wales, Australia (Allen and Harcourt 2001, Allen 2005). Ecological factors such as habitat structure, rates and types of predation, quality and ease of food being located are prime influences of social behaviour, and in general, group sizes tend to increase with increased water depth and openness of the habitat (Shane *et al.* 1986).

Careful consideration of reported group sizes and the habitat in which the study was conducted suggests that the inshore bottlenose dolphin groups in sheltered coastal waterways tend to be smaller than those for animals residing in open coastal waters. This variation may be explained as follows. For example, river dolphins live in shallow, structural complex habitats that offer escape routes or hiding places from predators, with low apparent rates of predation, and with prey more or less evenly dispersed. These dolphins are solitary or either found in small groups (Corkeron 1999; Wei *et al.* 2002). Inshore dolphins, which live in protected coastal waterways, are normally found in groups of tens. Their habitat is slightly more open, prey patches are slightly larger and more clustered, and predation pressure is potentially greater. The larger group sizes for coastal bottlenose dolphins, such as those found off Durban, could be due to the habitat being more open and fully exposed than the latter coastal areas. These groups of dolphins could be termed as coastal nearshore populations rather than inshore (Chapter 1). By contrast, pelagic dolphins are usually found in much larger groups, up to thousands of individuals, in very open habitats where huge prey patches are distributed in clumps, alienated by vast stretch of ocean, and predation pressures are assumed to be more extensive (Corkeron 1999).

Although dolphins were never absent from the Durban bay region, the number of dolphins increased markedly in the summer. Comparable seasonal influxes have been reported from several other studies (Ballance 1990; Acevedo 1991; Wilson *et al.* 1997; Barco *et al.* 1999). Such changes have been attributed to spatial variations in local conditions and topography, resulting in certain areas being more suitable for predator avoidance (Ross 1979), the rearing of offspring (Scott *et al.* 1990; Barco *et al.* 1999), mating (Mann *et al.* 1999) and foraging (Allen *et al.* 2001; Hastie *et al.* 2003).

Durban Bay's coastal zone is characterised by a semi-sheltered sandy shoreline. Travel was the dominant behaviour exhibited by observed dolphins, with relatively low levels of feeding observations; this implies that the Durban bay is mainly used as a thoroughfare for the dolphins as they move to adjacent areas potentially more suitable for foraging. This corroborates previous assertions that travelling is primarily a function of locating food and conspecifics (Shane 1990b; Hanson and Defran 1993; Bearzi 2005). The proportions of time spent travelling and feeding in this study off Durban are similar to those recorded elsewhere for coastal nearshore bottlenose dolphins. Hanson and Defran (1993) found that travel and feeding accounted for 69% and 19% of the total dolphin activity off San Diego, while off Santa Monica Bay bottlenose dolphins spent 63% of time travelling and 16% feeding (Bearzi 2005). Hanson and Defran (1993) assumed that these consistent proportions of behavioural states across months and seasons were likely to have been related to a year round occurrence of prey. Bearzi (2005) postulated that the large amount of time spent travelling off Santa Monica may have been related to food searching or feeding activities. This study off Durban suggests that prey abundance and distribution may, indeed, affect the proportion of time spent travelling.

The average speed of travel for bottlenose dolphins in Durban Bay (13.5 km/hr) is higher than that recorded for this species elsewhere in the world. Off Santa Monica bottlenose dolphins travel at an average of 4.3 km/hr (Bearzi 2005) while off the Northern Adriatic Sea they travelled at 7.15 km/hr (Bearzi *et al.*, 1999). Average travel speeds of 5.5 km/hr were recorded for dolphins off Sanibel Island, Florida (Shane 1990a) while dolphins off Argentina averaged 6.1 km/hr (Würsig and Würsig 1979). It may be argued that bottlenose dolphins in the study area travelled at higher speed because of their familiarity of the study area, which is open in nature with apparently few foraging opportunities. Peter (2007) further elucidated the familiarity of bottlenose dolphins off Durban with the study area by showing that dolphins move well within 10 meters of any of the shark nets permanently set off Durban Bay to protect bathers (Peddemors 1995). He also showed that bottlenose dolphins appeared to take a preferred route through the Durban shark net installation. A similar concept of preferred routes followed by bottlenose dolphins when travelling between foraging areas was raised by Peddemors (1995) following the tracking animal movements off the Durban Bluff.

Although dolphins spent less time in the study area as the day passed, most travelling bouts were recorded before midday. The frequency of travelling increased from winter (Jun) towards summer (Nov). Similar spring and summer increases in travelling have previously been recorded for the

KwaZulu-Natal coast (Peddemors 1995) and at other study sites such as San Diego (Hanson and Defran 1993) and Florida (Shane 1990b). In Florida this was assumed to be due to the spreading of prey resources in the warmer waters, consequently increasing the travelling time between bouts (Shane 1990b). In Durban a similar inter-dependency between travel and feeding appears to be prevalent. Even though Durban appears to be primarily used as a thoroughfare for bottlenose dolphins, it is also used as a feeding area during the early mornings and, to a limited degree, in the late afternoons. Temporal variations in feeding activities have also been reported elsewhere. Off Sanibel Island, Florida, bottlenose dolphins spent 40% of their feeding during morning and midday periods, with a drop in feeding only occurring during the afternoon and evening (Shane 1990b). Clement and Morris (1998) also observed that temporal utilization of habitats was significantly dependent on time of day. In San Diego, Hanson and Defran (1993) found that feeding peaks occurred in the early morning and late afternoon, with both peaks being similar in the time spent in this activity. The early morning and late afternoon peaks recorded in this study off Durban are similar to the feeding times found by Saayman and Taylor (1973) in the Eastern Cape of South Africa, where it was suggested to be related to the availability of food. Indeed, these times for increased foraging activity could be due to the susceptibility of capture of both diurnal and nocturnal fishes at dawn and dusk because of low light levels (Shane 1990b). Peddemors (1995) observed that feeding was almost always initiated at reefs and popular shore-angling sites in KwaZulu-Natal, which indicated that particular bottom topographies were required for increased prey. Although bottlenose dolphins are considered catholic in their diet and are likely opportunistic feeders, in KwaZulu-Natal they primarily feed on benthic reef fish (Cockcroft and Ross 1990) suggesting they do appear to primarily feed at particular sites. Comparable feeding activities were found in San Diego where dolphins fed more in reefs and estuary areas and less in sand areas (Hanson and Defran 1993). It was proposed that the sandy shoreline offers fewer prey resources and movement of coastal dolphins may be related to food resource availability. In this study, the time spent feeding was greatest near reefs, which are also close to the harbour mouth, a large natural estuary.

During this study the tracking of 4 groups of dolphins ceased when dolphins were last seen at the harbour entrance. This may well suggest that the dolphins entered the harbour. Bottlenose dolphins have been reported in the Durban harbour which they appear to use as an alternative foraging area (Dix 1998). Dix (1998) observed that these animals spent a greater amount of time in travelling and feeding than in social activities. Ballance (1992) also observed that 61% of all behaviour observed near estuaries was feeding. Estuaries are sites of large concentrations of

nutrients which support great numbers of filter feeding zooplankton and fish (Whitfield 2005). Presumably it is these large concentrations of potential prey which attract dolphins to these habitats. The seasonal variation in feeding observed during this study may be linked to variations in prey availability. During the months of June through August there is an increased abundance of fish in association with the annual sardine migration (Beckley and van der Lingen 1999). As the sardines rarely enter Durban Bay, this abundance of prey elsewhere in the home range of the bottlenose dolphins may lead to a reduced requirement on potentially marginal feeding habitat. This hypothesis would explain the decreased feeding activity seen during what is generally considered a period of prey abundance. Similar seasonal changes in observed feeding have been recorded and linked to prey availability in other studies (Hastie *et al.* 2004).

Milling behaviour was predominantly recorded either during or immediately after feeding. Despite the function of milling still not being clearly understood; milling was scored most during the early morning. This variation within the day closely resembles that found for feeding; suggesting that, in many cases, milling may possibly be a feeding associated behaviour. Similar observations have been made elsewhere. In what we described as milling, in Sarasota Bay Nowacek (2002) divided the behavioural activity and termed as 'pinwheel' and 'side swim'. He found that both these behaviours displayed high rates of occurrences during feeding or a probable feed. Likewise, Acevedo and Parker (2000) observed that milling; in conjunction with other defined feeding categories were related to spatial arrangement and location of prey. In an earlier study off KwaZulu-Natal, Peddemors (1995) also suggested that milling could be a predominantly feeding related behaviour. These observations suggest that future studies may legitimately combine milling with feeding behaviour for analysis.

Although socialising probably occurs continuously in dolphin schools, less than 10% of observations in this study included social activity. Social interactions between dolphins almost certainly occur throughout the day, but usually go unobserved in short term-studies. Only extensive, long term-studies such as those in Shark Bay, Australia (Connor and Smolker 1985; Smolker *et al.* 1992) and Sarasota, Florida (Shane *et al.* 1986; Wells 1991) can elucidate such associations between individuals.

Dolphins socialise for reproductive purposes, as well as for protection, efficient food-gathering, learning and possibly for other undiscovered reasons (Wells 1991). An increase in social activity during late winter was the only pronounced seasonal effect in Durban. Other coastal bottlenose

dolphin populations display spring, summer and winter increases in calving or social activity. In Aransas Pass, Texas, the mating activity of dolphins peaked during the spring and summer (Shane 1990b). Off the west coast of Florida bottlenose dolphins showed increased calving during spring through early autumn (Scott *et al.* 1990). In contrast to these spring through autumn social activity and calving peaks, dolphins off Sanibel Island socialised more during the autumn and winter (Shane 1990b). Both Shane (1990a) and Saayman *et al.* (1973) suggested that seasonal variation in dolphin behaviour might be linked to seasonal changes in water temperature and prey abundance.

