

**Boat traffic effects on the diving behaviour of bottlenose dolphins (*Tursiops truncatus* Montagu) in Sardinia, Italy.**

**Thesis submitted for the degree of  
Master of Science**

**By**

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**In association with the  
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*“It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change”.*

*- Charles Darwin*

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## **Abstract**

This study aimed to determine the relationship between bottlenose dolphin dive behaviour and boat traffic. Marine traffic has previously been observed to elicit responses in cetacean behaviours, but the cause and effects of these interactions has yet to be fully understood. Diving behaviour of free ranging wild bottlenose dolphins on the northeastern coast of Sardinia, Italy was observed using non-invasive direct observations of focal individuals and groups. A total of 1012 dives, totalling 160 hours, were observed. Short and long dives were discriminated between by using the median dive duration (12 seconds) as a cut-off. Five dive parameters (dive rate, short dive rate, long dive rate, dive efficiency and maximum duration) were used to facilitate and enhance dive analysis. Boat data, type and level of presence, clearly demonstrated a seasonal trend between peak and non peak periods. Tourist boats were most present during peak summer season, whereas fishing boat presence was uniform throughout the year. Dive behaviour also differed seasonally. When tourist boat presence was at its highest, there was an observed increase in travelling behaviour; this was reflected by low short dive rates, and shorter long dives. In absence of tourist boats, and during feeding behaviour, dive behaviour was represented by increased long dive durations, and increased frequency of short dives. Fishing boats did not elicit any changes in dive behaviour. The residential tendencies of this bottlenose dolphin community may have lead to some tolerance to marine traffic, but it is obvious that they are still responding to tourist boats. Group surfacing rates did not differ between boat approach and non approach situations, which may be suggestive of a “safety in numbers” strategy. Finer scale behavioural observations, such as dive behaviour analysis, could prove to be vital for understanding the potential long term implications of dolphin-boat interactions.

# Table of Contents

<b>Acknowledgements</b> .....	<b>ii</b>
<b>Abstract</b> .....	<b>iii</b>
<b>Table of Contents</b> .....	<b>iv</b>
<b>List of Figures</b> .....	<b>v</b>
<b>List of Tables</b> .....	<b>vi</b>
<b>1. Introduction</b> .....	<b>1</b>
1.1. Bottlenose Dolphin ( <i>Tursiops truncatus</i> ).....	1
1.1.1 Physical Characteristics.....	2
1.1.2 Sociality.....	3
1.1.3 Behaviour .....	4
1.1.4 Mediterranean Common Bottlenose Dolphin.....	5
1.2 Respiration and Diving Behaviour .....	6
1.3 Boat/Human Presence.....	8
1.4 Research Objectives.....	11
<b>2. The Study Area</b> .....	<b>12</b>
<b>3. Methods</b> .....	<b>13</b>
3.1. Data Collection.....	13
3.1.1 Part A: Focal Individual Respiration Rates .....	13
3.1.2 Part B: Group Surfacing Rates .....	16
3.2 Data Analyses.....	18
3.2.1 Part A: Individual Respiration Patterns.....	18
3.2.2 Part B: Group Surfacing Patterns.....	20
<b>4. Results</b> .....	<b>21</b>
4.1 Part A: Individual Respiration Patterns .....	21
4.1.1 Dive Data.....	21
4.1.2 Boats.....	24
4.1.3 Dive Parameters and Boats.....	29
4.1.4 Behaviour .....	30
4.2 Part B: Group Surfacing Rates .....	32
4.3 Results in Summary:.....	34
4.3.1 Part A: Individual Respiration Patterns.....	34
4.3.2 Part B: Group Surfacing Rates .....	35
<b>5. Discussion</b> .....	<b>36</b>
5.1 Overview of Results.....	36
5.1.1 Group Size.....	36
5.2 Part A: Individual Respiration.....	37

5.2.1 Surfacing Events .....	37
5.2.2 Boat and Dolphin Presence .....	37
5.2.3 Dive Behaviour, Seasonality and Boats .....	38
5.3 Part B: Group Surfacing Rates .....	41
5.4 Assessment of Techniques .....	42
5.4.1 Data Collection .....	42
5.4.2 Non-Invasive Techniques .....	43
5.4.3 Dive Descriptors/ Parameters .....	44
5.4.4 Recommendations for Further Study .....	44
5.5 Management Implications .....	45
<b>6. Summary &amp; Conclusions .....</b>	<b>47</b>
<b>References .....</b>	<b>49</b>
<b>Appendices .....</b>	<b>60</b>

## List of Figures

<b>Figure 1.1:</b> Map showing the global distribution of <i>Tursiops truncatus</i> .....	1
<b>Figure 1.2:</b> Geographic distribution of the common bottlenose dolphin in the Mediterranean Sea.....	5
<b>Figure 2.1:</b> Map of the study area (Golfo Aranci), on the North-eastern coast of Sardinia, Italy.....	12
<b>Figure 3.1:</b> Schematic view of the BDRI Microsoft Access database illustrating the dive data forms (designed in MS Access by Díaz López) used for inputting individual respiration and general sightings data.....	16
<b>Figure 3.2:</b> View of Microsoft Access (designed by Díaz López) database used for entering in group surfacings and sample specific data.....	17
<b>Figure 4.1:</b> Positive correlation found between the mean long dive duration and the mean number of short dives exhibited, per dive sample.....	23
<b>Figure 4.2:</b> Pie chart depicting the frequency of surface events. Regular dives were the dive type most frequently observed, in over 75% of dives.....	24
<b>Figure 4.3:</b> Mean boat presence of fishing boats (FB), ferries, outboards (OB) and sailboats (SB), during sample months from both 2005 and 2006.....	25
<b>Figure 4.4:</b> Boat presence comparison, between peak and non peak seasons, using the four boat categories.....	26
<b>Figure 4.5:</b> PCA loadings plot of the first principal component (using a variance-covariance matrix).....	27
<b>Figure 4.6:</b> PCA loadings plot of second principal component from the PCA.....	27
<b>Figure 4.7:</b> PCA scatter plot of the seasonal variability in boat presence.....	28
<b>Figure 4.8:</b> Behavioural budget determined from behaviour classifications during respiration sampling.....	30
<b>Figure 4.9:</b> Mean dive parameters, excluding maximum dive duration, for both feeding and travelling behaviour.....	31



**Figure 4.10:** Positive correlation between subgroup size and number of surfacings..... 32

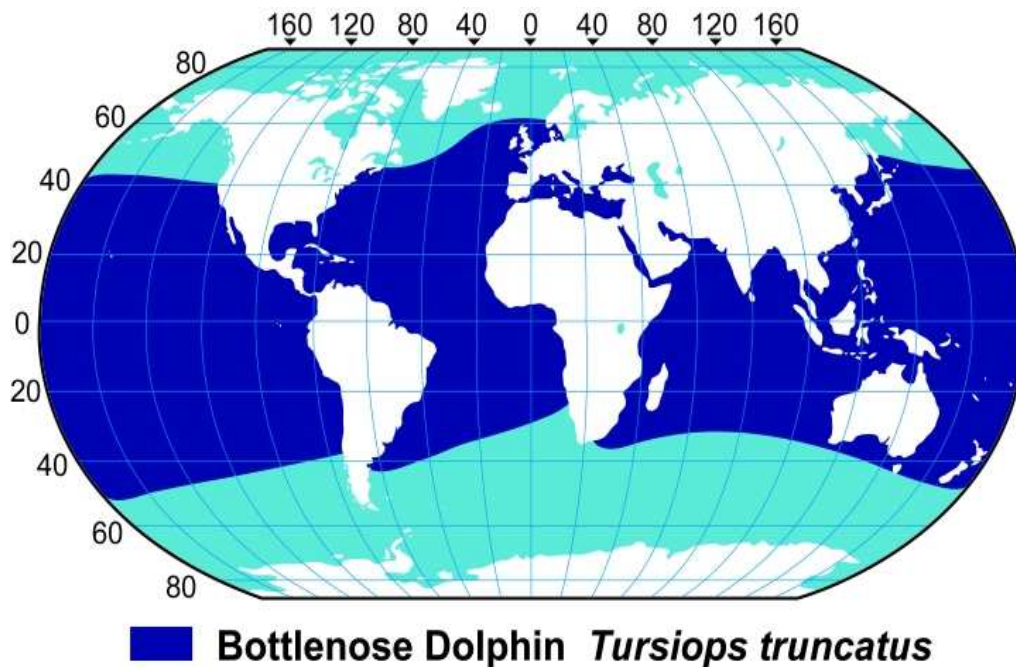
## List of Tables

<b>Table 1.1:</b> Taxonomy of the bottlenose dolphin ( <i>Tursiops truncatus</i> ).....	2
<b>Table 4.1:</b> Statistical summary of bottlenose dolphin dives as a whole, and also broken down to recognize short and long dives.....	22
<b>Table 4.2:</b> Univariate statistics of the five dive parameters used for dive analysis. Maximum dive duration was measured in seconds.....	22
<b>Table 4.3:</b> Correlation matrix between dive parameters. Maximum (Max) dive duration was not correlated with any of the other parameters.....	23
<b>Table 4.4:</b> Mean dive parameters ( $\pm$ s.e.) depicting the significant differences between peak and non peak samples.....	29
<b>Table 4.5:</b> Mean dive parameter values in presence and absence of tourist boats (TB)...	30
<b>Table 4.6:</b> Mean outboard, sailboat and fishing boat presence between feeding and travelling dive samples, divided by boat type. ....	31
<b>Table 4.7:</b> Summary statistics for all group surfacing samples, approach and no approach samples.....	32

# 1. Introduction

## 1.1. Bottlenose Dolphin (*Tursiops truncatus*)

Bottlenose dolphins (*Tursiops truncatus*) are a truly cosmopolitan species with a world wide distribution (Figure 1.1); they are environmentally adaptive and range from temperate to tropical climates in a variety of habitats including estuaries, pelagic waters and open coastal zones (Shane, 1990b). Much of their popularity stems from them being the most common cetaceans in public aquariums (Lott, 2004), but the extensive geographical range and flexible existence of the species makes it one of the most recognized, and equally one of the most studied, cetaceans in the world. Free ranging, wild bottlenose dolphin populations can be found in the Atlantic, Pacific and Indian Oceans, as well as the Black, Red and the Mediterranean Sea (Wells & Scott, 2002; Eisfield, 2003; Diaz Lopez *et al.*, 2002), each of which may face different environmental and anthropogenic pressures. This variability may contribute to inter-population differences, such as relative abundance, site fidelity, social dynamics and behaviour, for example.



**Figure 1.1: Map showing the global distribution of *Tursiops truncatus*. Reproduced with kind permission from the American Cetacean Society [www.ACS.online.org](http://www.ACS.online.org)).**

Movement tendencies of bottlenose dolphins can be as broad as their distribution; some display residential tendencies within specific areas (Scott *et al.*, 1990; Wilson *et al.*, 1999;

Diaz Lopez, 2002; Zolman, 2002), while others are thought to be migratory or even nomadic (Wilson *et al.*, 2006).

Bottlenose dolphins, as all other dolphin and whale species, are marine mammals belonging to the Order Cetacea. They are toothed (Suborder Odontoceti) animals that are members of the taxonomic family, Delphinidae (Table 1.1).

<b>Kingdom</b>	<i>Animalia</i>
<b>Phylum</b>	<i>Chordata</i>
<b>Class</b>	<i>Mammalia</i>
<b>Order</b>	<i>Cetacea</i>
<b>Suborder</b>	<i>Odontoceti</i>
<b>Family</b>	<i>Delphinidae</i>
<b>Genus</b>	<i>Tursiops</i>
<b>Species</b>	<i>truncatus</i>

**Table 1.1: Taxonomy of the bottlenose dolphin (*Tursiops truncatus*).**

The first accounts of bottlenose dolphins dates back several million years ago, (Barnes, 1990), and fossil records estimate delphinids appearing in the myocene period (Wells & Scott, 2002).

### ***1.1.1 Physical Characteristics***

The bottlenose dolphin has several distinct physical features which facilitate successful identification. The body colour is typically a subdued blend of brown to charcoal or grey, with a much lighter belly/ventral side. The rostrum tends to be short and stubby, and the species boasts a generally robust head with a prominent melon, and a body shape that tapers behind the dorsal fin. Slight physical variations exist for different populations, most likely a response to area-specific adaptations (Leatherwood & Reeves, 1983).

The bottlenose is a sexually dimorphic species, with males attaining a larger body size than females. Newborns measure 0.9-1.2m at birth and adults can reach a maximum length of approximately 4.1m (Leatherwood & Reeves, 1983). The majority of growth occurs within the first two years of the lifecycle (Wells & Scott, 2002). Different body size ranges are known to exist between different populations. Larger animals, for example, are usually

associated with colder and/or deeper waters such as those found in the North Sea (Eisfield, 2003),

Size differentiation between inshore and offshore populations in the Pacific and Indian Oceans has sparked questions regarding the current monotypic taxonomic classification of the genus, *Tursiops spp.* There is evidence of a second, smaller sized *Tursiops* species, *Tursiops aduncus*, in some bottlenose dolphin populations off South Africa (Ross, 1977), Australia (Möller & Beheregaray, 2001) and China (Wang *et al.*, 2000), but considerable overlapping characteristics have complicated definitive changes in *Tursiops* taxonomy and evolution. This report will focus solely on *Tursiops truncatus*.

The maximum life span for bottlenose dolphins is estimated at 40-50 years, with females reaching the higher end of the range. Sexual maturity occurs earlier for females than males, at 5-13 years for females (Mann *et al.*, 2000) and approximately 9-14 years for males (Wells & Scott, 2002). The gestation period lasts approximately 12 months (Mann *et al.*, 2000), and calves suckle for 1.5-2 years, although some may retain some level of maternal dependence for up to 6 years (Wells & Scott, 2002). Birth seasonality depends on area, but most studies have found the majority of birthing to occur in the spring and summer months (Mann *et al.*, 2000).