Socialising occurred in particular areas with no social activity observed towards the northern boundary (sector 1) of the study site. The low number of dolphin group sightings in the northernmost sector of the study area may be linked to an increased water turbidity in that region due to the outflow of the Mgeni River. Ross (1977) and Cockcroft (1992) documented that bottlenose dolphins avoid turbid water off the coast of KwaZulu-Natal. This behaviour has been interpreted as predator avoidance behaviour (Cockcroft 1992) but has also been attributed to potential reduced prey abundance and reduced prey detection capabilities in turbid water (Peddemors 1995). This study supports the hypothesis that bottlenose dolphins off KwaZulu-Natal tend to avoid turbid waters, leading to skewed distributions and habitat use along the coast.

The population of bottlenose dolphins off Durban appears to use the bay year-round (Peddemors 1995; Boonman 1998). Although residency patterns for individual animals require further research, preliminary investigations have suggested that at least 200 dolphins use the Durban bay (Peddemors 1995; Boonman 1998). Since boat and ship traffic continues to increase off the coast of Durban, the potential for impacts on these residents also grows. As a pre-requisite for determining “disturbed” behaviour, a comprehensive understanding of “normal” behaviour is essential, information that is inevitably lacking for nearly all species of cetaceans (Bejder 2005). This study provides such base-line data and indicates that different sectors of the bay are used differentially. The occurrence of preferred areas, particularly for feeding and resting, could have important implications on dolphin responses to and potential injury from boats.

Dolphins are probably disturbed most during feeding if they are actively engaged in fish tracking, during which time they apparently use transmission of sonar and there is a lack of processing of peripheral sensory information (Goodson *et al.* 1994). Disturbance of feeding activity could have potential long-term impact on the health of dolphins, suggesting that boat traffic should be

minimised in regions of known foraging hot-spots. This is corroborated by Allen and Read (2000) who showed that dolphins decrease their use of primary foraging habitats during periods of high boat density near Clearwater, Florida. The present study suggests that the area immediately north of the harbour entrance constitutes the primary feeding area for bottlenose dolphins using Durban bay. These data should therefore be taken into consideration in any management plans for the development of new small craft harbours and/or dolphin watching industry in the Durban bay.

Chapter 4
Short-Term Responses by Bottlenose Dolphins to Experimental Boat Approaches

Introduction

Human fixation on cetaceans is recorded in history for thousands of years in folklore, Greek and Roman mythology and legends (Morris and Gill 1999; Thompson 1999). Recently, cetaceans have become extremely popular with the general public and are sought after by humans for interaction at an increasing rate. This can be seen in the increasing popularity of marine parks and the escalating whale watching industry (the term 'whale watching' refers to any species of dolphin or whale) (IFAW 1999; Hoyt 2001; 2004; Carlson 2004). These types of tourism provide members of the public worldwide with many types of opportunities to learn about, observe, swim with (Bejder *et al* 1999; IFAW 1999; Samuels *et al.* 2000; Constantine 2001; Dudzinski 2001; Kyngdon *et al.* 2003; Valentine *et al.* 2004), or feed (Connor and Smolker 1985; Samuels and Bejder 2004; Trone *et al.* 2005) marine mammals. Moreover, it generates income for local communities where these activities occur (Duffus and Dearden 1993; Hoyt 2001).

World wide commercial cetacean-watching has developed at what seems to be an exponential rate in the last 4 decades (IFAW 1999). This trend shows no sign of declining. Hoyt (2001) estimated that commercial whale-watching tours are available in at least 87 countries and territories, and that the industry is worth at least US\$ 1 billion. In the face of this increasing popularity little is known about short or long-term effects of tourism on cetacean behaviour for most populations and species. Although single encounters with boats seldom cause major complications for cetaceans, repeated encounters have the potential for detrimental effects. One of the major challenges of marine tourism is protecting and conserving the environment whilst allowing tourist satisfaction (Samuels *et al.* 2003).

In some places the numbers of recreational vessels approaching dolphins is a cause for serious concern, particularly if the growth of this industry continues at a pace similar to that recorded in earlier years. Internationally, the number of whale watchers increased from 25 000 in 1994 to 510 000 in 1998. Over these four years direct expenditures and total expenditures (USD) increased from \$29 000 to \$311 000 and \$512 000 to \$ 69 186 000 respectively (IFAW 1999). Quantifying impacts of tourism is especially important in South Africa because, on average, 77% of the whale watch boat tourists in 1999 came from outside the country.

Although there are over 30 species of cetaceans that occur in South African waters, commercial whale watching focuses on mainly 4 of these species. These include the Indo-Pacific bottlenose dolphin

Tursiops aduncus, long-beaked common dolphin *Delphinus capensis*, humpback whale *Megaptera novaeangliae* and the southern right whale *Eubalena australis*. These species are easily targeted by the industry because their movements and distribution are somewhat expected and predictable. Thus, they can regularly and reliably be sighted either year round where resident populations occur, as in the case of bottlenose dolphins, or seasonally during annual migrations, as in the case for common dolphins, humpback and southern right whales. A variety of other species (e.g. Indo-Pacific hump-backed dolphin *Sousa chinensis*, dusky dolphin *Lagenorhynchus obscurus*, Heaviside's dolphin *Cephalorhynchus heavisidii*, killer whale *Orcinus orca*, blue whale *Balaenoptera musculus*, brydes whale *Balaenoptera edeni* and dwarf minke whale *Balaenoptera acutorostrata*) are sighted during tours, though are less predictable and are only the target species for commercial operations at limited places along the South African coast.

Boat-based whale watching poses the potential of detrimental consequences for targeted animals, in particular, for resident animals with small, coastal home ranges. These communities are often repeatedly sought out for extended, close-up encounters. However, in most cases, the biological importance of behavioural change in response to repeated disturbance has yet to be determined, nor is it recognised whether and in what ways, short-term responses elucidate into long-term effects on physical condition, reproduction, distribution and habitat utilization, and how those changes may affect survival and population size (Bejder 2005).

Bottlenose dolphins, *Tursiops* spp. are the species of small cetaceans most likely to be exposed to tourism (Samuels *et al.* 2003; Constantine *et al.* 2004). Despite their global distribution, they frequently live primarily in nearly-closed, resident populations with well defined home ranges (Shane *et al.* 1986; Wells *et al.* 1987). For example, the Sarasota population in Florida has resided within a 125km² area during 30 years of research with only a 2-3% annual immigration- or emigration rate. Elsewhere, however, populations have been described as seasonally migratory extending over ranges of approximately 400 km (Mead and Potter 1990; Peddemors 1995), while other populations are without defined home ranges exhibiting an apparent lack of boundaries (Ballance 1992). Although there appears to be some variation in the population structure of bottlenose dolphins around the world, they are long-lived mammals so populations that include individuals with limited home ranges could be negatively impacted through regular exposure to tourism.

Research on cetaceans exposed to tourism has shown that they may become habituated to moderate human presence (Martinez 2004; Trone *et al.* 2005). Such habituation can include a decrease in a behavioural response which occurs when a stimulus is repeated frequently with no apparent reward or punishment, or tolerance to the stimulus (Constantine 2001). If animals perceive a situation as threatening, however, then they are more likely to become sensitised to human presence (Irvine *et al.* 1981; Nowacek *et al.* 2001; Constantine 1999; 2001). Killer whales exposed to experimental approaches by a research boat have been observed using avoidance tactics similar to those observed when prey are escaping a predator (Williams *et al.* 2002). Similar results were found with harbour porpoises, which tended to swim away from approaching vessels (Polacheck and Thorpe 1990). Harbour porpoises also show differential responses based on the size and behaviour of the approaching vessel (Evans *et al.* 1993). Bottlenose dolphins have also exhibited a range of responses to human approaches, one of which is an increase in dive duration for mother-calf pairs in the presence of boats and thereby suggesting some form of avoidance behaviour (Nowacek 2001). Other responses include: changes in surfacing patterns (Janik and Thompson 1996) and foraging habitat selection (Allen and Read 2000). In Sarasota Bay, Florida, short-term shifts in local habitat use by bottlenose dolphins have been observed during periods of heavy boat traffic (Wells and Scott 1997).

As tourists desire more frequent and more intimate encounters with wild cetaceans, there is an imperative need for research that will assess the effects of such activities on the animals. Only a few countries have formulated legislative regulations to manage their whale- and dolphin-watching industry (e.g. Australia, New Zealand and the USA) while others have set-up voluntary "Codes of conduct" to minimise potential impacts. Generally, regulations and guidelines are based on little scientific research, if any, and do not distinguish between gender, age, habitat utilisation and social composition of target animals nor the habitat within which the activities occur. Yet these factors are known to influence responsiveness of cetaceans to vessels and boating activity.

Recording dolphin responses to boats and/or other human induced pressures is notoriously difficult. Theodolite tracking has proven to be a powerful tool with which to document cetacean responses to various anthropogenic stimuli (Kruse 1991; Bejder *et al.* 1999). In anticipation of a burgeoning boat-based whale and dolphin watching industry off the major South African cities, this study therefore used theodolite tracking to investigate short-term responses of bottlenose dolphins to experimental boat approaches in the Durban bay region.

Methods

As this project used a theodolite to investigate short-term responses of bottlenose dolphins to controlled boat approaches, it incorporated a zero-disturbance technique that allows accurate measurements of both the boat speed and direction and of the cetacean group speed, direction and dispersion. Distances between the study animals and boats could then be calculated. Theodolite observations were collected during "no impact" situations, i.e. no boats present, and during experimental and opportunistic boat approaches to the study animals. These techniques allowed measurement of group avoidance reactions to boats at various distances and enabled comparisons of behaviour before-, during and after a potential impact situation. One draw-back of using theodolite-based studies is that they often lack detail, i.e. the technique does not allow for detailed behavioural observations on an individual level or for individual identification of animals.

This study therefore incorporated the continual monitoring of the behaviours of the entire focal group of dolphins, as described in Chapter 3, before, during and after (BDA) controlled boat approaches during the summer (Oct-Feb) of 2004. The experimental vessel used was a 4.3m mono-hull semi-rigid inflatable with a 40hp Yamaha outboard engine. Approaches were always carried out side-on (i.e. from the left or right side of the dolphin group) using 4 different approach types or variables. These approach types include:

- (1). Slow approach (< 10km/hr) to the dolphin group and maintain a 20m distance;
- (2). Slow approach (< 10km/hr) to the dolphin group and maintain an 80m distance;
- (3). Fast approach (> 40km/hr) to the dolphin group and maintain a 20m distance;
- (4). Fast approach (> 40km/hr) to the dolphin group and maintain an 80m distance.

These distances were used based on the 50m dolphin approach limit according to recommended international legislation (IFAW 2001; Bejder 2005). Experiments were therefore carried out 30m within the advised 50m boundary (i.e. 20m distance between the boat and dolphin group) and 30m outside the boundary (i.e. 80m distance between the boat and dolphin group) to determine dolphin response. At present, South African legislature stipulates a distance of 300m between boats and whales, but there is no such legislation or recommended distance limit between dolphin groups and boats.

Although the project anticipated using a range-finder to accurately determine boat distances to the dolphins, it was found to be extremely difficult to use on dolphins. A series of trials were therefore conducted prior to the experiment, where all personnel involved in the experiment assessed their capability of estimating a distance to an object (shark net buoy) out at sea. These estimates were immediately compared to range-finder readings of the distance to enable the researchers to improve their distance estimates and maintain the pre-decided distances from dolphin groups during the experimental boat approaches.

Once a dolphin group was sighted, its position was recorded and tracked using an electronic theodolite (refer to Chapter 2). This was referred to as the 'no-boat', 'control' or 'before' observations. After a minimum of 10 minutes or 20 theodolite fixes of these non-interference observations the experimental boat operator was contacted via radio and asked to approach the focal animal group using a specific type of approach. The boat would then approach the dolphin group at the requested speed of approach to the predetermined distance, thereafter turning to travel parallel to the dolphins at their speed for ten minutes or 20 theodolite fixes before breaking off and leaving the animals. Thereafter, positions and behaviours were recorded for an extra 10 minutes known as the 'after' phase. The entire experimental period lasted for 30 minutes depending on dolphin group surfacings and/or number of vertical and horizontal angle co-ordinates.

Theodolite fixes were taken at the center of the dolphin group at 30 sec intervals. For the period of the 'during' phase, theodolite fixes were taken of the dolphin closest to the boat. The position of the boat was fixed immediately after the dolphin position fix. Field observations were restricted to Beaufort scale sea state of 3 or less.

Although BDA experimental procedure was carried out, behavioural data from Chapter 3 depicts 'normal' behaviour exhibited by bottlenose dolphins thus serving as a control. Thirty minutes of each track of the control was randomly pooled out and split into before, during and after phases (10 min each phase) for comparison. This was used to determine any change in behavioural use of the Durban bay following boat approaches during each of the four experiments and experimental phases.

Results

Between October 2004 and February 2005, 124 hours were spent in the field of which 29 hours 13 min were spent observing bottlenose dolphins during 32 focal follows. On all days but two, only a single experiment was conducted per dolphin school. On two occasions two schools were followed, leading to a single experiment being conducted on each during that one day. On another two instances the length of time that the dolphins were tracked through the research area allowed two experimental boat approaches to be carried out on that dolphin group. This led to a final total of 32 boat approach experiments used for analysis.

A total of 2922 theodolite fixes were collected during these experiments. The average focal dolphin group follow lasted 56.03 min (SE = 3.89 min, Range = 30.25 – 126 min), of which an average of 22.14 minutes were conducted in the ‘before’ experimental phase, 24.11 minutes in the ‘during’ phase, and 9.78 minutes in the ‘post’ phase.

Prior to carrying out the boat experiments, the reliability of distances maintained between the boat and dolphin group were analysed. There was no significant variation between researchers and the range finder during both the 20m (Figure 4.1 a) and 80m (Figure 4.1 b) trial (ANOVA, $n = 60$, $p = 0.0738$ and $n = 60$, $p = 0.7904$, respectively).

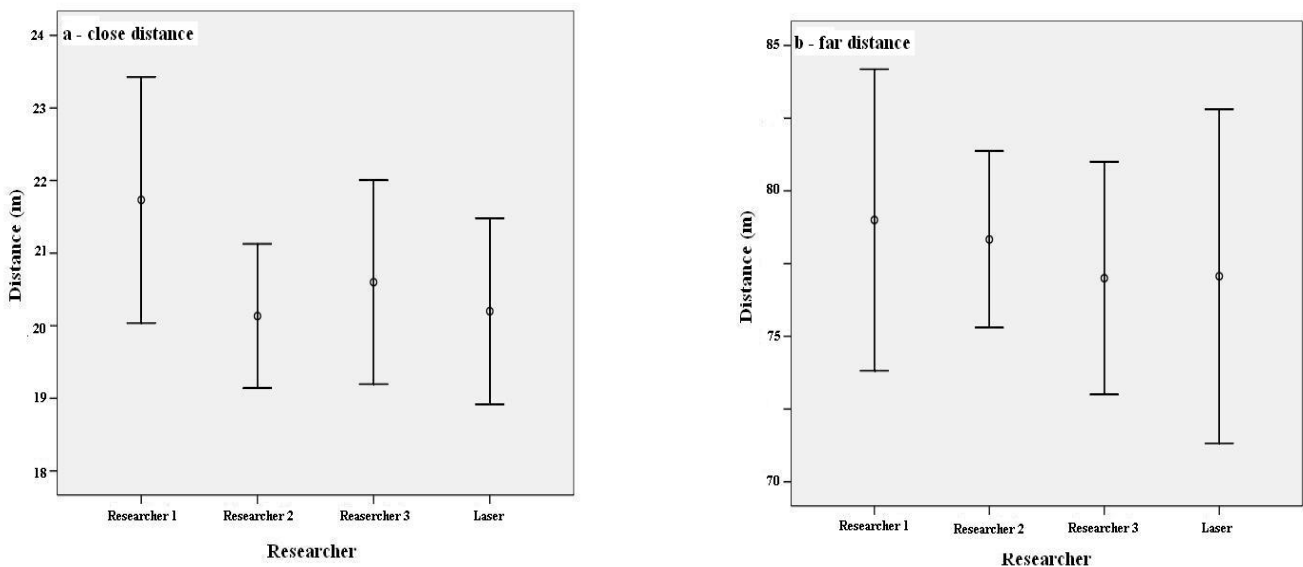


Figure 4.1: Variation in researcher-estimated and range finder distances where figure a represents a close distance of 20m and figure b a far distance of 80m.

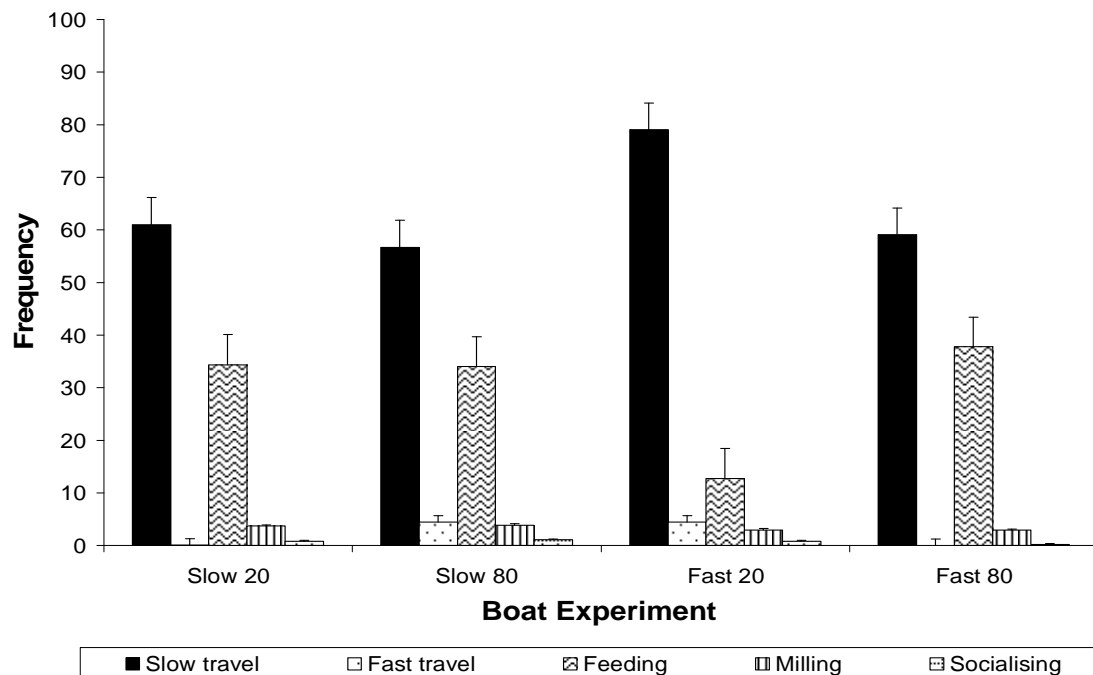


Figure 4.2: Overall mean frequency of behavioural events during each boat approach type. Error bars indicate 95% CI of the mean.