### **1.1.2 Sociality**

The bottlenose dolphin is a very social animal exhibiting dynamic group size and structure. The “fission-fusion” nature of their associations is defined by small groups of individuals in which group composition is highly variable (White, 1992 in Lusseau *et al.*, 2003). Associations have been observed to last anywhere from minutes to years (Connor, 2001; Lusseau *et al.*, 2005).

Although general associations are quite fluid in nature (Jefferson *et al.*, 1993), many populations show trends in social structuring. Rogers *et al.* (2004) showed that associations between dolphins were not random, and individuals appeared to have some companions which were more or less preferred. Most populations exhibit stronger associations between individuals of the same sex, which seems to be linked to reproductive status (Lusseau *et al.*, 2003; Rogers *et al.*, 2004), but mixed sex groupings have also been found in some populations (Eisfield, 2003; Lusseau *et al.*, 2003). Maternal investment is high for bottlenose

dolphins (Mann *et al.*, 2000), and as a result, mother and calf associations are among the strongest. This is especially evident during the first year when the calf is still highly dependent.

Whilst group size is generally thought to increase with marine depth or “openness” (Shane *et al.*, 1986), in coastal bottlenose populations this typically ranges from 2 to 29 individuals (Shane *et al.*, 1986; Scott *et al.*, 1990; Bearzi *et al.*, 1997; Diaz Lopez, 2002; Eisfield & Robinson, 2004; Lusseau *et al.*, 2003; Kerr *et al.*, 2005), with offshore populations often found in larger groups sometimes consisting of hundreds of dolphins (Jefferson *et al.*, 1993), but it is important to note that in each independent study, the definition of “group” and “group size” will influence how dolphin presence is determined (Shane *et al.*, 1986).

### **1.1.3 Behaviour**

The behaviour of bottlenose dolphins is very complex and often fluctuates seemingly unpredictably. Studies have concluded that behaviour is not solely impacted by one factor, but instead is “dictated by a complicated web of interacting elements” (Shane, 1990a). During its relatively long life span, this “highly adaptive” species shows a repeated ability to learn and adapt its behaviours to optimize its survivability (Shane, 1990b); displaying a “large degree of behavioural plasticity” (Pace *et al.*, 1998).

Bottlenose dolphin behaviours have been divided into many categories; the most common of these are travelling, socializing, feeding and resting (Shane, 1990a). Feeding (Diaz Lopez & Bernal Shirai, 2006) and travelling (Shane, 1990a) are typically the most frequently observed, or perhaps most easily identified behaviours (Lynn, 1995).

As highly opportunistic feeders, bottlenose dolphins are able to exploit those prey species most readily available and/or abundant. The species has a large range of prey species which consist mostly, or in some cases completely (Barros & Wells, 1998), of fish, but may also include smaller proportions of cephalopods and crustaceans (Barros & Odell, 1990; Santos *et al.*, 2001). Intraspecific variability in diet composition often exists between geographically distinct populations as a result of environmental variation (Lewis & Schroeder, 2003).

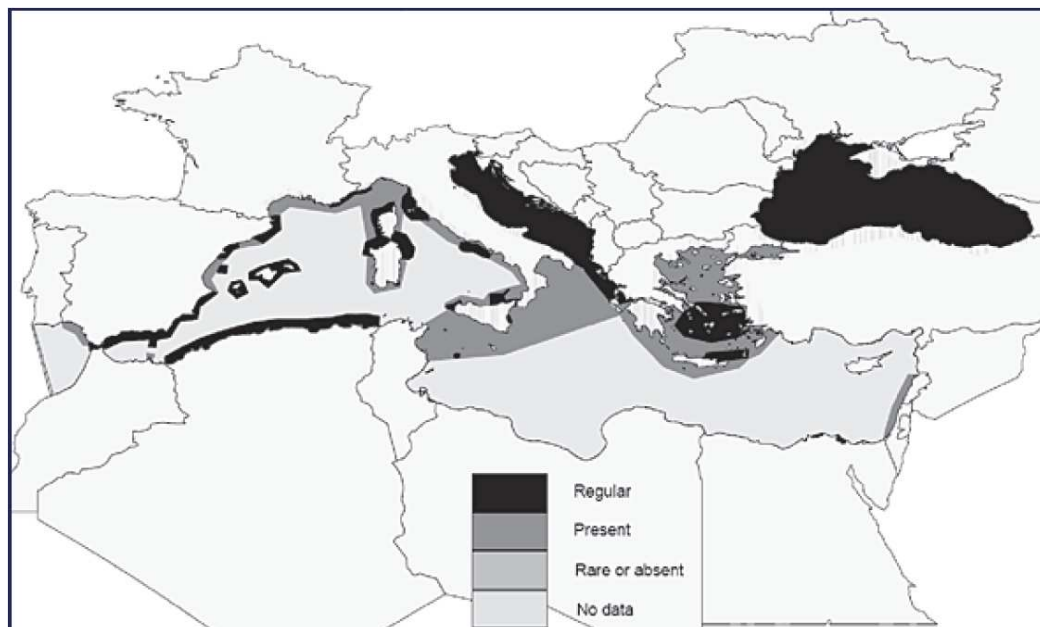
Bottlenose dolphins also exhibit a wide array of feeding techniques which are highly dependent on temporal and environmental conditions (Shane, 1990b; Pace *et al.*, 1998; Diaz

Lopez, 2006). Feeding may involve both individual and cooperative behaviours (Bel'kovich, 1991; Eisfield, 2003; Diaz Lopez, 2006) such as solitary feeding rushes (Shane, 1990a; Diaz Lopez, 2006) and group herding of prey fish (Wells & Scott, 2002; Diaz Lopez, 2006) .

Behavioural analysis involves many challenges as behaviours can change as quickly as their social networks and their ability to quickly “disappear”. Many behaviours, other than feeding, have been identified for bottlenose dolphins, such as travelling, socializing, resting, etc. (Shane, 1990a). Travelling behaviour is often represented by continuous, directional swimming, while feeding is often represented by longer dives in one area or visible foraging on various prey. Both travelling and feeding behaviours have been associated with diurnal and seasonal patterns (Brager, 1993; Lynn, 1995).

#### ***1.1.4 Mediterranean Common Bottlenose Dolphin***

In the Mediterranean Sea, the common bottlenose dolphin is one of the most abundant coastal cetacean species (Figure 1.2), but despite this, population numbers have suffered a decline in the last 50 years. Mediterranean bottlenoses are believed to be geographically isolated from Atlantic populations, and are most commonly found along the continental shelf in water depths less than 200m (Bearzi & Notarbartolo Di Sciara, 1992; Bearzi, 2002).



**Figure 1.2: Geographic distribution of the common bottlenose dolphin in the Mediterranean Sea. (Adopted from Reeves & Nortarbartolo di Sciara, 2006).**

The diet of Mediterranean bottlenose dolphins is consistent with other populations, and consists of mainly fish, but also cephalopods and crustaceans (Alessandri *et al.*, 2001; Blanco *et al.*, 2001). The high abundance of fish in their diet coincides with them being one of the species most frequently involved in fisheries interactions in the Mediterranean (Bearzi, 2002). Numerous reportings within the Mediterranean include observations of dolphins following fishing boats and trawlers (Fortuna *et al.*, 1998; Pace *et al.*, 1998; Bearzi, 2002), presumably using them as opportunistic feeding platforms. Studies have also shown the increased use of fishing nets and gill nets as alternate sources of prey (Diaz Lopez, 2006) as well as the exploitation of marine fish farms (Diaz Lopez *et al.*, 2005).

Mediterranean bottlenose dolphin populations are seemingly more dispersed, and are found in smaller entities than in other populations (Bearzi, 2002; Diaz Lopez *et al.*, 2005). Group size of the Mediterranean populations ranges between 2-18 individuals (Gannier & Gannier, 1990; Bearzi & Notarbartolo Di Sciara, 1992). Off the Northeast coast of Sardinia, where there is evidence of resident individuals, group size is, however, found to be smaller, comprising as few as 4 or less animals (Diaz Lopez *et al.*, 2005).

## **1.2 Respiration and Diving Behaviour**

Cetacean species, in general, are difficult to study because the majority of their time is spent underwater. Their behavioural activities are not readily visible to researchers and observers as they disappear during dives whilst leaving minimal traces of their whereabouts (Mann, 1999). Unfavourable sea and weather conditions further reduce the quality of dolphin observations, significantly limiting comprehensive cetacean research (Hooker & Baird, 2001). Fortunately for scientists, underwater activities must be interrupted by bouts of surfacings, for the purpose of respiration (Baird *et al.*, 2005). Surface observations of dive behaviour can be gathered opportunistically to gain insight into the general respiratory behaviours of cetaceans. Analysis of dive behaviour is therefore considered a reliable method for studying the overall ecology of a marine mammal species and can be indicative of how a species uses the water column (Baird *et al.*, 2005; Bernal Shiray *et al.*, 2006).

Respiration is correlated with physiological responses. For example, there is a direct relationship between the respiration rate and the metabolic rate of bottlenose dolphins (Yazdi *et al.*, 1999; Lusseau, 2003); increased metabolism resulting in an elevated oxygen requirement (Lusseau, 2003). Fluctuations in metabolic rate might result from increased



energy output required for diving, changes in swimming speed, and also heightened stress levels in the presence of disturbances (David, 2002).

Both aerobic and anaerobic respiration can be used to fuel activities such as swimming and diving. The aerobic dive limit is the maximum breath-hold that can be supported by available oxygen reserves, (i.e. before complete depletion of oxygen stores) (Yazdi *et al.*, 1999; Kooyman & Ponganis, 1998; Williams *et al.*, 1999). Prolonged dive times, over the aerobic dive limit, are energetically expensive (Mori, 1999) and result in the unfavourable use of stored oxygen from the body tissues due to lack of air intake (Lusseau, 2003). Submergence durations dictate the respiratory responses involved with diving (Williams *et al.*, 1999) but divers should primarily rely on aerobic respiration. Energy demands will depend on both dive duration and dive depth (Williams *et al.*, 1999). To achieve longer submergences, animals must balance the physiological costs of diving with the amount of available oxygen reserves (Kooyman, 1989; Williams, 2001). Restoration of these oxygen stores is vital following long, drawn-out dives and is achieved by repeated or extended surfacings. These surface durations are thought to be related to the aerobic dive limit (Fortuna *et al.*, 1998) as the frequency of ventilation dives serves as an indicator of the “re-establishment” or recovery of oxygen and carbon dioxide levels in the tissues (Hooker & Baird, 1999, Fortuna *et al.*, 1998).

Hooker & Baird (2001) describe diving behaviour as two separate classification units: surface behaviour and subsurface behaviour. The former involves visual, and sometimes acoustical, observations of surface activities considered to be indicative of dive behaviour, whereas the latter involves the employment of technological aids such as sonar, tags and time depth recorders (TDRs) to quantify dive characteristics, underwater vertical movements, and information pertaining to dive depth and dive duration.

Dive behaviour encompasses several actions and submergence times can therefore be indicative of specific underwater behaviours (Peharda & Bearzi, 1993). Studies have found that dolphin breathing rates vary significantly with respect to different behavioural activities, such as travelling, foraging, resting and socializing, (Shane, 1990; Fortuna *et al.*, 1998; Bearzi *et al.*, 1999, Diaz Lopez & Shiray, 2005). Longer dives are most commonly observed during foraging behaviour (Shane, 1990; Brager, 1993; Pace *et al.*, 1998), whereas short dives are thought to serve as either respiratory bouts or for the purpose of travel (Hooker & Baird, 2001).

Dive and surface behaviours (including both dive frequency and duration) are very dynamic and are readily influenced by many factors (Baird *et al.*, 2005) including water depth (Curnier, 2005), boat presence (Janik & Thompson, 1996; Nowacek *et al.*, 2001), prey abundance (Acevedo-Gutierrez & Parker, 2000), time of day (Baird *et al.*, 2005) etc. Researchers have observed various responses to these factors, including longer dives (Curnier, 2005), fewer surfacings, shortened inter-breath intervals, varied dive patterns depending on spatial arrangement of prey, and fewer dives at night, respectively. Dive variability has also been used to interpret the energetic costs involved with many behavioural activities, such as different foraging strategies (Fortuna *et al.*, 1998), opportunistic feeding behaviour (Pace *et al.*, 1998), diurnal dive patterns (Mate *et al.*, 1995) and responses to boat traffic (Nowacek *et al.*, 2001).

### **1.3 Boat/Human Presence**

Most bottlenose dolphin populations are found on oceanic coastlines. Maritime traffic is often very high in these seaside regions, and dolphins inhabiting or exploiting these areas are readily exposed to heightened levels of boat traffic. There has been a steady incline in marine traffic over the past few decades (Hildebrand, 2004) and there is increasing evidence that marine traffic is threatening to cetacean populations (Goodwin & Cotton, 2004). Increased human presence in coastal geographic areas, especially during peak tourism season, increases the frequency of dolphin-boat contacts and interactions (Hastie *et al.*, 2003), which inevitably increases the potential for disturbances.

Boat encounters may elicit a variety of cetacean behavioural responses. Observed changes in behaviours include decreased surfacing frequencies (Janik & Thompson, 1996), shorter dive times (Nowacek *et al.*, 2001), changes in group composition and habitat use of humpback whales (Scheidat *et al.*, 1999), changes in behavioural activity and avoidance tactics (Lusseau, 2003), and increased call durations of killer whales (*Orcinus orcus*) (Foote *et al.*, 2004).

Dolphin reactions to boats are often classified in terms of positive, negative or neutral responses (Crosti & Arcangeli, 2001; Goodwin & Cotton, 2004; Leung Ng & Leung, 2003). In general, positive reactions are behaviours such as boat approaches and bow riding, while negative reactions include when the animals move away or change swimming direction/speed or exhibit increased dive times. Neutral responses are those where there is no noticeable change in behavioural activity (i.e. feeding, travelling, etc) and animals appear “uninterested”. These classifications are only quantitative in nature, however, and therefore it is still difficult

to actively determine if the animals are responding to the presence of boats, the type of boat interaction, and/or to the increase in underwater noise levels (Goodwin & Cotton, 2004).

Contrary to what may be perceived, positive responses may still have serious consequences for animals. A positive reaction might still incur extra metabolic costs, for example, if it interferes with the time and energy invested in vital behaviours such as foraging (Janik & Thompson, 1996) or also if it interrupts important resting behaviour patterns (Constantine *et al.*, 2004). Excessive anthropogenic presence may also interfere with other activities such as feeding, mating, calving and social interactions (Marsh *et al.*, 2003). Changes in the “normal” durations of these behaviours are clearly evident from studies examining the interactions between bottlenose dolphins and dolphin tour boats (Crosti & Arcangeli, 2001). These tour boat-elicited behavioural changes may have important energetic implications.

The degree of behavioural response can be influenced by different types of boats, and also dependent on the level of boat presence. Encounters which are perceived as threatening increase the sensitivity of animals to anthropogenic activities (Constantine *et al.*, 2004). Boat interactions which are long in duration, deemed intrusive, or those which are unpredictable in nature are more likely to elicit evasive or negative behaviour (Lusseau, 2003). Small, moving motor boats and other similar planing-hulled boats have been found to elicit more negative reactions than other types of moving boats (Constantine *et al.*, 2004). Whale and dolphin watching boat interactions are increasingly common in coastal areas. The behaviour of these tourism boats is unique from most other vessels in that they attempt to follow the dolphins for the purpose of prolonged encounters, often resulting in erratic movements by the vessel including quick changes in speed and direction. This type of boat behaviour has been found to produce stronger responses (Lusseau, 2003).

Vertical and horizontal evasive movements are common responses exhibited by dolphins in the presence of boats. These aversion tactics have been likened to predator avoidance strategies, in which animals change their location, direction or movement patterns in order to avoid a potential threatening situation (Lusseau, 2003). Group synchronization of behaviours, such as breathing (Hastie *et al.*, 2003), foraging and resting (Constantine *et al.*, 2004) in the presence of boats, is also thought to a type of anti-predator response which helps to maintain high levels of social cohesion of groups.

Fishing boats and trawlers often provide dolphins with a chance for a “free meal” and therefore may elicit opportunistic approaches to capitalize on higher than normal fish density, within and surrounding fishing nets (Wells & Scott, 2002). Alternatively, fish dispersion, resulting indirectly from boat presence, may also be what is causing an increase in animal movements, as they chase the alarmed prey (Janik & Thompson, 1996).

The distance between the focal individual or group and the boat is also significant in determining the type and extent of reaction (Nowacek *et al.*, 2001). Janik & Thompson (1996) found that dolphin surfacing rate in social groups decreased with the presence of approaching boats, for example. Decreased surfacing rates of groups, when comparing before and after boat presence, suggested that animals exhibited longer dives in avoidance of approaching vessels.

Most dolphin species are relatively long-lived, and those residing in coastal areas with consistently high levels of marine traffic may have repeated exposure to boats and disturbance levels over their lifetime. Chronic exposure may be especially evident for animals with high site fidelity and similarly for those found in small isolated populations (Constantine *et al.*, 2004). Bottlenose dolphins in Sarasota Bay have experienced long term exposure to marine traffic, but boats continue to elicit short term changes in dolphin behaviour (Nowacek *et al.*, 2001). Similarly, in New Zealand, regular and frequent exposure to boats continues to elicit irregular responses of bottlenose dolphins in the area (Constantine *et al.*, 2004).

Conversely, animals may experience what appears to be a de-sensitization to boat traffic, on the basis of a reduced response. Habituation refers to a decreased sensitivity over time due to repeated exposure and/or continuous stimuli. Typically, habituation occurs when it is not energetically necessary for an animal to adopt an avoidance response (Richardson *et al.*, 1995) or when there is neither cost nor benefit to a stimulus (Bejder *et al.*, 2006). Frequent occurrence of high levels of marine traffic in Aberdeen, Northeast Scotland, have seemingly resulted in habituation of the dolphins to boats (Sini *et al.*, 2005).

It has clearly been established that boats can change or disturb marine mammal behaviour, but with world wide marine traffic on the rise, these interactions may continue to impede or alter marine mammal activities. Extensive disturbance, especially within small communities or populations may drastically change the structure or fitness of these groups. Finer scale behavioural research is needed to better determine which aspects of behaviour are being

modified, in attempts to understand the implications of these responses. Special consideration should be placed on not only short-term effects but on the long-term implications; this will be useful for successfully monitoring and managing marine traffic, in hopes of minimizing their negative effects on marine mammals.

#### **1.4 Research Objectives**

Boat induced changes in diving behaviour may have serious implications for dolphin populations habitually exposed to heightened marine traffic. Respiration is necessary for survival and as such, changes in respiratory/dive behaviour pose both energetic and health risks for these animals.

This project proposes the use of direct visual observation of bottlenose dolphin diving behaviour in Golfo Aranci, north-eastern Sardinia, Italy in order to determine the relationship between respiration patterns and boat presence. Golfo Aranci is an area of high marine traffic in the summer months, and boat presence over the duration of the research period will be used to quantify the effects of this activity on dolphin diving. In this respect, the objectives of the present study are:

- i) to enlist and establish the usefulness of five dive parameters to better explain observed variability in bottlenose diving behaviour;
- ii) to test for seasonal differences in both boat presence and bottlenose dolphin dive behaviour and determine the relationship between these variables;
- iii) to examine the variability of dive parameters with respect to the level and type of boat traffic observed as well as the presence/absence of boats in the study area;
- iv) to examine behavioural differences and the subsequent changes in dive behaviour between types of boat present; and
- v) to determine whether or not the presence of absence of boat approaches results in subsequent changes in dolphin group surfacing rates.

Most studies have only looked at the short-term effects of boat presence on cetaceans, but these seemingly unimportant short-term effects may lead to cumulative, long-term implications. Determining the effects of boat traffic on diving behaviour is one step towards understanding how these animals are affected by, and respond to, such anthropogenic pressures.

## 2. The Study Area

Golfo Aranci (40°59'N, 009°37'E) is located on the north-eastern coast of Sardinia, Italy (Figure 2.1). Studies of bottlenose dolphins in the area, conducted by the Bottlenose Dolphin Research Institute (BDRI), have been ongoing since 1991. This research has demonstrated a degree of residency of identifiable individuals in the area, and current predictions from mark-recapture studies estimate a minimum number of 42 dolphins using this area (Díaz López, *et al.*, 2002; Díaz López & Bernal Shiray, 2006).



**Figure 2.1:** Map of the study area (Golfo Aranci), on the North-eastern coast of Sardinia, Italy.

Marine traffic in the Gulf of Aranci and the greater Gulf of Olbia consists of a variety of boat types including mostly sail boats, outboards, fishing boats, ferries and trawlers. There is a substantial increase in overall boat traffic during the summer months of May to August, which tends to peak in July and August (Díaz López *et al.*, 2002). The bathymetry of the area deepens somewhat gradually and ranges from 0 to 65 meters in depth (pers.comm, Díaz López). It is important to mention the presence of a marine fin fish farm in the Gulf which operates 21 floating aquaculture style nets occupying approximately 2.4 hectares (Díaz López *et al.*, 2005).

### 3.

## Methods

### 3.1. Data Collection

Behavioural observations were made from a 5.3m motorized vessel in the Gulf of Aranci and surrounding area during the late spring/summer, May to August, 2006. Data collection was performed using two methodologies; one examining the dive behaviour of focal individuals, and the second analysing surfacing rates of entire dolphin groups, both with respect to boat presence. For this experiment, dives and dive behaviour refer to surfacing patterns and durations of bottlenose dolphins without information on dive depths (Hooker, 1999; Hooker & Baird, 1999). Dive observations were only made under sea conditions of less than 4 on the Douglas scale.

#### 3.1.1 *Part A: Focal Individual Respiration Rates*

This study focused on the direct observation of dive/surface behaviour of focal individuals as a non-invasive research method representative of free-ranging dolphin behaviour. Hastie *et al.* (2003) define surfacing as a “discrete, unambiguous event” which can be easily classified; focal observation presented a detailed way of observing such individual behaviour (Altmann, 1974; Mann, 1999; Hooker & Baird, 2001).

Respiration data was only recorded for focal individuals that could be visually identified in the field from “natural markings” present on the dorsal fin or body surfaces using photo-identification techniques (after Wilson, 1995). Archived photo-identification data from BDRI, (comprising 34 recognizable dolphins within the Gulf of Aranci and the Gulf of Olbia) were studied to facilitate individual recognition of study animals during focal follows. The small size of this resident community makes individual follows optimal; focal individuals were generally recognized immediately, due to the distinctiveness of markings on their body, without the need for later searches in the BDRI photo archives for positive matching. This subsequently eliminated recognition uncertainties which may have occurred whilst tracking an individual when other dolphins were also present.

The primary objective of each dolphin encounter was to determine the composition and size of each group and, when possible, to identify a focal individual for dive data collection. During sightings involving the presence of 2, or more, well-marked dolphins, a single focal

individual was chosen at random. Sampling of unidentifiable animals was only carried-out when it was certain that the animal in question was solitary (after Mann, 1999).

General sightings data for each encounter included information on the location/area of the dolphin sighting, the presence of boats, environmental conditions, behavioural activity and, where applicable, swimming speed of the animals (if dolphins were travelling) and observed fish presence (using an echo-sounder).

Sampling observations and methodology were made using a combination of both continuous and instantaneous point sampling. Continuous sampling involved sampling all of the events related to a desired behaviour, whereas instantaneous sampling involved observational sampling of predetermined activities at fixed intervals (after Altmann, 1974; Nowacek *et al.*, 2001). The focal animal sampling was based on instantaneous point sampling (Mann, 1999). Continuous sampling of dive behaviour commenced following the initial detection of an identifiable focal individual and persisted until the animal either left the area or until weather conditions/light no longer permitted positive visual confirmation. Instantaneous sampling was carried-out at 3 minute intervals following the initiation of continuous sampling, at which time the number of boats present within the visual area was also recorded. Boats were simply categorized by type: i.e. fishing boats, outboards, sail boats and ferries. Any specific reactions to varying boat types by the animals were documented. Fish presence and water depth were also recorded instantaneously.

Respiratory data collection involved timing, to the nearest second, the dive intervals of dolphins using a digitalized stopwatch. . The start time of dive data collection was noted followed by the chronological time, in seconds, of each subsequent surface. Follows were determined to be “finished” when positive confirmation of focal individual could not be achieved, i.e. when the focal individual was not recognizable due to its position in the water, when the focal individual surfaced too far away for accurate observation, or when unambiguous identification was biased by the presence of other similarly marked, or unmarked, individuals in proximity.

Surface events were classified during dive observations. These events fell under one of five distinct categories: regular dive, fast surface, tail stock, fluke(s) up, or “other”, which included less frequently observed surface behaviours such as back breach, full leaps and spy hops, for example. Following the definitions of Shane (1990a), a regular dive consists of a

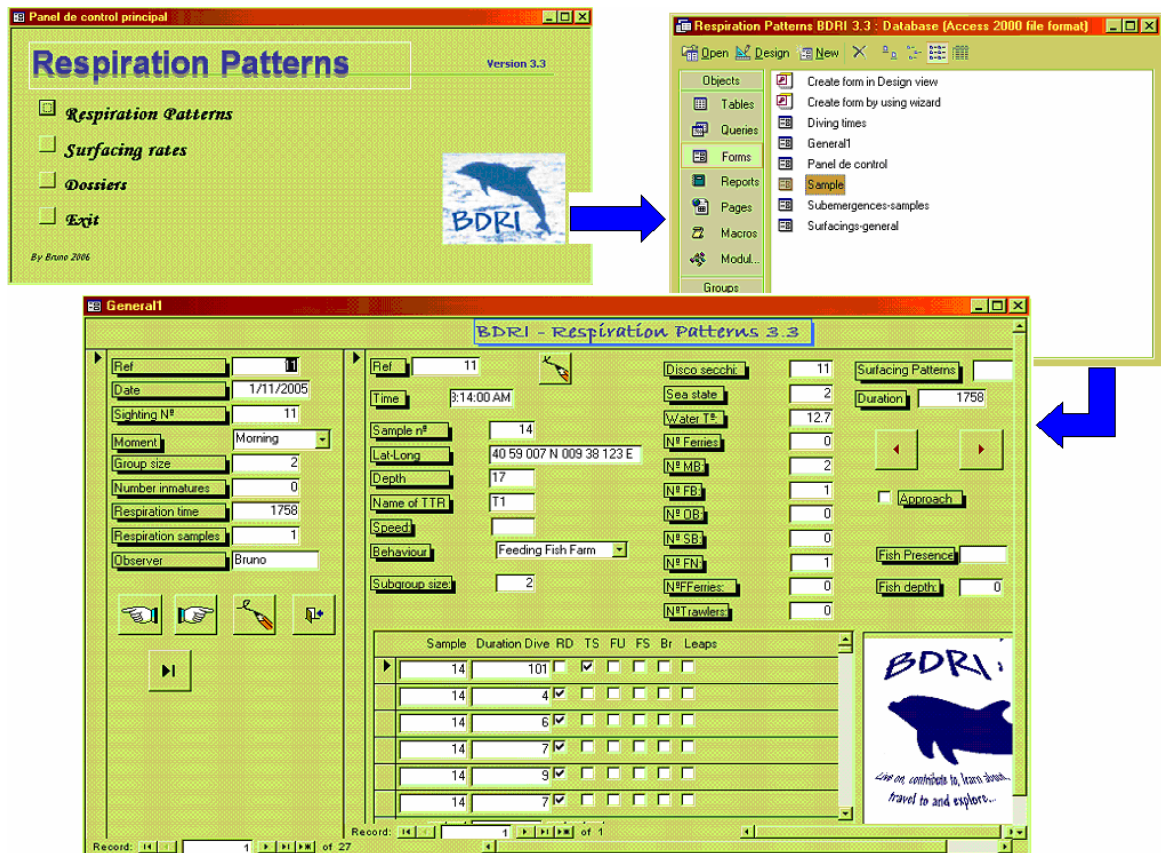


surface in which only the blowhole, back and dorsal fin are exposed; a fast surface is similar to the regular dive, but is executed at higher speeds resulting in more of the dolphin's ventral side being exposed, as well as the formation of white water around the dolphins body; tail stock surface is a dive where the dolphin's back is arched and the tail stock (also known as the peduncle) is exposed without the appearance of the flukes; and fluke(s) up is a behaviour in which the dolphin arches its back but this time with flukes visible above the water surface before submerging (Shane, 1990a; Bernal Shiray *et al.*, 2006).