The bottlenose dolphin groups off Durban did not change their behaviour in response to boat approaches during all periods of experimentation (ANOVA, slow travel: $n = 1354$, $p = 0.181$, fast travel: $n = 24$, $p = 0.783$, feeding: $n = 664$, $p = 0.584$, milling: $n = 94$, $p = 0.868$, socializing: $n = 18$, $p = 0.826$) (Figure 4.2). Fast travel and socialising were barely observed and this is also seen throughout the study area when the experimental boat was present compared to the controlled experiments (Figure 4.9). During the slow approach to 20 m the frequency of slow travel increased when the boat approached the dolphin group (from 56% to 77%) and decreased after the boat left (47%), but this change was not significant (ANOVA, $n = 533$, $p = 0.192$) (Figure 4.3). Neither was there a significant difference in feeding when the boat approached (22%) and after the boat left the dolphin group (48%, $n = 233$, $p = 0.586$). During slow approaches to 80m, slow travel increased from 34% to 85% but again no statistical difference was detected ($n = 156$, $p = 0.058$), whilst feeding and milling significantly decreased after the boat left the group (from 39% to 2%, $n = 36$, $p = 0.022$ and from 8% to 1%, $n = 9$, $p = 0.013$; respectively). Similar to these results for the slow approach to 80m, feeding and milling decreased significantly for fast approach to 20m (from 22% to 4%, $n = 13$, $p = 0.013$ and from 5% to 0.7%, $n = 13$, $p = 0.012$). However, within the fast approach to 80m

experiments no statistical difference was observed for each behavioural category displayed by dolphins between each phase ($n = 356, p > 0.05$). While the boat was with the dolphin group ('during phase'), there was no difference in dolphin behaviour between experiments (slow travel: $n = 438, p = 0.159$, fast travel: $n = 12, p = 0.131$, feeding: $n = 224, p = 0.064$, milling: $n = 36, p = 0.294$, socializing: $n = 6, p = 0.222$).

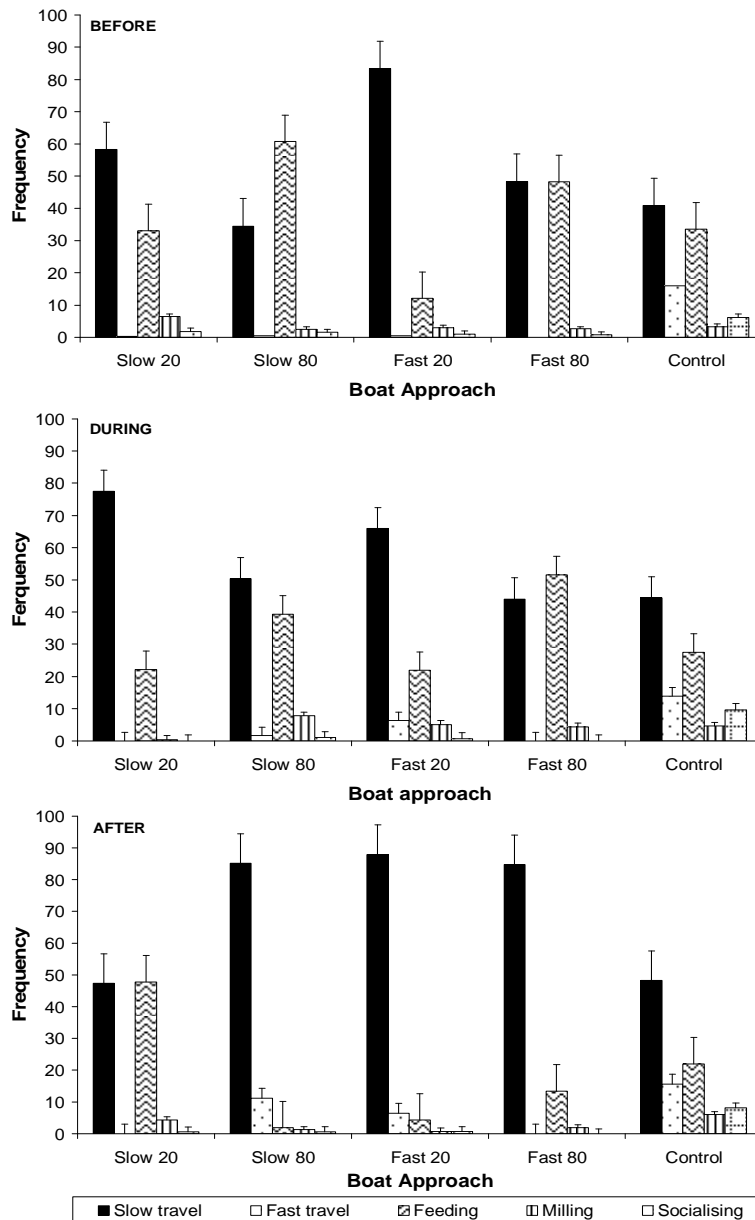


Figure 4.3: Frequency of behavioural events during each boat approach type. Error bars indicate 95% CI of the mean.

Since Dolphins were behaving 'normally' on days that experiments were conducted and there was limited 'bias' due to extraneous factors (e.g. Big ships moving into the harbour/other boat traffic that may have influenced the experiment/environmental conditions [abiotic or biotic]), all data were 'pooled' to compare to the data collected in Chapter 3 (control) for a comparison (Figure 4.3). When each phase of each experiment was compared to the control experiments there was significantly higher slow travel activity (ANOVA, $n = 2782$, $p = 0.003$) and correspondingly lower feeding activity ($n = 1503$, $p = 0.025$) before the boat approached the dolphin group for the fast 20 experiments. When the boat approached the dolphin group during this type of approach feeding increased but did not statistically differ to the control ($t = -1.068$, $df = 3$, $p = 0.364$). After the boat left the dolphin group there was no significant difference for each behaviour between the control and each experiment.

The average group speed recorded between each of the three phases under different approach types are shown in Figure 4.4. There was a significant difference in speed within slow 20 (Kruskall – Wallis ANOVA, $n = 32$, $p = 0.038$) and fast 20 approach ($n = 30$, $p = 0.004$) but no significant difference in dolphin group travel speed for the slow 80 ($n = 26$, $p = 0.663$) and fast 80 ($n = 48$, $p = 0.138$) boat approaches. Tukey type *post hoc* for the 3 phases within the slow 20 approach showed no significant difference before and during approaches ($n = 32$, $p = 0.164$) while during fast 20 approaches there was a significant increase between the before-after phase ($n = 30$, $p = 0.005$) as well as the during-after phase ($n = 30$, $p = 0.021$). There is an insignificant increase in group speed with increasing group size up to groups of 60 individuals (linear regression – $f = 1.37$, $r^2 = 0.047$, $p = 0.251$) (Figure 4.5 a) but this relationship breaks down once groups become 'super-pods' i.e. 150 individuals (linear regression – $f = 0.057$, $r^2 = 0.002$, $p = 0.813$) (Figure 4.5b).

None of the focal follows ended with a change in group size, i.e. group split or join. Dolphin groups were more likely to form tighter formations during follows in which the experimental boat approached the group at more than 40km/hr and at a very close distance (ANOVA, $n = 32$, $p = 0.027$) (Figure 4.6).

The overall average time spent by dolphins in the study area during boat experiments was 46.88 min (SE = 8.9 min, Range = 33.6 – 50.0 min) (Figure 4.7). There was no difference in time spent by dolphins in the area within and between each experiment as well as between each experimental phase (Figure 4.8).

Analysis of changes in how dolphins utilised different sectors of the bay following boat approaches indicate that time spent in slow travel increased in most sectors of the study area in the presence of the boat with the most significant differences found in sector 4 and 6 (paired samples t test, $t = 4.357$, $df = 4$, $p = 0.022$; $t = 3.059$, $df = 5$, $p = 0.0038$ respectively) (Figure 4.9). Fast travel and socialising was barely observed in the study area during boat presence, with significant differences found in sectors 4 and 5 for both behavioural categories (fast travel: $t = 5.121$, $df = 7$, $p < 0.0012$; $t = 3.614$, $df = 5$, $p = 0.0031$; socialising: $t = 3.476$, $df = 6$, $p = 0.0034$; $t = 5.116$, $df = 6$, $p < 0.0001$ respectively).