Behavioural activities were divided into four commonly used categories: feeding, socializing, resting and travelling, respectively (Shane, 1990; Díaz López, 2006). Classification of behaviours were determined *a posteriori*, after the field session was complete, and followed strict data analysis of *in situ* observations. These classifications were determined as a function of focal group sampling using precise, objective parameters such as dive duration, swimming speed and heading, observation of prey, presence of fishing nets or fishing boats, group behaviour, etc (after Díaz López, 2006). Feeding was distinguished, for example, by repeated variable dives in one area, or feeding rushes. Continuous, uni-directional swimming was indicative of travelling, whereas resting was classified as very slow movement or drifting. Obvious physical contact and/or physical displays and splashing between individuals was indicative of social behaviour (after Shane, 1990a).

Whenever possible, in order to minimize the effects of boat presence on dolphin behaviour, the engine of the research vessel was shut-down and stabilized at fixed points during observational recordings. When it was necessary to follow focal individuals, the boat was manoeuvred in a predictable, constant manner using minimal speed and avoiding any sudden changes in direction. Sampling was carried out at different times of the day (morning, afternoon or evening) during the field season, eliminating a time of day bias across the sampling period. Survey paths varied depending on prevailing weather conditions and sightings.

All data was entered into a relational database system (compiled in Microsoft Access) for subsequent analysis (illustrated below in Figure 3.1).



**Figure 3.1: Schematic view of the BDRi Microsoft Access database illustrating the dive data forms (designed in MS Access by Díaz López) used for inputting individual respiration and general sightings data. The information entered into each form was interrelated by a number of common fields or identities which facilitated extraction of information required from simultaneous files. This was accomplished by using the database’s “Query” function.**

### **3.1.2 Part B: Group Surfacing Rates**

When identification of recognizable focal individuals for respiration sampling was not possible, boat-dolphin interactions were observed for groups; a group being considered as one or more dolphins in close proximity, engaged in the same activity (after Shane, 1990a). The first priority was to determine group size and composition. Following this, surfacing patterns of dolphin groups in the presence and absence of approaching and non-approaching boats were observed, independent of individuals (modified from methods used by Janik & Thompson, 1996). The surfacing frequencies were examined in relation to approaching/passing boats, or those in close visual proximity. This was achieved by counting the number of dolphin surfacings that occurred during an instantaneous one minute period when dolphins were in direct presence of boats. Control group data was collected for group

surfacing rates in the absence of boats, when no boats were detected within the visual range, and when the observation vessel was also shut down. These observations were also made for one minute periods.

As with the focal individual sampling, classification of behavioural status (feeding, travelling, socializing, and resting) for all surfacing observations were made following strict examination of *in situ* data variables. The type of boat(s) in the direct vicinity was recorded, along with the number of boats that were similarly in the visual area. General sightings data, similar to those collected in the individual observations, were also made for group observations.

It was not possible to directly determine individual surfacing rates within the group, but mean surfacing ratios, called individual ventilation rates (IVR), were determined by using the total number of group ventilations per minute and dividing that number into the number of individuals in the focal group. This calculation could only be applied where a positive correlation between the number of surfacings and the number of individuals in a group was obtained.

The surfacing data was also subsequently entered into the Microsoft Access database structure for further analysis (Figure 3.2).

Surfacings Rates 3.3	
Number of ventilations / minute	
Ref	1
Date	6/10/2006
Sighting nr	187
Moment	Morning
Group size	7
Number of immatures	0
Surfacing samples	4
Observer	Kari
Ref	1
Time	7:49:00 AM
Subgroup size	7
Nr immatures Sub	0
Behaviour	Feeding Fish Farm
Speed	0
Approach	<input checked="" type="checkbox"/>
Number of surfacings:	40
Number of OB	1
Number of MB	4
Number of Ferries	0
Number of FB	0
Other Boats	0
Number of FN:	1

**Figure 3.2: View of Microsoft Access (designed by Díaz López) database used for entering in group surfacings and sample specific data. Data was again sorted, using various criteria, with the “Query” function.**

### **3.2 Data Analyses**

All data were analyzed with Paleontological Statistics, PAST, version 1.44 (Hammer *et al.*, 2001) and are presented as means  $\pm$  the standard error, or as the median value, when specified. Statistical significance was tested at the  $p < 0.05$  level.

The daily encounter rate was considered as the total number of sightings ( $N_s$ ) as a function of the time spent searching for dolphins ( $t_{se}$ ):  $DER = N_s / t_{se}$ . Searching time stopped at a sighting and was restarted upon completion of sighting (Diaz Lopez, 2006).

#### ***3.2.1 Part A: Individual Respiration Patterns***

Respiration samples were collected and analyzed because of their “demonstrated utility” in cetacean behavioural and disturbance studies (Nowacek *et al.*, 2001). For the purpose of this study, a dive sample was defined as the continuous observation of diving behaviour of a focal individual, with a minimum duration of 3 minutes or which included a minimum of 10 consecutive dives (dos Santos *et al.*, 1990; Casale, 2001). Each dive sample was considered independent, as continuous sampling revealed a high level of variability (in terms of boat presence, group size, individual, water depth and behaviour). There were no breaks in the sample data. Dive data collected during 2005 by the Bottlenose Dolphin Research Institute, using the same methodologies as in 2006 (described below), were also incorporated into the analyses.

It has been well established that bottlenose dolphin dives are not homogenous in terms of duration (dos Santos *et al.*, 1990; Peharda & Bearzi, 1993; Bearzi, 1999; Bernal Shirai *et al.*, 2006). Dive data should at minimum be divided into two categories which divide shorter respiratory dives from longer dives which are most likely related to foraging (Hooker & Baird, 2001) but the variability of dive behaviour can make distinction between short and long dives difficult (Baird *et al.*, 2005). Some studies use an arbitrary 30 second cut-off to separate short dives from long dives, but this does not take into account variability. To avoid the subjectivity of this commonly used cut-off, I have instead used the median dive duration to objectively distinguish between short and long dives.

Once an arbitrary limit was set, datasets for both short and long dives were tested using univariate statistics. The mean and median duration, as well as duration range, of: a) all dives, b) short dives and c) long dives were determined. The mean short and long dive durations

were used for analysis in order to avoid pseudo-replication which would occur when using raw dive times, due to time series dependency (Lusseau, 2003). To assist in the interpretability of dive data, and to avoid redundancy in dive analysis, I also selected the following parameters to explain bottlenose dolphin dive behaviours.

1. Dive rate (DR): number of dives per minute.
2. Short dive rate (SDR): number of short dives per minute.
3. Long dive rate (LDR): number of long dives per minute.
4. Dive efficiency (DEff): percentage of time spent during long dives as a function of sample duration.
5. Maximum duration (Max): the dive of longest duration.

The dive parameters are likely to be highly correlated due to a strong level of inter-relatedness between the values. In order to avoid the redundancy, dive parameters had to be tested singularly between variables, using Kruskal-Wallis non parametric analysis of variance.

Mean dolphin group and subgroup sizes were determined from all samples, along with mean water depth from respiratory sampling locations. Surfacing events (i.e. regular dives, tail stock, etc.) were also analyzed to determine the relationship between type of surface event and subsequent dive duration.

Boats were classified into 4 general categories: fishing boats (including both trawlers and small fishing boats), outboards, sail boats, and ferries (including both regular and fast ferries). A non parametric correlation matrix was constructed for boat presence, sorted by boat type.

The seasonality variability between the four boat categories was explored using Principal Component Analysis (PCA). PCA is a method of multivariate statistical analysis which reduces multiple variables to a smaller number of factors which best explains the variability being assessed (Maeda *et al.*, 2000). Dive samples and all corresponding data were separated into two seasons: “peak” (June, July and August) and “non peak” (all other months of the year). PCA was used to analyse and graphically explore which boats were contributing to the highest level of seasonal variability between the four boat types (fishing boats, outboards, sailboats and ferries). Non parametric multivariate analysis of variance (NPMANOVA), based on Spearman rho distance measure, was also run to detect seasonal differences between

boat types. The significance was computed by permutation of group membership, with 5000 replicates.

These analysis methods were used to determine if a more specific categorization of boats was required, based on similarities or differences in seasonal presence. Mean short and long dive duration, as well as dive parameters, were tested for seasonal differences, as well as for differences depending on presence or absence of boats, based on seasonal categories. When significant differences were observed, post hoc analysis was performed for using Kruskal-Wallis analysis of variance.

Analysis of behavioural classifications of each dive sample determined those behaviours observed most frequently. Variability of dive parameters and short and long dive durations were tested between (dominant) behaviours. The influence of boat presence on behaviour, was examined by testing for variations between the type and level of boats present during different behaviours (Kruskal-Wallis non parametric analysis of variance). Behaviours samples were also compared between seasons.

### ***3.2.2 Part B: Group Surfacing Patterns***

Group surfacings data was divided into two groups, those samples collected during boat “approach” and those with “no approach”. The mean group size, or subgroup size, of each sample was compared for both approach and no approach. The number of surfacings observed during boat approaches was compared statistically, using Kruskal Wallis test, with the number of surfacings during no approach conditions. This was only possible once it was confirmed that the mean group sizes were not significantly different and therefore comparable.

Individual ventilation rates (IVR) were calculated for each sample, but in order to confirm the relevance of the IVR, I first had to test for positive correlation between subgroup sizes and the number of surfacings. If positive, subsequent comparisons could be made between the dive rates (those determined from individuals; Part A) and the individual ventilation rate from group data, as a means of testing the validity of group observations as opposed to those focused solely on individuals. Comparisons were also made between the mean IVR’s of each behaviour , from the group surfacing data, and compared to the dive rates for the same behaviours observed in Part A.

## 4.

## Results

### **4.1 Part A: Individual Respiration Patterns**

During the 3 month research period (May- August, 2006), I realized 42 days at sea, totalling an observation effort of 9626 minutes (160 hours). The mean daily encounter ratio (DER) of bottlenose dolphins was 0.3 dolphins per hour. A total of 33 hours was spent with dolphins, of which almost 11% was used for collection of respiratory patterns.

Respiration data collected by the BDRI throughout 2005 and early 2006 was also included into the analysis. Sixty-two bottlenose dolphin dive samples were collected during this time. A total of 1021 dives, totalling over 8.5 hours (515 min) of dive data, were collected and analysed from both 2005 and 2006. These samples included 32 dolphin followings of 11 focal bottlenose dolphins. These included 9 well marked, easily recognizable, photo identified individuals and two less identifiable individuals whose respiratory behaviour collection were facilitated by solitary presence.

#### ***4.1.1 Dive Data***

The mean duration of the dive samples was 513 sec (8.5 min), and samples included an average of 16 dives per sample. The average duration of bottlenose dolphin dives was  $30.3 \pm 1.3$  seconds but dives ranged widely from 2-249 seconds. The median dive duration was 12 seconds. This was subsequently used as the cut-off dive duration to distinguish between bottlenose dolphin short dives and long dives. Univariate statistics of all dives, short dives and long dives are described in Table 4.1. On average, long dives were more than 7 times longer than short dive durations, and accounted for over 87% of the overall dive duration.

<i>Dive type</i>	<i>n</i>	<i>Median duration (sec)</i>	<i>Mean duration ± s.e. (sec)</i>	<i>Range (sec)</i>
<b>All Dives</b>	1021	12	30.3 ± 1.3	2-249
<b>Short Dive (&lt;13sec)</b>	518	7	7.4 ± 0.1	2-12
<b>Long Dive (&gt;12sec)</b>	503	36	53.9 ± 2.1	13-249

**Table 4.1: Statistical summary of bottlenose dolphin dives as a whole, and also broken down to recognize short and long dives.**

The five dive parameters used for dive behaviour analysis are described in Table 4.2. These values were based on the overall averages, of each parameter, per dive sample. The bottlenose dolphins in this study averaged approximately two dives per minute, with almost equal short dive and long dive rates. Despite this, dolphins spent almost 90% of total sample durations engaged in long dives. The maximum dive time varied greatly, but the longest dive observed was 249 seconds.

<i>Dive parameters</i>	<i>Mean ± s.e.</i>	<i>Median</i>	<i>Range</i>
<b>Dive Rate (DR)</b>	2.04 ± 0.08	1.9	0.8 - 4.5
<b>Short Dive Rate (SDR)</b>	1.14 ± 0.19	0.7	0 - 9.1
<b>Long Dive Rate (LDR)</b>	1.15 ± 0.07	1.1	0.3 - 2.7
<b>Dive Efficiency (DEff)</b>	0.89 ± 0.01	0.9	0.7 - 1.0
<b>Maximum Dive Duration (Max)</b>	117.7 ± 6.67	114	34 - 249

**Table 4.2: Univariate statistics of the five dive parameters used for dive analysis. Maximum dive duration was measured in seconds.**

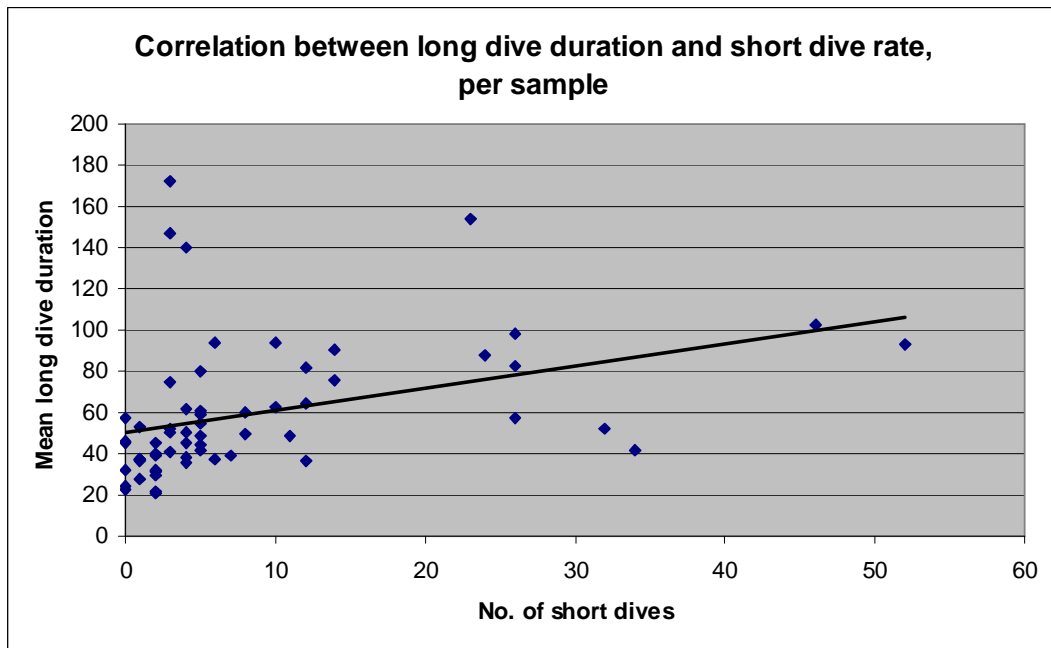
There were no correlations between maximum dive duration and the other dive parameters ( $p > 0.05$ ), but the remaining non parametric correlations of dive parameters revealed a high level of association (See Table 4.3).



	<i>DR</i>	<i>SDR</i>	<i>LDR</i>	<i>DEff</i>	<i>Max</i>
<i>DR</i>		p < 0.05 rs = 0.33	p > 0.05	p < 0.05 rs = -0.50	p > 0.05
<i>SDR</i>			p = 0.04 rs = -0.27	p < 0.05 rs = 0.06	p > 0.05
<i>LDR</i>				p < 0.05 rs = 0.61	p > 0.05
<i>DEff</i>					p > 0.05
<i>Max</i>					

**Table 4.3: Correlation matrix between dive parameters. Maximum (Max) dive duration was not correlated with any of the other parameters.**

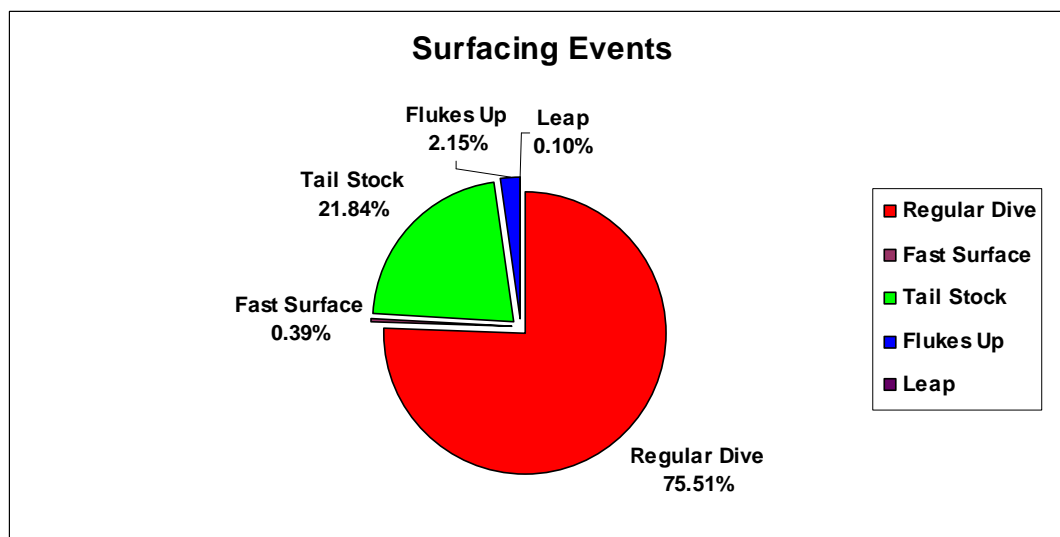
There was a positive correlation (p < 0.05, rs = 0.60) found between long dive durations and the mean short dive rate, per sample (Figure #).



**Figure 4.1: Positive correlation found between the mean long dive duration and the mean number of short dives exhibited, per dive sample.**

The average group size during dive observations was  $2.1 \pm 0.2$  dolphins while mean subgroup size was only slightly smaller, at  $1.9 \pm 0.1$  individuals. The mean water depth from initial sighting locations of dive samples was  $31.6 \pm 2.3$ m.

Bottlenose dolphin surface events were not homogeneous across dives. Regular dives were the most frequently used surface event, observed in over 75% (n=771) of the 1021 dives, followed by tail stocks (22%), flukes up (2%), fast surfaces (<1%) and leaps (<1%) (Figure 4.1).



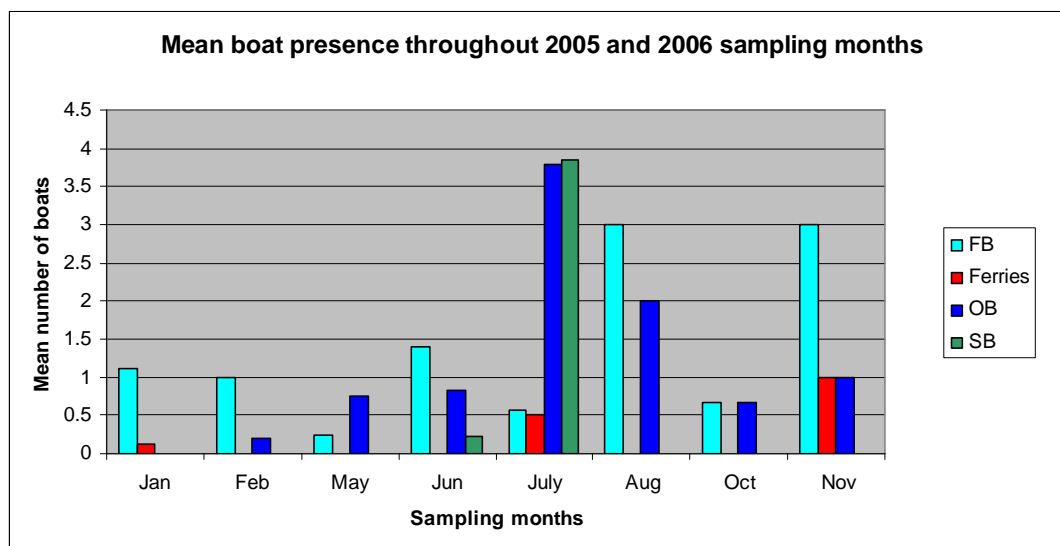
**Figure 4.2: Pie chart depicting the frequency of surface events. Regular dives were the dive type most frequently observed, in over 75% of dives.**

Dive durations following these surface events were significantly different. Mean dive durations following a flukes up or tail stock surface were the longest, with mean durations of  $73.6 \pm 8.9$  and  $58.9 \pm 3.9$  seconds, respectively, but were statistically different from each other ( $p < 0.05$ ). Dive durations following regular dives were the shortest (mean=  $20.8 \pm 1.0$  sec; median= 10 sec) and were significantly shorter from those following tail stocks and flukes up ( $p < 0.05$ ). The minimal amount of fast surfacings and leaps made statistical comparisons of dive durations useless.

#### **4.1.2 Boats**

Boat presence during dive observations was highly variable and ranged from zero boats present to a maximum of 14 boats present in one dive sample. The mean overall boat presence per dive sample was 3.5 boats. Of the four boat categories (ferries, outboards,

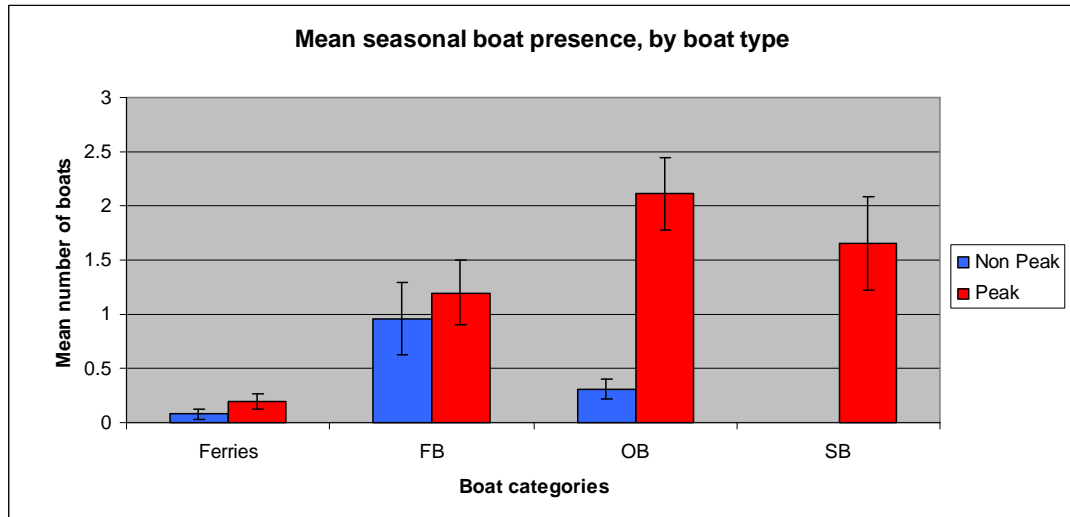
sailboats and fishing boats) outboards were present most frequently during dive samples, with an overall mean of  $1.3 \pm 0.2$  outboards per sample, followed by fishing boats ( $1.1 \pm 0.2$ ), sailboats ( $1.0 \pm 0.3$ ) and lastly ferries ( $0.1 \pm 0.04$ ). Boat presence, principally outboards and sailboats showed an increase towards peak tourism period in July whereas fishing boats were present in all months of dive data collection (Figure 4.2).



**Figure 4.3: Mean boat presence of fishing boats (FB), ferries, outboards (OB) and sailboats (SB), during sample months from both 2005 and 2006. Notice the lack or minimal presence of boats, excluding fishing boats, during standard winter, spring and fall months.**

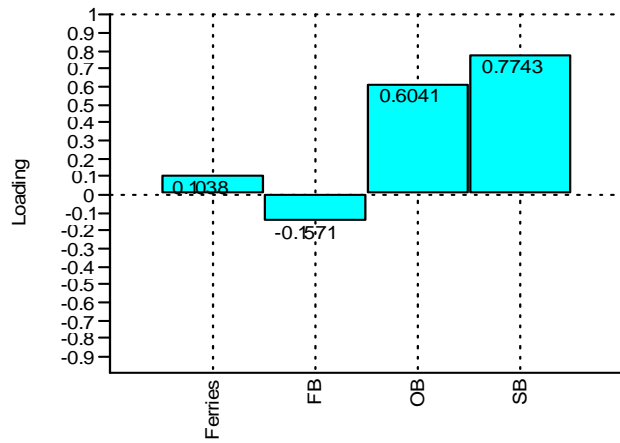
Non parametric correlations tests (Spearman  $r_s$ ) were made between the four boat types. Fishing boat presence was not correlated with the presence of any of the other three boat categories ( $p > 0.05$ ). Ferry, outboard, and sailboat presence were all positively correlated with one another ( $p < 0.05$ ;  $r_s > 0$ ).

There were 26 dive samples collected during the “non peak” season, and 35 collected during the three months (June, July and August) designated as the peak season. Mean seasonal boat presence varied considerably between these two seasons, as shown in Figure 4.3. Sail boats were the only boat type which was not present in any of the winter samples.