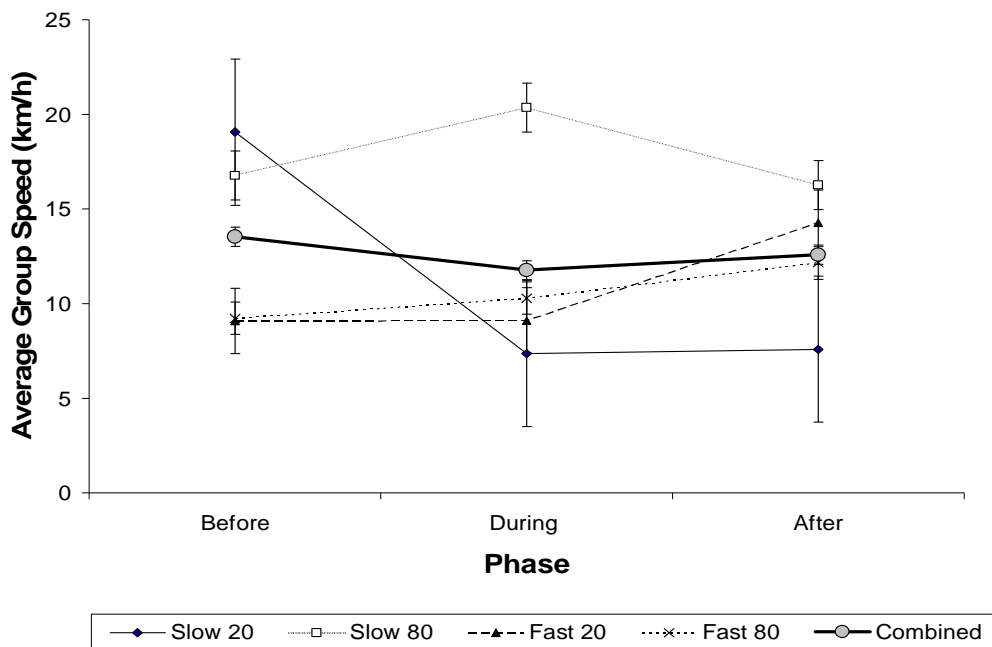


Figure 4.4: Mean group speed of bottlenose dolphins recorded during the three phases of each boat approach type. Error bars indicate 95% CI of the mean.

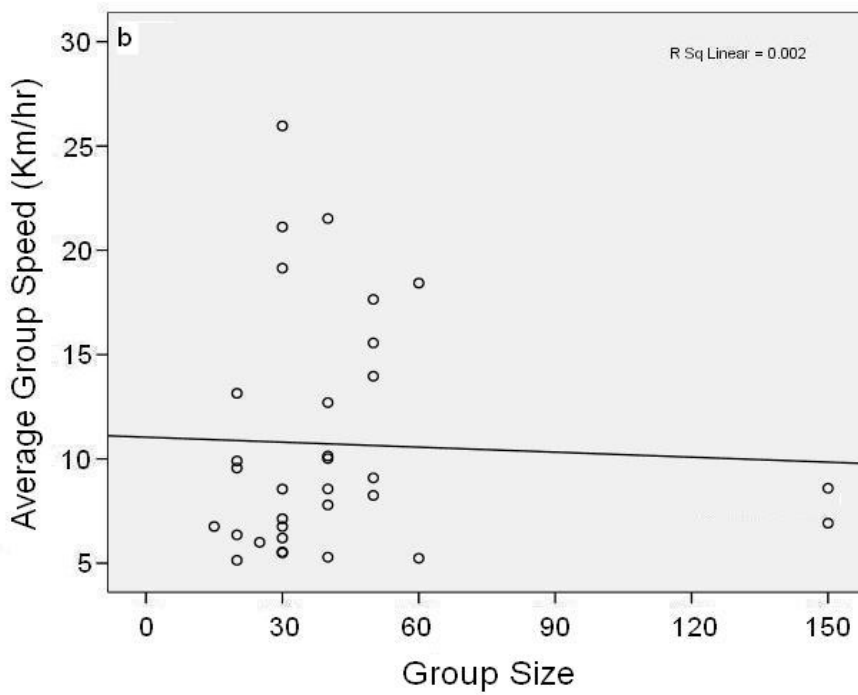
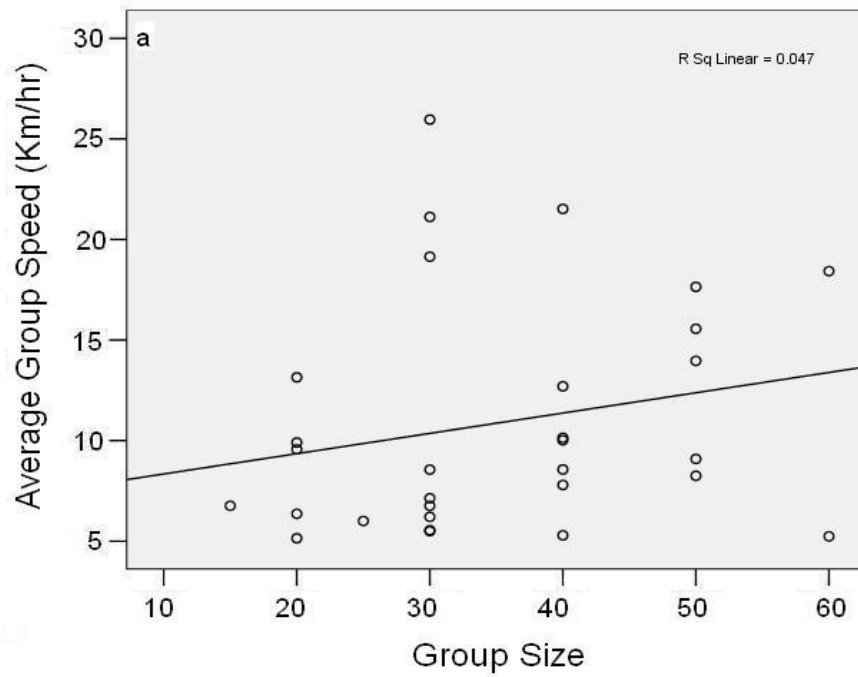


Figure 4.5: Average group speed of bottlenose dolphins recorded for different group sizes a) up to 60 individuals and b) up to 150 individuals (“superpods”) in a group.

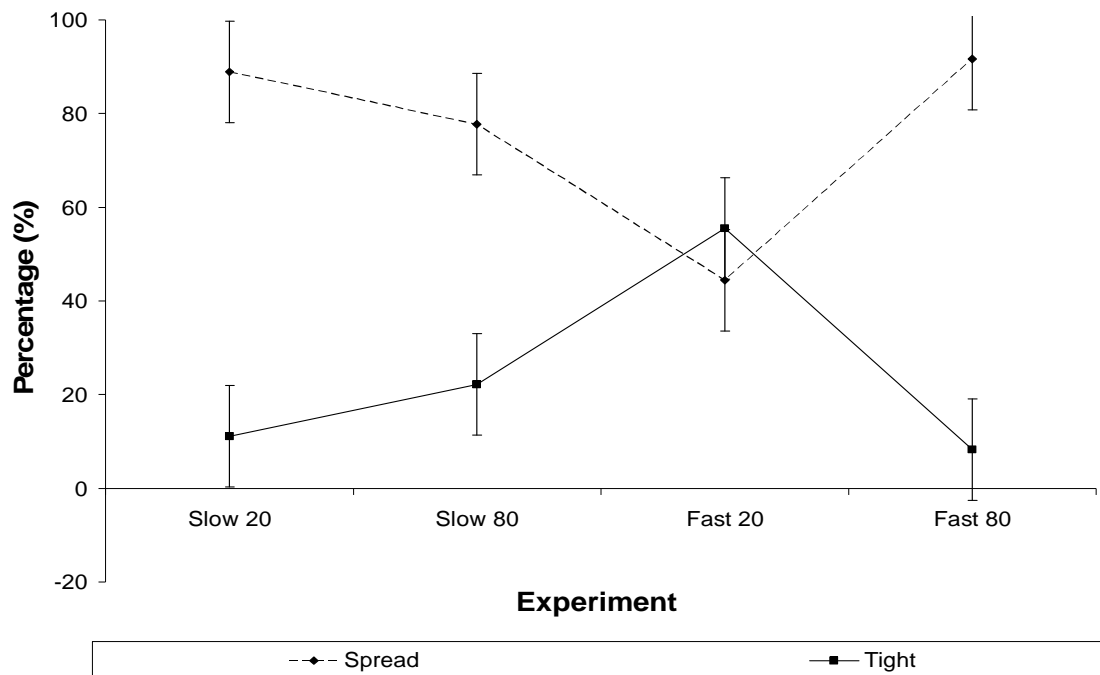


Figure 4.6: Group formations observed during each experiment. Error bars indicate 95% CI of the mean.

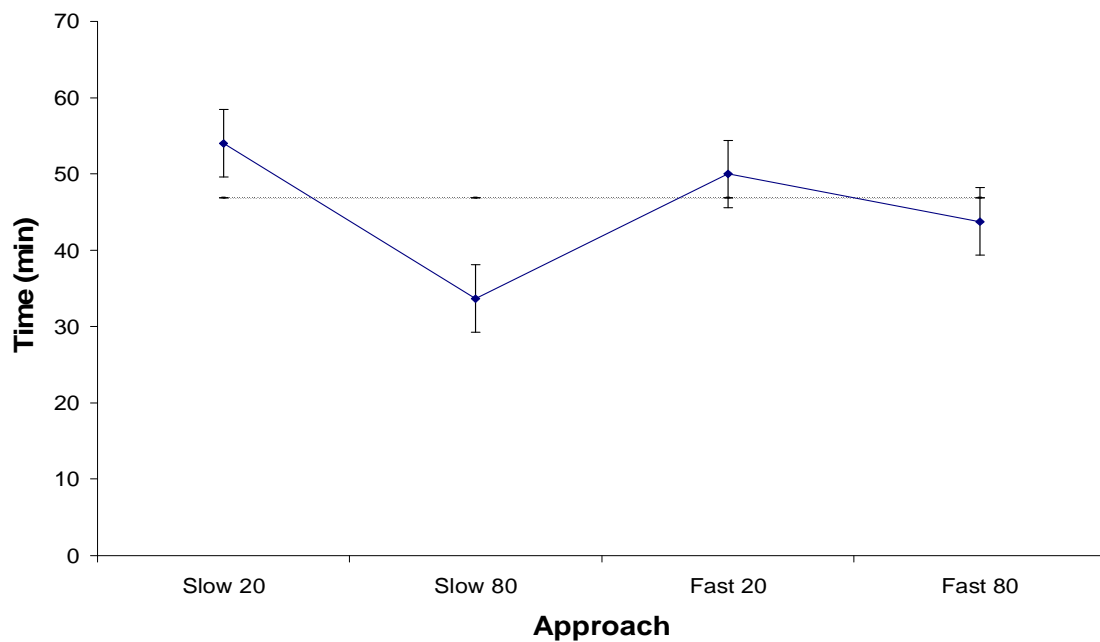


Figure 4.7: Average time spent by dolphins within the Durban bay research area during each boat experiment. The straight line represents the mean (46.9min) during all experiments. Error bars indicate 95% CI of the mean.