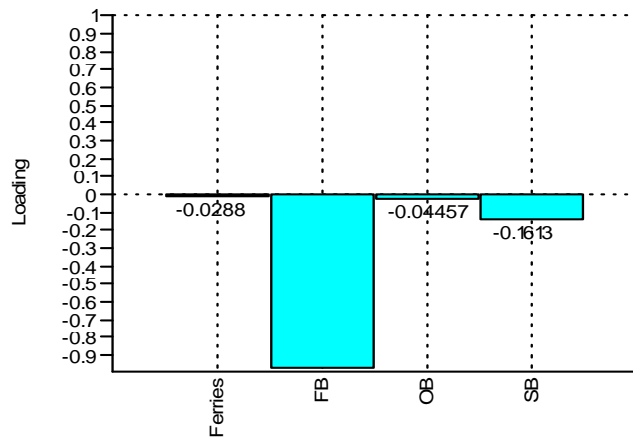


**Figure 4.4: Boat presence comparison, between peak and non peak seasons, using the four boat categories. Sailboats were not present at all during non peak respiratory samples.**

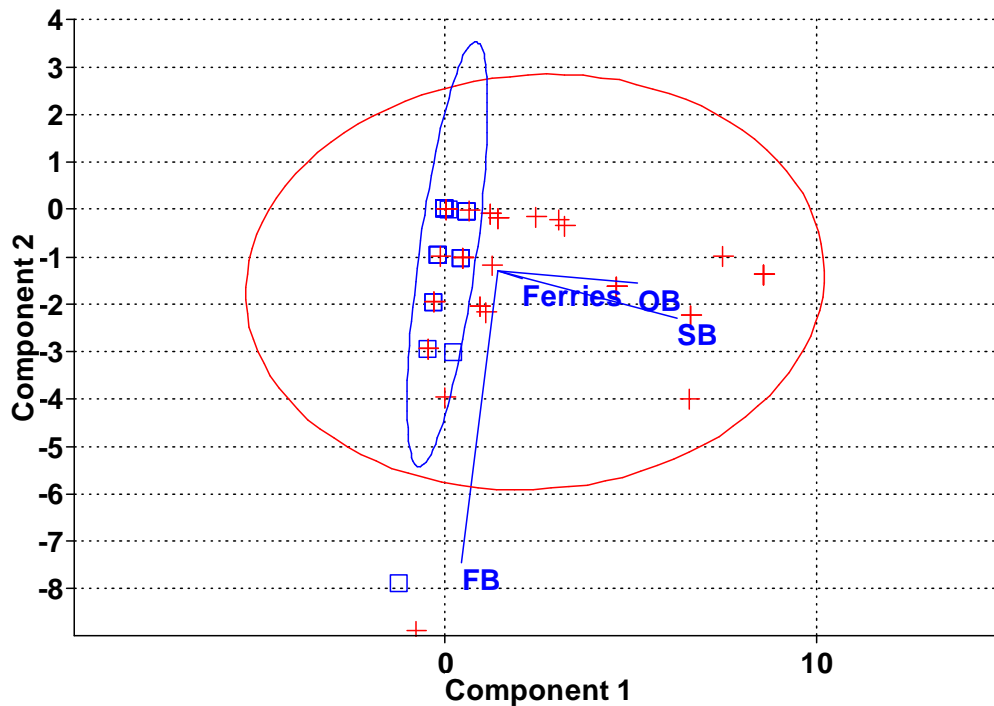
The first two principal components identified from the PCA of peak and non peak boat presence accounted for over 88% of the variability in boat seasonality. The first component, answering for more than 60% of the variability, was most affected by the varying presence of sailboats and outboards and minimally by ferries and fishing boats (Figure 4.4; Figure 4.6). The second principal component, attributing to over 20% of all variability, was almost solely due to fishing boat presence (Figure 4.5; Figure 4.6; See Page 27).



**Figure 4.5: PCA loadings plot of the first principal component (using a variance-covariance matrix). Sailboats, outboards are both strongly influencing boat presence. Fishing boats are responsible for a slight negative effect on the overall 61% of variability.**



**Figure 4.6: PCA loadings plot of second principal component from the PCA. Fishing boats account for virtually all of the 27% of variability.**



**Figure 4.7: PCA scatter plot of the seasonal variability in boat presence.** The red ellipse encompasses all peak season boat presence data points (red crosses), in which the majority of variability along the first principal component (x) axis is due to sailboats (SB), outboards (OB) and ferries. The blue ellipse and square markers depict winter boat presence, which are mostly attributed to fishing boats (along the second principal component (y) axis).

NPMANOVA showed a highly significant difference ( $p < 0.01$ ) between peak and non peak boat presence, between the four boat types. Post hoc analysis showed no seasonal differences in either fishing boat ( $p > 0.05$ ) or ferry presence ( $p > 0.05$ ). There was however a highly significant difference in both outboards ( $p < 0.01$ ) and sailboats ( $p < 0.01$ ) from non peak to peak season, with both experiencing a higher presence during the peak summer season.

To account for the statistically-proven seasonal differences between fishing boat and other boat presence, the four initial boat categories were fit into two new boat categories: fishing boats (FB) and tourist boats (TB). Tourist boats included both outboards and sailboats, as these boats demonstrated seasonal variation. Ferries were excluded from further boat related analysis due to their extremely low presence in all dive samples.

### 4.1.3 Dive Parameters and Boats

There was no significant difference between the dive rates of peak and non peak samples, but all other dive parameters were found to differ significantly between seasons. On average, dolphins performed a higher rate of short dives than long dives in the non peak season ( $p < 0.05$ ). The opposite was true for the peak period, during which the rate of long dives was significantly greater than short dives. Maximum dive durations were highest during the non peak period (Table 4.4).

	<i>DR</i>	<i>SDR</i>	<i>LDR</i>	<i>DEff</i>	<i>Max</i>
<b>Peak</b>	$2.0 \pm 0.10$	$0.7 \pm 0.10$	$1.4 \pm 0.10$	$0.92 \pm 0.01$	$98.2 \pm 6.3$
<b>Non peak</b>	$2.1 \pm 0.10$	$1.7 \pm 0.37$	$0.8 \pm 0.08$	$0.85 \pm 0.01$	$144 \pm 11.3$
<b>* = Significant difference</b>		*	*	*	*

**Table 4.4: Mean dive parameters ( $\pm$  s.e.) depicting the significant differences between peak and non peak samples. \* Denotes those dive parameters in which there was a significant seasonal difference ( $p < 0.05$ ).**

Mean short dive duration showed no seasonal variation ( $p > 0.05$ ), but long dives, on average, were significantly longer in the non peak season (mean=  $74.4 \pm 6.8$ ) than in the peak season (mean=  $48.1 \pm 4.5$ ;  $p < 0.05$ ).

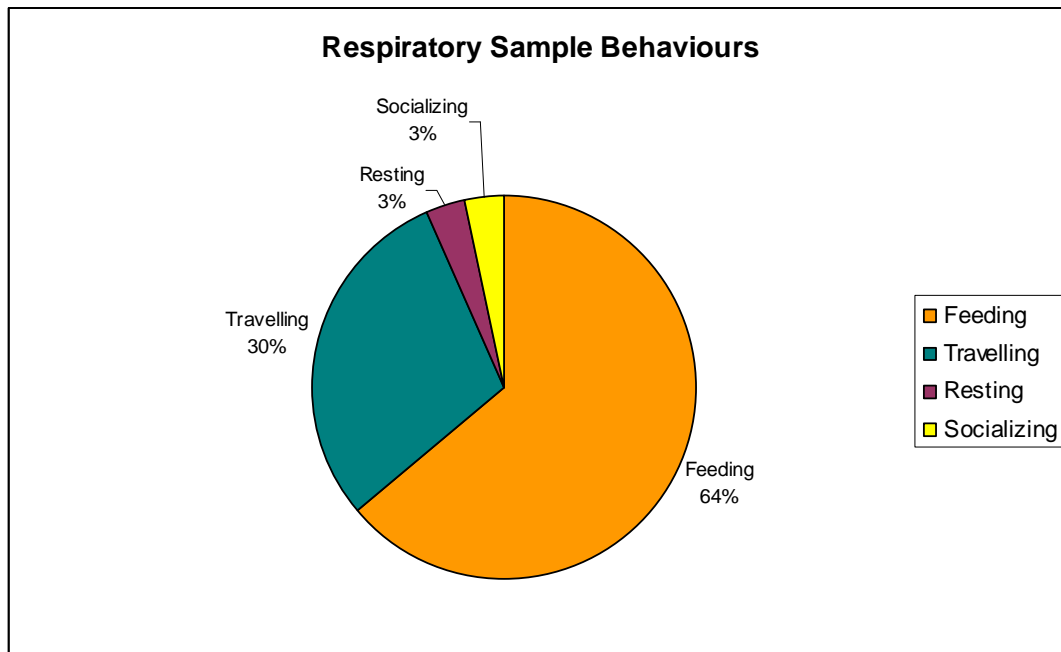
The mean durations of both short and long dives did not differ with regards to the presence or absence of fishing boats. Similarly, all five of the dive parameters were consistent, both in presence and absence of fishing boats. Short dive durations did not change with presence or absence of tourist boats. Long dive durations were longer when tourist boats were absent, but they occurred more frequently (higher long dive rate) when tourist boats were present (Table 4.5).

	<i>DR</i>	<i>SDR</i>	<i>LDR</i>	<i>DEff</i>	<i>Max</i>
<b>TB Presence</b>	1.9 ± 0.1	0.82 ± 0.26	1.3 ± 0.1	0.92 ± 0.01	112.5 ± 8.6
<b>TB Absence</b>	2.2 ± 0.1	1.6 ± 0.24	0.93 ± 0.08	0.85 ± 0.01	124.8 ± 10.6
<b>* = Significant difference</b>		*	*	*	

**Table 4.5: Mean dive parameter values in presence and absence of tourist boats (TB). \*Denotes significant difference.**

#### 4.1.4 Behaviour

Feeding was the most dominant bottlenose dolphin behaviour observed in the study area, and was classified in almost 64% (n=39) of the 61 dive samples. Travelling was the second most frequent behaviour and accounted for close to 30% (n=18) of the observed behaviours, while both socializing and resting each accounted equally for 3% of the dive samples (Figure 4.7). Due to the relatively low occurrence of both resting and socializing behaviours, only the two dominant behaviours (feeding and travelling) were used for subsequent analysis.

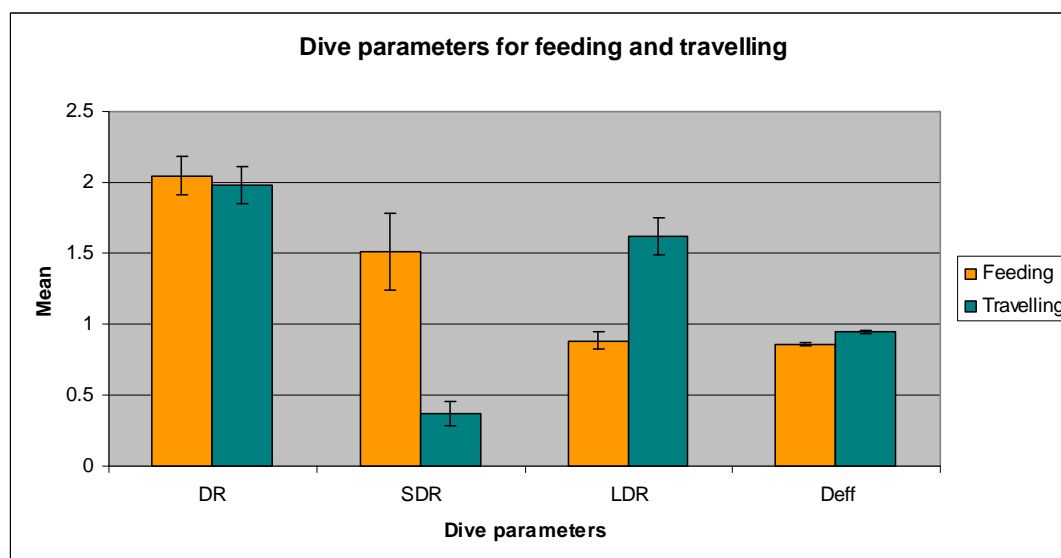


**Figure 4.8: Behavioural budget determined from behaviour classifications during respiration sampling. Feeding is the most frequently observed behaviour.**

Short dive durations did not vary significantly between feeding and travelling, but it was noted that long dives observed during dolphin feeding behaviour were significantly longer



that those observed during travelling ( $p < 0.05$ ). Dive rate did not differ between feeding and travelling, but short dive rates ( $p < 0.01$ ) and long dive rates ( $p < 0.01$ ), between the two behaviours were both highly significantly different. Long dives were performed at a higher rate during travelling, whereas short dive rate was highest during feeding (Figure 4.8).



**Figure 4.9: Mean dive parameters, excluding maximum dive duration, for both feeding and travelling behaviour. There were significant differences observed in short dive rate (SDR), long dive rate (LDR) and dive efficiency (DEff).**

Boat presence between the two dominant behaviours showed some variability. Both outboard and sailboat presence were significantly higher during travelling behaviour than during feeding. Fishing boat presence was consistent between behaviours (Table 4.6).

	<i>Mean no. of boats</i>
<b>Feeding OB</b>	$0.69 \pm 0.20$
<b>Travelling OB</b>	$2.83 \pm 0.48^*$
<b>Feeding SB</b>	$0.05 \pm 0.04$
<b>Travelling SB</b>	$3.11 \pm 0.68^*$
<b>Feeding FB</b>	$1.23 \pm 0.32$
<b>Travelling FB</b>	$0.67 \pm 0.20$

**Table 4.6: Mean outboard, sailboat and fishing boat presence between feeding and travelling dive samples, divided by boat type. \* Denotes a significant difference in boat presence between the two behaviours.**

Feeding behaviour was observed somewhat consistently between seasons with 59% of samples from the non peak period, and 41 from the peak period. Conversely, travel behaviour was not consistent between seasons. An overwhelming 94% of travelling behavioural samples were observed during the peak season.

#### **4.2 Part B: Group Surfacing Rates**

During the 42 days at sea, 62 one minute group surfacing samples were collected. Samples determined during a boat approach comprised %50 of samples (n=31), while non approach samples comprised the remaining 31 samples. The overall mean group size was  $3.60 \pm 0.26$ , while the average subgroup size was  $3.34 \pm 0.26$  individuals.