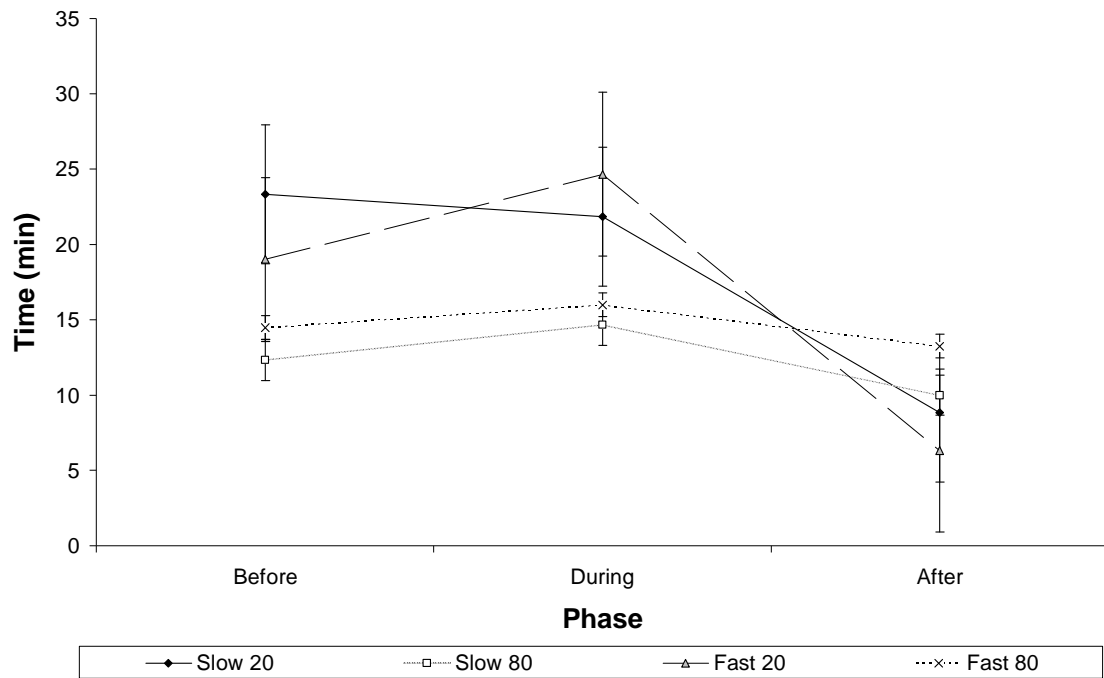


Figure 4.8: Average time spent by bottlenose dolphins within Durban bay during each phase of the boat experiments. Error bars indicate 95% CI of the mean.

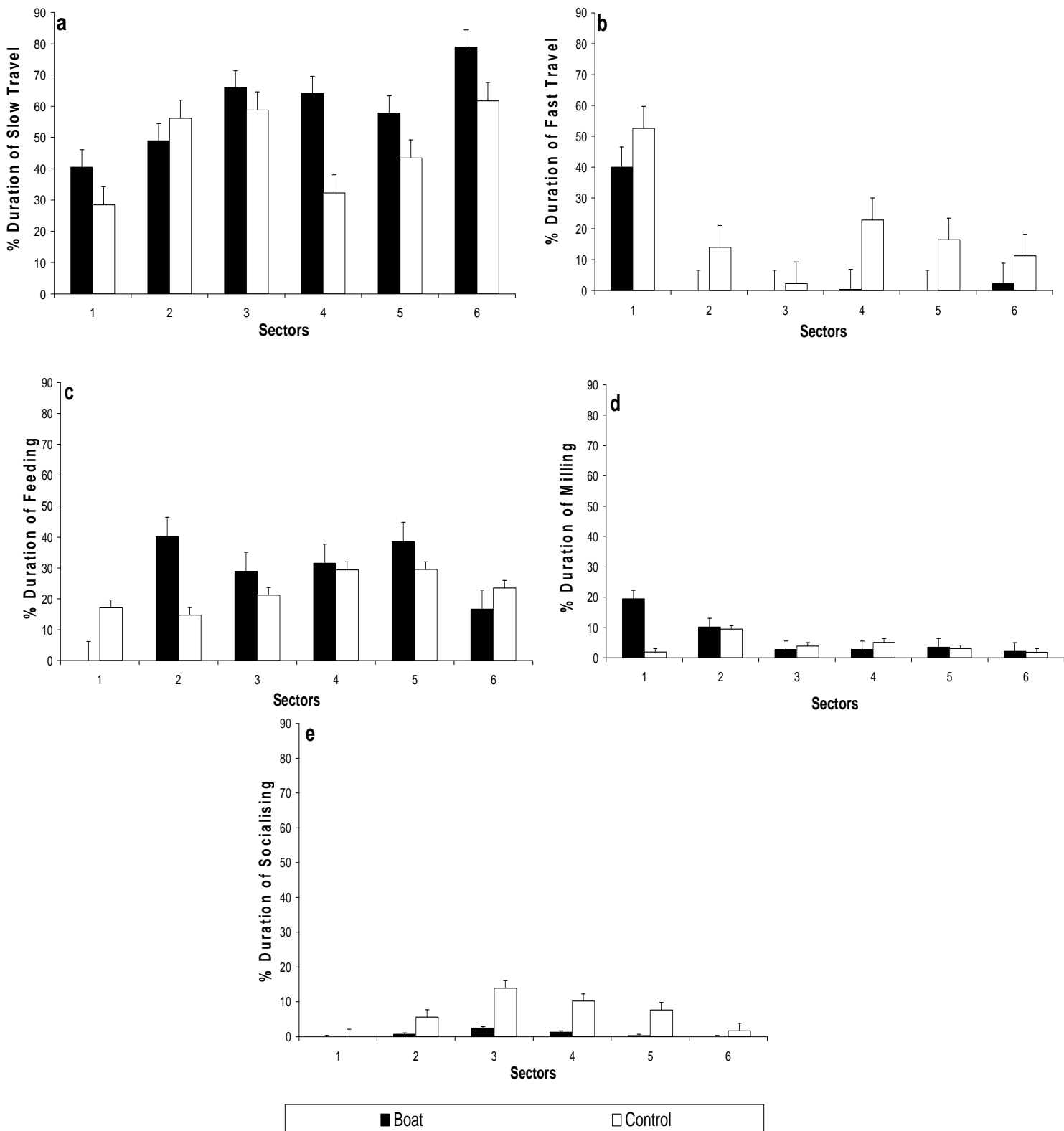


Figure 4.9: Average time spent in each behavioural category in each sector in the Durban bay during boat and ‘control’ experiments. Error bars indicate 95% CI of the mean.

Discussion

Estimating distance at sea from a small boat has historically been considered a problem (Connor *et al.* 2000). One way to overcome this is by means of a laser range finder. In this study researchers inevitably improved their ability to calculate distances of an object (buoy) from the experimental boat when compared to the distance measured using a laser range finder. This insignificant difference between observer-estimated distance and that determined via a laser range finder, allowed the experimental boat approaches to dolphin groups to be conducted with acceptable precision.

During all experiments the experimental boat was the only boat that accompanied the dolphins. Hence, this research has focused specifically on understanding the effect of a boat on dolphin behaviour using before-during-after (BDA) technique of experimentation. As the original behavioural state was undisturbed, this offered a suitable control for the experiments.

It has been suggested that changes in behaviour may allude to risking animal well-being (Duffus and Dearden 1990). Morton and Griffiths (1985) suggested that compromised well-being is more likely when more than one aspect of the behavioural repertoire is altered, irrespective of whether the consequences are short or long-term (Morton and Griffiths 1985). This research showed no significant changes in the behaviour of bottlenose dolphins off Durban, with no apparent effect from either the type of boat approach or the distance between the boat and focal group. Although feeding and milling was observed to decrease following two approach types (slow 80 and fast 20) with a concomitant increase in travelling it appeared that this was not due to the boat having a negative response but that it could have been due to prey availability. Furthermore, when overall frequency of occurrence of each behavioural category was compared to the “control” (Chapter 3), slow travel and feeding increased by 16% and 3% respectively, again suggesting that these experimental boat approaches produced minimal harmful affect on the dolphins. If the boat negatively impacted the dolphins we would expect feeding to decrease and fast travel to increase, but this was not so. An increase in feeding is unlikely to be the result of boat presence and could be linked to changes in prey distribution and movements within the research area between the control and experimental periods. As bottlenose dolphins are primarily opportunistic feeders (Chapter 3; Cockcroft and Ross 1990), changes in prey abundance and distribution would affect time spent feeding in an area.

The results from this study do not concur with those reported for similar studies investigating dolphin responses to boat traffic. In New Zealand, the Doubtful Sound population of dolphins increased the time spent travelling while socializing halved and resting decreased from 11% to 1% following disturbance (Constantine *et al.* 2004). Similarly, Lusseau (2003) and Allen (2005) both observed an increase in travelling but a complete absence of resting behaviour for bottlenose dolphins following experimental boat approaches off New Zealand and Australia, respectively. As resting was not observed at all within the Durban bay study area, potential changes in this important behaviour could not be assessed in the current study. Considering that Durban Harbour is the busiest port in Africa, it is understandable why dolphins would not rest in the nearshore waters of the Durban bay and use the area primarily as a thoroughfare (Chapter 3).

In this study, behavioural change was based on dolphin consistency in movement and group cohesion/dispersion responses. With respect to movement consistency, focal groups maintained their speeds and course change did not significantly vary. Dolphins inevitably slowly travelled through the area suggesting that these animals are 'comfortable' with the presence of a boat. The intensity of the reaction may, however, be influenced by the type of boat. Richardson *et al.* (1995) and Tyack (1998) found that engine size and consequent underwater noise may be a source of disturbance given cetacean reliance on acoustics for communication, orientation and predator/prey detection. Furthermore, Bejder *et al.* (2006) suggested that vessel size could also possibly be a source of disturbance, and larger tour vessels are likely to be more intrusive than research vessels with smaller quieter engines. This difference in response to vessel type was highlighted by Mattson *et al.* (2005) who found that dolphin-watching boats, motor boats, shrimp boats and jet skis variously affected the group size and behaviour of dolphin groups. Contrastingly, Rogan *et al.* (2000) found that the Shanon Estuary dolphins themselves would initiate interactions with ships and yachts, but no judgment could be made on the disturbance level.

Although vessel size may influence how dolphins react, it appears that vessel speed also influences dolphin responses. Liret (2001 – as cited in David 2002) found that adult bottlenose dolphins were attracted to boats that were travelling at speeds greater than 5 knots, and the duration and distance of the interaction increased if the boat tried to approach the animals. It appeared that slow passing boats or small boats did not stimulate a positive reaction among the dolphins because they do not have a sufficiently sizeable wave or wake. The sub-adults are the first and among the most often in the interaction, while females accompanied by new-borns keep their distance. This means that different

individuals (determined by age and gender) may respond differently to boat approaches. Although our experiment showed that a small boat travelling at more than 40 km/hr did not cause a disruption in behaviour, the age and gender of the dolphins exposed to this experiment are unknown. However, it is to be expected that females with calves would be most sensitive to any form of disturbance and would avoid the boat immediately or after few minutes of approach, whereas, sub-adults and adults would continue their original behaviour until the boat is suspected as a threat and then move away from the boat or area to be less exposed.

If animals perceive a situation to be threatening, they are likely to adopt avoidance strategies similar to those observed when escaping a predator (Lima and Dill 1990). Cetaceans can respond by displaying vertical or horizontal avoidance. As we could not record the underwater behaviour of bottlenose dolphins during these experiments, our data focuses on horizontally exhibited behaviour. Bottlenose dolphins in the current study did not alter their behaviours when approached by the boat nor did they increase travel behaviour or group speed. Although the dolphins did not exhibit any dramatic movement away from the boat, the group dynamics changed when the boat approached with a decreased dispersion leading to an increase in school density. Additionally their overall time spent (46.9 min) in the Durban bay was not significantly different to the time spent by the dolphins during the control period (43.5 min). The above results indicate that these animals became aware of the boat but did not identify it as a threat.

Short-term behavioural responses of delphinids to boats have been illustrated in previous studies, for example, influences on breathing synchrony (Hastie *et al.* 2003) including changes in inter breathing intervals (Janik and Thompson 1996) and dive times (Ng and Leung 2003; Lusseau 2003a; Janick and Thompson 1996), changes in swimming direction (Au and Perryman 1982; Nowacek *et al.* 2001) and increase in swimming speeds (Kruse 1998, Nowacek *et al.* 2001) and vocalisation rates (Scarpaci *et al.* 2000; Lemon *et al.* 2006). As the data from the present study off Durban did not indicate any of these recognised short-term avoidance responses, they do not support the notion that the dolphins off Durban avoid boats. This could be because this is such a heavily used area. There are approximately 800 small vessels registered at Durban Underwater Club and Durban Skiboat Club and an additional 4000 boats registered with the National Ports Authority (personal comms. NSRI 2007). This excludes the ship traffic from the harbour. It is therefore hypothesised that this bottlenose dolphin population could be 'habituated' to boats, particularly considering that Durban has the busiest port in Africa.

Unfortunately there are no long-term data to indicate whether there has been a change in total population size using the Durban bay, or whether there has been a change in habitat utilization by the Durban dolphins following recent increased vessel traffic. The estimated population of approximately 200 bottlenose dolphins using the Durban bay waters (Boonman 1998) may be close to what the habitat can support, particularly as there is limited reef structure within the Durban bay, which would limit their ability to target the reef-associated prey that they appear to prefer (Cockcroft and Ross 1990; Peddemors 1995).

The plasticity of bottlenose dolphins to various human-induced disturbances has been indicated by the variation in their response. Gerrodette and Gillmartin (1990) found that animals may abandon the area that was once preferred as long as disturbance persists. Similarly, long-term sighting records in Shark Bay shows shifts in habitat use away from the area in which dolphin watch boats operate (Bejder *et al.* 2004). Habitat shift is a form of avoidance and dolphins may remain in an area of vessel disturbance while responding behaviourally to minimise impacts (Bejder *et al.* 1999). Bottlenose dolphins near Clearwater, Florida, decrease their use of primary feeding grounds during periods of heavy vessel activity but re-inhabit the same area when traffic is reduced (Allen and Read 2000). In Fiordland, New Zealand, tour boat presence also only displaced bottlenose dolphins for a short term (Lusseau 2004).

As anthropogenic activity has been shown to displace dolphins from their areas of residency, preferred habitat or areas either used temporarily or permanently, it was important to define critical areas for the bottlenose dolphin population off Durban (Chapter 3) before a boom in the dolphin-watching industry in this area occurs. Dolphins fed throughout the study area but spent most of the time feeding near reefs, which are located near the harbour entrance. Feeding is an important behaviour in the activity budget that, most likely, would be affected by boat traffic and/or changes to the harbour entrance. These data suggest that government resource managers should consider excluding this area from future boat-based dolphin watching licenses. This is supported by Allen and Read (2000) who observed a decrease in use of primary feeding habitats during high vessel activity. In New Zealand, determining critical habitat allowed key locations that needed to be safe guarded under the Marine Mammal Protection Regulations (Lusseau and Higham 2003) to be identified and thus permitted the management of dolphins under only one piece of legislation (Lusseau and Higham 2004). Such an approach was successful in reducing Hector's dolphin (*Cephalorhynchus hectorri*) bycatch in gill nets (Slooten *et al.* 2000) and in Canada this helped to minimise boat interactions with killer whale (*Orcinus orca*) in an ecological reserve (Kruse 1991; Williams *et al.* 2001).

Whilst Durban is used as a thoroughfare for *T. aduncus*, it also serves as a small-scale feeding ground (Chapter 3). Future persistent disturbance has the potential to displace these animals which will potentially have significant consequences on the ability of the resident dolphins to obtain sufficient nutrients to survive. Displacement could reduce the size of their home range, cause individuals to move to less favourable areas which in turn could have significant impacts on their energy budgets, survival and reproductive success (Bejder 2005). Since bottlenose dolphins are social animals (Smolker *et al.* 1992; Connor *et al.* 1992; 2000), disruption of social bonds through displacement of individuals as well as their offspring which continue to use their natal ranges as adults (Connor *et al.* 2000) may have far reaching problems in the long-term. Lusseau and Newman (2004) showed that the disappearance of a key member in Doubtful Sound led to a division of two sub-communities which were affiliated by a few common individuals.

This study off Durban suggests that boats do not have a negative impact on the dolphins using this bay and that a regulated increase in dolphin-viewing operators may not be detrimental to this population. However, it is not known how short-term responses elucidate into long-term impacts. To prevent far reaching future negative repercussions, precautionary measures should be taken into account. It is therefore proposed that the closest distance that boat-based dolphin watching vessels should be allowed to any dolphin group be 50 m. In this way clients would be satisfied, thereby ensuring a dolphin watching industry could sustain itself, while minimizing impacts on dolphin behaviour and society. However, it is proposed that a detailed study should be carried out to assess the degree of habituation of this population to different vessels, number of vessels near a group and length of interactions.

Another consideration to regulating dolphin viewing permits off Durban is the time that dolphins are sighted – i.e. from dawn to approximately 11:00 am (Chapter 3). Irrespective of the number of operators, clients appear to have a 4 to 5 hour “window period” in which to view these animals. Owing to this, most operators will depart in the early mornings trying to maximise their time and effort in searching and viewing. This may lead to almost all operators in close proximity to one dolphin group at the same time. Along the coast of Ilan County, Taiwan, Chou *et al.* (2004) reported eight boats around one group of dolphins and a preliminary study there showed that the critical distance for behavioural change of dolphins was 50-100 m. In Mauritius, a population of 12 dolphins are surrounded by approximately 30 commercial dolphin watching boats throughout the day (personal

comms. Sauzier 2007). This indicates the importance of including maximum boat numbers and distance of approach in any future dolphin watching regulations in South Africa.

Without long-term data for Durban, it remains unclear as to whether or not short-term responses or increased vessel traffic (no data available) would prove detrimental over time. Intrusive, persistent and unregulated vessel traffic that focuses on animals while they are resting, feeding, nursing their young or socializing can disrupt those activities and possibly cause future long-term problems. Bejder (2005) linked short-term changes in sociality and movements to long-term impacts on bottlenose dolphin habitat use and reproductive success. He found that there was a decline of 14.9% in the number of dolphins using the impact site when the number of tour operators increased to two (excluding the research vessel). These data highlight the importance of our study in obtaining baseline data prior to the initiation of any major boat-based dolphin watching industry off Durban.