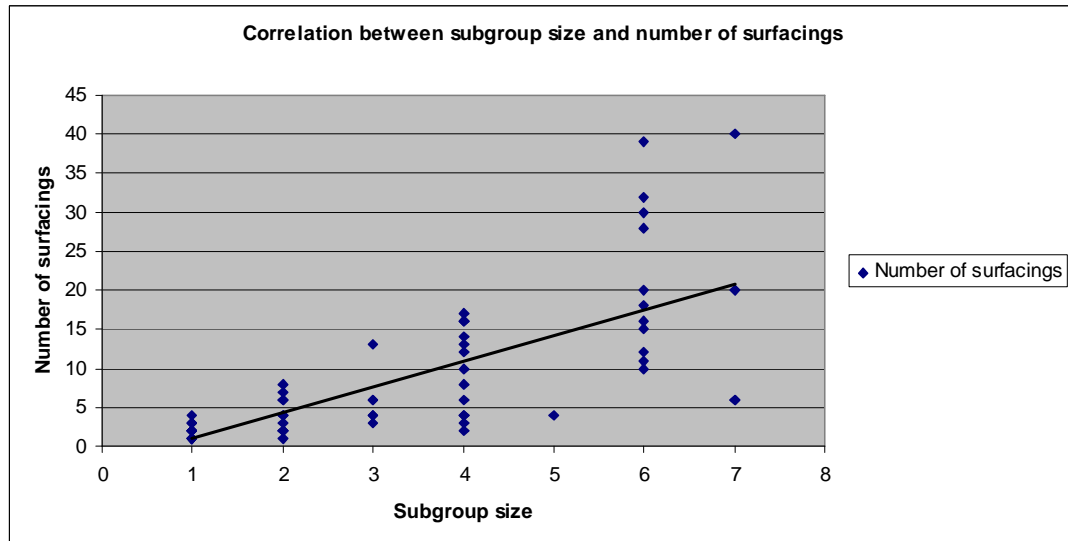
There was no significant difference found between mean subgroup size between approach and no approach ( $p > 0.05$ ) and therefore the number of surfacings, between the two sample sets, were comparable.

The number of surfacings did not differ significantly between approach and no approach conditions ( $p > 0.05$ ). During approach situations, dolphins exhibited a mean number of  $10.1 \pm 1.9$  dives (median= 6), and they realized  $7.5 \pm 1.5$  dives for non approach observations (Table 4.7). The number of surfacings for both approach and non approach situations ranged from 1-40 and 1-32, respectively.

	<i>Number of surfacings (mean <math>\pm</math> s.e.)</i>	<i>Subgroup size (mean <math>\pm</math> s.e.)</i>
<b>All samples</b>	$8.8 \pm 1.2$	$3.34 \pm 0.26$
<b>Approach</b>	$10.1 \pm 1.8$	$3.71 \pm 0.33$
<b>No approach</b>	$7.48 \pm 1.5$	$2.97 \pm 0.38$

**Table 4.7: Summary statistics for all group surfacing samples, approach and no approach samples.**

The number of surfacings observed was positively correlated with the number of individuals per subgroup (Figure 4.9).



**Figure 4.10: Positive correlation between subgroup size and number of surfacings.**

The group size and/or, when applicable, subgroup size was positively determined for each sample and an “individual ventilation rate” (IVR) was calculated, based on the number of ventilations as a function of group size. The overall mean IVR for all samples was 2.4 surfacings per minute. The mean IVR for approaches and non approaches was 2.5 and 2.3 surfacings per minute, respectively. There was no significant difference ( $p>0.05$ ) between the mean IVR of approach and non approach situations.

The overall dive rate observed in Part A for individual respiration patterns was 2.04 dives per minute. There was no significant difference between the group IVR and the dive rate from individuals ( $p>0.05$ ). Although the group IVR during travelling behaviour (mean=  $1.94 \pm 0.23$ ) was lower than the observed IVR during feeding behaviour, the two values were not significantly different ( $p>0.05$ ). Similarly, the individual dive rate calculated in Part A did not differ significantly between feeding and travelling behaviour.

### **4.3 Results in Summary:**

Many significant findings were made with regards to bottlenose dolphin dive behaviour and boat presence, the most important of which are summarized here:

#### ***4.3.1 Part A: Individual Respiration Patterns***

- Overall boat presence in the study area was highest during the peak summer months of June July and August.
- Outboards and sailboats had a seasonal presence, which peaked dramatically in the peak season, whereas fishing boats were present homogeneously, year-round.
- Short dive durations were consistent in all comparisons, regardless of season, presence or absence of either fishing boats or tourist boats, or behaviour (travel or feeding).
- Long dives were:
  - longer during the winter;
  - longer in absence of tourist boats;
  - longer during feeding than during travelling behaviour.
- Dive rates did not vary depending on season, presence or absence of either fishing or tourist boats, or depending on either feeding or travelling behaviour.
- Short dive rate was:
  - higher during non peak period;
  - higher in absence of tourist boats;
  - higher during feeding.
- Long dive rate was:
  - higher in peak season;
  - higher in presence of tourist boats;
  - higher during travelling.
- Dive Efficiency was:
  - highest during the peak season;
  - higher in presence of tourist boats;
  - higher during travelling.
- Maximum dive durations were:
  - higher in non peak season.

- 94% of travel samples were observed during the peak period, while feeding samples were more evenly distributed (approximately 60:40) between peak and non peak seasons.

#### ***4.3.2 Part B: Group Surfacing Rates***

- There was no significant difference in the amount of group surfacings between approach and non approach samples.
- Group IVR was not significantly different than the individual dive rate determined in Part A.
- Feeding IVR did not differ significantly from travelling IVR.

## 5.

## Discussion

### 5.1 Overview of Results

Marine mammals inhabit an environment which is completely different to ours, one which requires them to use their senses very differently to humans. Despite the difficulties in determining the relationship between anthropogenic activities and cetaceans (Lusseau & Higham, 2004), previous studies have confirmed that marine traffic elicits behavioural changes in bottlenose dolphins (Janik & Thompson 1996; Nowacek *et al.*, 2001; Lusseau, 2003b).

In order to attempt to quantify dolphin responses to boats, this project examined bottlenose dolphins on the north-eastern coast of Sardinia, Italy, to determine if animals exhibited changes in their dive behaviours with respect to changes in the type and level of marine traffic. Of the factors analysed, dive behaviour differed both seasonally and also in the presence of tourist boats. Conversely, dive behaviour did not change with respect to fishing boat presence or absence. In terms of behaviours, travelling was dominant when tourist boats were around, whereas feeding was most frequent when tourist boats were lacking or absent. Both dive rate and short dive duration were unchanging throughout dive samples.

Respiratory data was collected from over 26% of the 42 resident bottlenose dolphins identified in the study area (Díaz López *et al.*, 2002). The mean dive duration of these individuals falls directly in the middle of the 20-40 second range found in other bottlenose dolphin studies (Würsig, 1978; dos Santos *et al.*, 1990; Peharda & Bearzi, 1993; Lynn, 1995; Mate *et al.*, 1995).

#### **5.1.1 Group Size**

The mean bottlenose dolphin group size observed in this study ( $2.11 \pm 0.16$  dolphins) was smaller than the typical group sizes found in other populations. The use of different criteria and definitions of a “group” of dolphins may attribute to the high level of variability in group sizes determined between studies (Shane *et al.*, 1986). Group size seems to be dependent on many factors, but most importantly is a “trade-off” between the effectiveness of foraging behaviour, and decreasing risks of predatory attacks (Wells & Scott, 1999 in Kerr *et al.*, 2005). As there has been no direct evidence of predatory involvement on bottlenose dolphins

in the study, or surrounding area, optimal foraging is likely a huge determinant of group size of this population. Boat presence may also temporarily affect group size.

## **5.2 Part A: Individual Respiration**

### ***5.2.1 Surfacing Events***

Dive durations indicate a potential relationship between types of surfacing event. Regular dive was the most frequently observed surface behaviour prior to diving, and dive durations following this event were shorter than other surface events observed. Shane (1990a) found similar results when studying dive behaviour of bottlenose dolphins in Sanibel Island, Florida. The use of “tail stock” or “flukes up” surface behaviours prior to diving have resulted in longer dives, suggesting a potential link of these events with foraging behaviour (Shane, 1990a; Pace *et al.*, 1998; Bernal Shiray *et al.*, 2006). According to the physics of diving, arching the body for a dive allows dolphin to descend quicker and at a steeper angle underwater. This may be beneficial in terms of energy in that they can obtain maximum depth quicker, allowing more time for effective hunting of prey (Shane, 1990a).

### ***5.2.2 Boat and Dolphin Presence***

Heightened overall boat presence during the summer months correlates with the increased tourist activity in the study area. The north-eastern coast is made up of numerous small coastal cities and towns which all experience significant population increases during the summer. The Golfo Aranci harbour and larger harbours in the surrounding area (such as Olbia and Porto Rotundo) are used as gateways to the rest of Sardinia, and boast a very active traffic exchange. These harbours are frequently used by both ferries and fast ferries from mainland Italy, greatly contributing to the influx of tourists. This is a trend typical of coastal areas. The observed increase in marine traffic, mainly tourist boats (outboards and sailboats), can therefore be attributed to the upsurge in human presence/activities during the summer. The month of July boasted the highest overall boat traffic, coinciding with the beginning of summer holidays. Although overall boat presence increases substantially during the peak season, approximately 40 fishing boats operate, year round (independent of seasons), from the harbour in Golfo Aranci (Díaz López, 2005).

Bottlenose dolphins in this area are also sighted year round, but this is not equally distributed, as daily encounter rates of dolphins tends to be higher during fall and winter (Díaz López,

2006). There were slightly more dive samples collected during the non peak season (57%) than the peak season, but the difference was minimal.

### **5.2.3 Dive Behaviour, Seasonality and Boats**

The rate of dives performed is a critical factor in determining the level of energy expenditure, although interpreting dive behaviour solely using the dive rate can be clouded by the inclusion of the often high proportion of short dives. It is therefore important to categorize dives by dive type, i.e. short and long dives (Hooker & Baird, 2001). Despite bottlenose dolphins being able to modify their dive techniques in order to reduce energetic output during apnea (Skrovan *et al.*, 1999), the metabolic cost of dives changes are likely variable with respect to dive type and duration.

Overall dolphin dive rates were uniform throughout all of the respiratory samples, at approximately 2 dives per minute, irrespective of changes in boat traffic, seasonality or other variables. This dive rate is comparable with those of bottlenose dolphin dive studies in Florida (Mate *et al.*, 1995) and Texas (Lynn, 1995), and according to Hooker & Baird (2001) indicates a somewhat stable level of global energetic costs. However, unlike the overall dive rates, the rates of both short and long dives varied depending on seasonality, boat presence and behaviour. Energy expenditure therefore likely changed in conjunction with oxygen related demands associated with performing various types of dives (Williams, 2001). It is necessary to determine if dive behaviours are changing in response to boats, and most important the extent of these behavioural modifications, as unplanned behavioural changes could have serious energetic costs.

Williams *et al.* (1999) predict that a sedentary bottlenose dolphin will have an aerobic dive limit of approximately 4.5 minutes (268 seconds). The maximum dive time observed in this study (on only one occasion) was 249 seconds. On average, bottlenose dolphin swim speeds are between 1.5 and 2.0m/s (Yazdi *et al.*, 1999; Butler, 2001). Transport costs (those required to move a certain speed at a certain distance) are at a minimum at this speed. At increased swimming speeds of 2.9m/s, the aerobic dive limit is estimated to occur at only 1.3 minutes. Although no swimming speeds were collected during this experiment, these data suggest that the majority of bottlenose dolphins fall within their calculated aerobic dive limit (Butler, 2001), but that dives performed at excessive speeds and durations may result in anaerobic respiration.



There was no significant variability in the duration of short respiratory bouts (short dive duration), under any conditions, but there was a marked change in the frequency of these short dives. Short dive rate was higher during the non peak season than during peak season. Interestingly enough, the same was true of long dive durations; long dives were longest during the non peak period when compared with peak summer season. As long dive duration increases, the number of recovery ventilations (in the form of short dives) also increased. This was confirmed by a positive correlation found between mean long dive duration and number of short dives per sample, further underlining the importance of short dives for respiratory recovery; i.e. the longer the long dive duration, the more oxygen levels are depleted, and the more short dives must be executed to successfully re-establish these oxygen levels (Hooker & Baird, 2001). Based on the fact that the duration of short dives was stable, it is therefore hypothesized that the level of aerobic recovery is achieved by modifying not the duration of surfacings, but instead the frequency. This would have to be verified by larger and longer dive samples.

In essence, this study highlighted two trends which were observed with respect to bottlenose dolphin dive behaviour. During the peak season, when tourist boat presence was at its highest, there was an observed increase in bottlenose dolphin travelling behaviour; this was reflected by low short dive rates, shorter long dive durations, and a high dive efficiency. The second trend occurred during non peak season, in absence of tourist boats, and during feeding behaviour, and was represented by increased long dive durations, and increased frequency of short dives, and a lower dive efficiency.

Dolphin responses to boats are often classified as positive, negative, or neutral (Leung Ng & Leung, 2003; Goodwin & Cotton, 2004). Positive and negative responses involve active movement on the part of the dolphin, either towards or away from the vessel and can be useful in assessing the biological significance of boat interactions (Lusseau, 2003).

Travelling behaviour was most frequently observed during the peak period. Travelling tendency, in the presence of boats, could be an elicited response of the dolphins to the boats. In presence of marine traffic, Lusseau (2003) observed a positive increase in four behavioural transitions, three of which resulted in animals changing their initial behaviour to one of travelling. Feeding behaviour and travelling behaviour were inversely related. It is possible that tourist boats disturb feeding behaviour, resulting in a switch to travelling behaviour. This

would explain why the long dive rate, clearly associated with travel behaviour, was higher in the peak summer season, coinciding with a high presence of tourist boats. A higher frequency of long dives likely represents either a positive or negative response to heightened, and potentially, invasive tourist boat presence. Directionality of movement was not determined, making it difficult to conclude positive or negative responses, but most studies find that tourist associated boats frequently elicit negative type responses by the dolphins (Goodwin & Cotton, 2004), and this is highly probably in this case as well.