The boat-based dolphin-watching tourism in Durban is presently very small (two operators) when compared to other established areas where resident animals are located. This study could therefore serve as baseline for scientific research. Given the prolonged period of time required to detect trends in population size and habitat use, and a potential increase in commercial dolphin-viewing operators, it is imperative that guidelines for dolphin viewing should be formulated, implemented and regulated as soon as possible. It is suggested that Durban could be used for a long-term study on this population as such research is important not only because cetaceans are long-lived but also as these animals are resident to the “greater” Durban area, with some individuals being sighted for over 20 years (Chapter 1). Additionally, long-term results always shed more in-depth light on the interpretation of short-term results. In conclusion, Bejder *et al.* (2004) stated, “An absence of a long-term perspective will undermine management efforts when moderated short-term behavioural responses to anthropogenic stimuli are erroneously interpreted as positive outcomes for targeted animals.” But the opposite is also true – a short-term behavioural change is not necessarily an indicator of a negative impact!

Finally, it should be noted that this study has been unique in that, unlike bottlenose dolphins in the Bay of Islands (Constantine *et al.* 2004), Fiordland (Lusseau 2004), Shark Bay (Bejder 2005) and Port Stephens (Allen 2005), dolphins off Durban do not represent a tourism-exposed population of cetaceans. In conclusion, it is believed that the results from this study indicate potential for continued sustainable boat-based tourism on the ‘local’ bottlenose dolphins, but that this should be regulated and monitored prior to the establishment of a large industry.

Chapter 5
Conclusions

The dolphins occurring off Durban are amongst the most threatened in the province of KwaZulu-Natal. Contributing factors to their decline are: Ongoing incidental captures in shark nets (Cockcroft *et al.* 1991; 1992; Peddemors 1995; Peter 2007), high organochlorine levels e.g. DDT and PCB's (Cockcroft *et al.* 1989), siltation of near-shore reefs (Martin 1987) and over-fishing of their prey (van der Elst and De Freitas 1988). Furthermore, the potential increase in boat-based dolphin watching tourism and its impacts could add to these contributing factors (at present, there are only two operators in the Durban region). International studies on cetaceans have documented that boat disturbance include changes in: surfacing, ventilation and dive patterns (Janik and Thompson 1996; Nowacek *et al.* 2001; Lusseau 2003; Lemon *et al.* 2006), swim speed, course and orientation (Bejder *et al.* 1999; Williams *et al.* 2002; Bejder 2005; Lemon *et al.* 2006), group dispersion/cohesion (Bejder *et al.* 1999; Nowacek *et al.* 2001; Bejder 2005), behavioural states/activity budgets (Constantine and Baker 1997; Lusseau 2003; Samuels and Bejder 2004; Bejder 2005), and ranging patterns and habitat use (Allen and Read 2000; Samuels and Bejder 2004; Bejder *et al.* 2006). As baseline data for many studied populations are anecdotal, lacking or insufficient (Samuels and Bejder 2004; Bejder 2005), this work is one of the first studies in dolphin-boat interaction research prior to an increase in the boat-based whale and dolphin watching industry. This study is crucial in allowing future comparisons of dolphin use of the Durban bay region following the anticipated boom in the boat-based cetacean watching industry.

Land-based theodolite tracking was undertaken in the Durban bay to define the natural distribution, habitat utilization and behavioural patterns of bottlenose dolphins in the area (Chapter 3). These data were subsequently incorporated in experiments to determine dolphin reactions to boat approaches to obtain an estimate of the impact of boat interactions on the population (Chapter 4). Unfortunately, since this research was primarily land-based, the most vital tool in dolphin research, i.e. reliable recognition of individuals, could not be employed in this study. The incorporation of such data would have allowed more stringent analysis of whether the groups tracked comprised 'new' or 'naïve' dolphins. As determination of the 'natural' behaviour was paramount in this study, it was deemed inappropriate to approach the dolphins by boat to obtain photographs of individuals as these approaches may influence the data collected. However, the importance of photo-identification techniques is recognised and its role in allowing long-term studies of individuals and groups of dolphins is critical to further elucidating the lives of these animals.

During long-term studies, the number of individuals in a population being studied are regularly monitored using this technique of photo-identification (e.g. Sarasota, Monkey Mia). This constant monitoring makes use of different researchers over time. Therefore, measurement of photographic quality and individual distinctiveness for photo-identification analyses (Chapter 2) was incorporated in this thesis to provide an additional data set for analysis and development of my skills. Chapter 2 therefore looked at the reliability between researchers, with differing levels of experience in photo-identification techniques, in scoring photographic quality and identifying individual dolphins (i.e. scoring the degree of serrations and pigmentation on either edge of the dorsal fin, including, counting the number of notches and calculating the Defran ratio).

Since photo-identification is valuable to the study of wild populations, it was necessary to assess if researchers obtain the same information from the same photograph. Surprisingly, researchers were unable to reliably quantify variables of photo quality and individual distinctiveness, but experienced researchers were found to be more adept than inexperienced researchers in counting notches on the dorsal fin of bottlenose dolphins. These notches are important in assisting to identify individuals in a population and if an error occurs, the animal will be incorrectly catalogued. This in turn will affect abundance estimates as well as studies on sociality that makes use of this technique. These results therefore highlight the necessity for researchers to be trained in photo-identification techniques prior to carrying out their study. Recently, a computer-assisted program (*Finscan*) was developed to analyse digital images of dolphin dorsal fins. For the effective use of *Finscan*, training and experience in photo-identification has also been found to be necessary (Gailey 2001).

In an effort to determine the effects of boats on dolphin behaviour, the activity budget of undisturbed dolphins had to be ascertained. In Chapter 3, the distribution, movement patterns and behaviour of bottlenose dolphins were monitored from land using a theodolite within Durban. Dolphins were observed throughout the bay with most groups being sighted before midday and in water depths less than 30m. Five major behavioural categories were observed; slow travel being the most dominant followed by feeding. These data imply that dolphins mainly use the bay as a thoroughfare. However, inter-dependency between travel and feeding seems to be prevalent. Feeding activities comprised 27% of the activity budget and occurred mainly during the early morning and late afternoon. Although dolphins fed throughout the study area, the time spent feeding was greatest near reefs, which are located near the harbour entrance. The importance of feeding within the activity budget, the decreased use of primary feeding habitats during high

vessel activity (Allen and Read 2000) and the high incidence of feeding near the harbour, indicate that feeding is an important behaviour that, most likely, would be affected by boat traffic and/or changes to the harbour entrance. These data suggest that government resource managers should consider excluding this area from future boat-based dolphin watching licenses.

There has been dispute over whether or not the impacts of boat-based cetacean tourism on target animals are small enough to justify its continued development and promotion as sustainable ecotourism (Orams 1999; Samuels and Bejder 2004). Although whale and dolphin watching off Durban is very small (currently only including two operators), Durban is the busiest port in Africa. In Chapter 4, land based surveys were carried out to observe the effects of an experimental boat on bottlenose dolphins off Durban. Short-term changes in behaviour, group speed, group size and spread were not significant during slow and fast approaches and for approaches to a close distance. Dolphin groups continued with their 'normal' behaviour and spent the same amount of time in the bay when compared to their distribution and behaviour in the absence of the experimental boat (Chapter 3). These results are in contrast to those documented for bottlenose dolphins in other locations (e.g. Lusseau 2003b; Constantine *et al.* 2004; Bejder 2005). Constantine (1995) found that responses vary between species and tourism location to dolphin watching activity. Most previous studies were carried out in enclosed bays with high incidences of whale and dolphin watching, whereas Durban has an open, fully exposed coastline and dolphin watching is minimal. This could suggest that the dolphins have not learned to avoid boats following historical harassment. However, Durban has a very high incidence of boat traffic, suggesting any learned negative response would have been present in the local dolphins. Alternatively, these results could imply that exposure to high levels of boat traffic since birth could desensitise dolphins. In order to sufficiently test these hypotheses, future research should be conducted in an area where dolphins are not currently exposed to high levels of boat traffic.

Albeit that boat-induced impact was not found, it was uncertain if resident or transient animals were tracked and exposed to the experimental approaches. Future dolphin tourism impact studies should attempt to incorporate photo-identification studies to identify which animals use the area and which individuals are experimented on. Furthermore, boat-based research using different types of boats with different engine sizes should be conducted to determine any potential optimum combinations to allow development of a sustainable boat-based cetacean-watching industry. Additionally, future research should include periods where dolphins are followed for as long as possible to analyze the time required until a negative response in dolphin behaviour is recognised. This will help in regulating the

industry by permitting certain types of boats to be used, as well as the time limit dolphin operators may spend with a dolphin group. Such a study could be difficult as suitable land-based sites allowing long-distance tracking of dolphins and/or boats are difficult to find.

Finally, although this study suggested that the bottlenose dolphins using the Durban bay were potentially extremely habituated to boat approaches, possibly as a consequence of the busy port and high vessel traffic, caution should still be taken when designing future industry-related regulations. To avoid potential future detrimental impacts on these dolphin groups, the boat-based dolphin viewing industry should be permitted and the Marine Living Resources Act should include a 50m minimum distance between dolphin viewing operators and a dolphin group. Future research would help in formulating additional guidelines as stated above. It should be remembered that the overall goal of management strategies designed to control interaction between tourists and the natural environment is twofold: first, to protect the environment from detrimental impacts and, second, to provide for and promote enjoyable tourist experiences (Orams 1995).

Chapter 6
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