Feeding conditions and prey availability in the study area are very much sustainable during the summer months (Díaz López & Bernal Shirai, 2006). As such, boat avoidance may not be as costly during this time, as dolphins do not need to spend as much energy on foraging. Travelling behaviour, potentially brought on by tourist vessels, is more energetically feasible during a time when prey availability is high.

This increase in peak season travelling behaviour was followed by an overwhelming increase in feeding behaviour during non peak season. Shane *et al.* (1986) also observed this behavioural trend between winter and summer months. Fish abundance in the study area has been found to decrease between the fall and spring period (Díaz López & Bernal Shirai, 2006). Decreased food availability in the winter months coincides with declining water temperatures, both of which are factors contributing to heightened energetic requirements during this time. In order to contend with reduced prey and colder temperatures, dolphin foraging behaviour needs to intensify in order to fulfil greater energetic needs during these harder months (Shane, 1990a; Brager, 1993; Díaz López & Bernal Shirai, 2006).

Feeding behaviour is best recognized by longer drawn out dives (Shane, 1990; Brager, 1993). In accordance with this, dive behaviour during feeding was represented by longer long dives, increased short dive rate, and higher maximum dive durations. Increased feeding behaviour during the non peak season coincided with the time of year when tourist boats were at a minimum. It is most safely assumed that dive durations were extended to complete longer search and capture time, resultant from limited or patchy prey resources. Exhibiting longer dives can be physiologically costly in that animals must re-establish depleted oxygen stores by performing short dives, while simultaneously balancing energetic expenditure (Hooker & Baird, 2001; Williams, 2001).

The major requirements for all animals are air and food; marine mammals will “therefore optimize their diving behaviour to maximize food gain, under the limitations of oxygen requirements” (Hooker & Baird, 2001). During this non peak season, it has been well established that tourist boat presence is virtually negligible, and boat presence at this time is almost solely attributed to fishing boats. Fishing boat behaviour is often predictable and consistent, and the lack of changes in dive behaviour, under these conditions, suggests that these boat interactions are not deemed to be intrusive by the dolphins. Bottlenose dolphins in the study area are sighted year round, and as such may be accustomed to the continued fishing boat presence. Increased time underwater for foraging purposes, due to limited prey availability, appears to be what is affecting the dive behaviour, and not the presence or absence of fishing vessels.

In this study, fishing boat presence did not differ between the two behavioural states (travelling and feeding). Outboard and sailboat presence were both significantly higher during travelling than feeding. From this it is possible to infer that increased presence of tourist boats may be eliciting a disturbance response, in the form of avoidance, which results in an increase in observed travelling behaviour. These changes were evident in the examination of dive behaviour.

### **5.3 Part B: Group Surfacing Rates**

Group observations are advantageous in that they allow simultaneous sampling of numerous individuals (Mann, 1999). In some instances this can be difficult, as observers may be attracted to the most obvious behaviour demonstrated. Luckily, in this study, the bias was negligible as each surfacing event, from every individual within the group, was clearly visible and easily counted. Typical small group sizes of bottlenose dolphins in this area greatly contributed to facilitating these observations.

Respiratory synchrony within bottlenose dolphin groups has been suggested to be influenced by boat presence (Hastie *et al.*, 2003), yet in this case, the approach or non approach of boats did not elicit a noticeable reaction or change in bottlenose dolphin group surfacing rate. Dolphin groupings are often a response to predators, or in response to some sort of risk/threat (Lusseau, 2003). Perhaps in groups, animals felt safer than when solitary, and it was not deemed necessary to change dive rates or behaviours. This may suggest a sort of “safety in numbers” mentality.

Alternatively, perhaps the animals were highly aware of the oncoming vessels, long before visible approach. Underwater acoustic cues from the vessel's propeller and engine may be enough of a warning system to alert the dolphins to oncoming traffic, allowing sufficient time for changes in dive behaviour. Any warranted behavioural adaptations to these approaching boats may indeed occur well before the observable approach distance. Continuous observations of group surfacing behaviour would need to be analysed long before any potential boat approaches to indeed confirm this theory.

The individual ventilation rates observed during the group surfacings were consistent with individual dive rates calculated from Part A of this study, suggesting that not only were one minute samples sufficient to discover a trend in bottlenose dolphin diving, but also that observing group dive behaviour may be representative of individual dive behaviour.

## **5.4 Assessment of Techniques**

### ***5.4.1 Data Collection***

The data collection from 2006 occurred during a three month period, during which I had to train and familiarize myself with bottlenose dolphin dive data collection methods as well as general field techniques required for cetacean observations. This inexperience may have been reflected in the duration of dive samples during this unavoidable training period. As a result, initial dive samples may have been shorter in length. Although data was collected in what was considered a sufficient amount of time for distinguishing trends in bottlenose dolphin dive behaviour, caution must be heeded when making conclusions using a relatively small data set. It could be argued that a small amount of samples or short sample durations could influence the overall trends in the data.

Individual follows are feasible both in terms of theory and methodology (Mann, 1999), but individual variability in responses might also affect data (Nowacek *et al.*, 2001). Dive behaviour data was not randomly sampled, but instead was collected from well marked, readily identifiable individuals. This has the potential to create a sampling bias in the data, as the same individuals may have been repeatedly sampled over the course of data collection.

Short term behavioural observations and analysis are always made with the assumption that it is representative of conventional behaviour (Hooker & Baird, 2001). Continuous evaluation

of short term disruptions or changes in bottlenose dolphin dive behaviour is therefore crucial for attempting to determine the potential long term effects of marine traffic on these animals.

The appropriateness of data collection from a boat may be questionable in terms of anthropogenic impacts and tolerance (Lusseau & Higham, 2004), but the vessel was deemed necessary for the successful gathering of dive data. The research boat was a continuous presence in all respiratory samples, and it may have contributed to boat-related responses. In attempts to minimize impact, all dolphin followings were made in a somewhat standardized, consistent and predictable way and were not thought to have a major impact on the observed behaviour of the animals. If a follow was believed to have caused a evident dolphin response, all behavioural observations were ceased.

#### ***5.4.2 Non-Invasive Techniques***

It was decided, for the purpose of this study to use only visual observations of bottlenose dolphin dive behaviour, as opposed to the employment dive data tags, such as time depth recorders (TDRs). These tags provide a large quantity of data, but only for a short period of time, as attachment usually only lasts for sometimes a few days, or as little as a few hours or minutes (Hooker & Baird, 2001). The information collected is useful, but short analyses may not be entirely representative of behavioural activities occurring over larger temporal scales. Deployment of these units has also proven to be difficult, especially for large dolphins and whales, and methods currently in use include penetrating tags and also those which use suction cups for attachment.

Some studies using TDRs have been found to influence or alter wild dolphin behaviour. Reactions to these tags are varied; the level of response is thought to be dependent on species and population (Hooker & Baird, 2001). Reactions exhibited by tagged bottlenose dolphins (Schneider *et al.*, 1998) imply that data from the tags are unlikely to be representative of the natural behaviour of these animals. In contrast, visual surface observations have proven to be a non invasive research method which is representative of free ranging dolphin behaviour (Bearzi *et al.*, 1999; Bernal Shiray *et al.*, 2006)

### ***5.4.3 Dive Descriptors/ Parameters***

The use of the median dive duration was an arbitrary cut-off between short and long dives was decided upon, in attempt to be as objective as possible. Dive trends were quickly determined using this cut-off, and it was thought to be a valid divisor.

The use of a variety of dive parameters provided a detailed inspection of bottlenose dolphin dive behaviour. The five dive parameters proved to be an informative way to determine exactly how dive behaviour was modified in the presence or absence of anthropogenic disturbances. By dividing one set of dive data (overall dive times) into various parameters, we gained insight into the respiratory and recovery adjustments made by the sampled dolphins. From this we can infer what may be typical responses expected under variable boat conditions.

### ***5.4.4 Recommendations for Further Study***

The following are some recommendations for further research on dive behaviour and boat traffic which aim to improve subsequent studies:

- Examine dive behaviour and boat presence with respect to time of day to detect potential diurnal patterns between the two variables.
- If two identifiable individuals are in one group, simultaneously gather dive behaviour data from both, and test for individual variability, under identical conditions.
- Incorporate dolphin-boat inter-distance data to determine the relationship between boat proximity and dive response.
- Examine sex-differences in dive behaviour (i.e. females, especially those with calves, may display different responses to boats)
- Test the hypothesis that larger body size should result in increased dive capabilities.
- Use longer group surfacing sample durations.

In general, running dive studies over longer periods of time increases sample size. Any trends therein would be readily visible. This is also true for the durations of dive samples analysed. With an increase in the number of dive samples collected, criteria for data selection for subsequent analysis could become stricter.

### **5.5 Management Implications**

Bottlenose dolphins in the Mediterranean subsist as many different subpopulations. The World Conservation Unit (IUCN) currently lists the status of the Mediterranean subpopulation of common bottlenose dolphin as “vulnerable”. Although there currently exists insufficient information on the present growth or decline trends, past trends showed a decrease in numbers of this “subpopulation” (Reeves & Notarbartolo di Sciara, 2006). Mediterranean cetaceans, including the common bottlenose dolphin, are protected under ACCOBAMS (Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area). In this agreement, countries agree to “co-operate to create and maintain a network of specially protected areas to conserve cetaceans”. It also stipulates that actions must be taken to integrate cetacean conservation with maritime activities (ACCOBAMS agreement; [www.accobams.org](http://www.accobams.org)), but strong measures need to be taken to assure these acts are enforced, and unfortunately are often lacking.

Marine tourism is an industry which is greatly on the rise, and which will undoubtedly intensify in the future (Constantine, 2004). This will likely be most evident in coastal areas, which unfortunately is often prime bottlenose dolphin habitat (Shane *et al.*, 1986). Currently, the whale and dolphin watching industry in the Mediterranean Sea is rather primitive compared to other coastal cetacean populated areas (Guidelines, 2004), but with increasing demand for such enterprises, it is vital that vessel regulations, commercially or otherwise, become implemented. “High risk management areas” are defined as those where there is a convergence between animal density and boat passages (Russell, 2001). Consideration of a possible Special Area of Conservation (SAC), a designation of an ecologically important and therefore protected marine area, may be useful in avoiding becoming a high risk management area by implementation of successful monitoring of dolphin-boat interactions.

Despite evidence of potential dolphin “habituation” to the local fishing boats, this term must be used carefully so as not to be misleading in management applications. Incorrect application may suggest that boat impact is insignificant, when there may still be consequences for unidentifiable behavioural changes. Boat presence may disrupt dolphins

from prime habitat, resulting in physical displacement from ecologically important areas and potentially causing increased stress levels as a result (Evans *et al.*, 1992). Alternatively, despite potentially harmful boat exposure, dolphins may have no other choice but to demonstrate continued presence and use of area if it is a critical habitat (Bejder *et al.*, 2006).

Both ecological and economic factors must be considered and integrated in order to establish conservation and management of bottlenose dolphins (David, 2002). This study may prove to be valuable for other bottlenose dolphin populations, in which extrapolations could be very useful for defining future long term management strategies of bottlenose dolphin populations.



## 6. Summary & Conclusions

Thus far, the effects of boats on dolphin behaviour have only been described, but the implications and biological significance of these disturbances has yet to be completely understood (Lusseau, 2003). It is relatively easy to examine the direct negative effects, such as boat strikes and traumas, but is much more difficult to determine the potential negative indirect effects of boat presence on marine mammals (Nowacek *et al.*, 2001). Changes in behaviour may be clearly visible to an observer, but disturbance exists on many levels. It is virtually impossible to conclusively determine which aspect of boat presence is affecting the dolphins, whether it is the increase in underwater noise which disturbs them, the movements of the boat, or merely anthropogenic presence.

This study highlights the connection between dive behaviour and potentially invasive tourist boats; dolphins are altering their dive behaviour with respect to the seasonal increase of outboard and sailboat presence. Many of the dolphins observed in this study display residential tendencies (Díaz López, *et al.*, 2002; Díaz López & Bernal Shiray, 2006). High site fidelity, leading to animals being termed as “residents”, may contribute to a higher degree of tolerance or habituation to marine traffic than those animals which are more transient (David, 2002), although this may be out of necessity (Bejder *et al.*, 2006). This area has been identified as an ecologically important feeding area for bottlenose dolphins. The presence of a marine fish farm has been linked to increased abundance of dolphins in the area (Díaz López *et al.*, 2001; Díaz López, 2002; Díaz López, 2005) as it appears to be a platform of opportunistic feeding due to a high wild fish density surrounding the cages. Due to the ecological importance of the area, the animals may have adapted a certain level of tolerance to anthropogenic disturbances, despite the implications of behavioural modification.

Bottlenose dolphins are recognized as large brained social animals that have the ability to learn from their environments (Shane *et al.*, 1986; David, 2002). This may explain why there were no observed dive behaviour changes in response to fishing boats in the area. Resident animals that remain in the study area on a year round basis may have become accustomed to the chronic presence and predictable nature of fishing boats, and may have become desensitized to these vessels. Seasonal fluctuations in tourist boats, and more erratic behaviour on their part, would make dolphin tolerance much less likely.

The results obtained in this study suggest that this non invasive observational method is representative of free ranging wild bottlenose dolphin diving behaviour, and may prove useful for management of this and other dolphin populations exposed to high levels of anthropogenic activity. It could take up to 30 years to conclusively determine the longer term effects of boat presence on the overall fitness of the long lived bottlenose dolphin (Wilson *et al.*, 1999; Constantine *et al.*, 2004). Further research is needed to examine the long term effects of seemingly short term behavioural changes, as they may have drastic implications on energetics, reproduction and distribution of these already vulnerable cetaceans. Finer scale behavioural observations, such as dive behaviour analysis, could prove to be vital for understanding the potential respiratory and energetic implications of dolphin-boat interactions.

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## **Appendices**

This section includes a CD-Rom containing dive data and analyses.