Effects of tourism operations on the behavioural patterns of dolphin populations off the Azores with particular emphasis on the common dolphin (*Delphinus delphis*)

Tese de Doutoramento

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Unless we change direction, we are likely to end up where we are going

Chinese proverb

All big things are made up of trifles. My entire life has been built on trifles.

Mahatma Gandhi

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CONTENTS

Porpoising Atlantic spotted dolphins off the south coast of São Miguel Island

CONTENTS

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RESUMO

Nos Açores encontram-se cerca de 30% das espécies de cetáceos atualmente conhecidas. Esta grande diversidade constitui um suporte para o desenvolvimento de atividades marítimas recreativas como a observação de cetáceos e a natação com golfinhos. Estas atividades começaram nos Açores nos anos 1990 com uma só empresa na ilha de Pico mas atualmente é desenvolvida por 24 empresas distribuídas em quatro ilhas. O crescimento contínuo das atividades recreativas com cetáceos aumenta a probabilidade de que estas tenham efeitos negativos nas populações alvo. Existem vários estudos a nível internacional sobre os efeitos a curto prazo que se podem detetar durante as interações com barcos turísticos. Estes incluem alterações de comportamento, como mudanças de direção e velocidade de deslocamento, de coesão dos grupos ou das vocalizações usadas na comunicação e na ecolocalização. Estas alterações por si só podem levar a um aumento individual do dispêndio energético assim como a uma diminuição da energia adquirida durante a atividade de alimentação, se esta for interrompida. A longo prazo, porém, poderão os impactos individuais refletir-se negativamente ao nível populacional.

A atividade está regulamentada nos Açores, estando a revisão da legislação a ser discutida com os operadores. Estes regulamentos visam evitar que as atividades de observação e de natação sejam prejudiciais para as populações de cetáceos. Porém, para a elaboração de uma legislação eficaz é fundamental o conhecimento da ecologia e do comportamento de base das espécies exploradas e os Açores ainda carecem destas informações, assim como dos efeitos das atividades turísticas atuais. Entre as espécies mais avistadas e mais representativas do turismo local encontramos o golfinho comum (*Delphinus delphis*) que, apesar do seu nome e de ser relativamente abundante nas águas do Arquipélago, permanece uma espécie cujo comportamento é ainda muito pouco conhecido. Outros golfinhos comummente avistados são o roaz (*Tursiops truncatus*) e o pintado (*Stenella frontalis*).

Neste sentido o presente estudo visa (1) descrever pela primeira vez os patrões comportamentais do golfinho comum, com particular atenção na variabilidade temporal do balanço de atividade, (2) estudar mudanças comportamentais desta espécie durante a interação com os barcos turísticos, sejam estes de observação ou de natação, (3) avaliar a resposta comportamental das três espécies de golfinho durante as atividades de natação, (4) usar os resultados para sugerir medidas e apoiar decisões de gestão em matéria de conservação dos recursos naturais e de desenvolvimento sustentável das atividades turísticas.

Os padrões comportamentais dos golfinhos comuns foram estudados durante duas épocas em 2013 e 2014 utilizando binóculos e uma câmara digital a partir de uma plataforma em terra, na costa sul de São Miguel. Os dados relativos aos estados comportamentais foram recolhidos através de seguimentos focais com técnica de amostra instantânea, enquanto os eventos comportamentais de superfície foram amostrados com a técnica de amostra contínua, sendo estes tipicamente de breve duração.

O balanço de atividade revelou que os golfinhos comuns passam a maior parte do tempo em alimentação (2013) ou em deslocação (2014). Variações temporais foram detetadas também a nível mensal e diário, com a deslocação registando um pico nos meses de junho e julho e a atividade de alimentação diminuindo na faixa horária do meio-dia. Grupos maiores foram observados principalmente durante os meses de verão e durante a atividade de alimentação. Os golfinhos comuns exibiram vários comportamentos de superfície como saltos, *porpoising*, batimentos da cabeça na superfície da água e batimentos caudais. Estes comportamentos foram registados durante as atividades de alimentação, deslocação e socialização, sugerindo que podem ter funções diversificadas dependendo do contexto em que são usados.

A mesma metodologia foi utilizada para registar mudanças de comportamento durante interações com barcos turísticos. Os resultados indicam que os golfinhos comuns interagem com as atividades turísticas durante 10% do seu tempo, uma percentagem ainda baixa se comparados com outras populações da mesma espécie, por exemplo da Nova Zelândia. Porém, estas interações demostraram ter efeitos no comportamento, sendo que na presença de barcos os golfinhos diminuíram o tempo passado em alimentação e aumentaram o tempo de socialização. Também o tempo necessário para voltar à atividade antecedente foi afetado pela interação, aumentando no caso da alimentação e diminuindo no caso da socialização. De igual modo, a duração média das atividades foi afetada: a fase de alimentação registou uma redução temporal na presença de barcos em comparação com situações de controlo. A falta de informação acerca dos padrões de residência desta espécie não permite avaliar o impacto cumulativo que esta espécie poderia sofrer com o aumento das atividades turísticas.

Para avaliar os efeitos das atividades de natação e em particular das interações nadadores-golfinhos, recolheram-se dados a partir de embarcações turísticas durante três épocas, de 2013 a 2015. A colaboração com duas empresas com base em dois portos da costa sul de São Miguel, Ponta Delgada e Vila Franca do Campo, permitiu obter uma amostra que abrangeu toda a área tipicamente utilizada pelas empresas durante estas atividades. Através do método de *scan sampling* registou-se que as três espécies de golfinhos mostraram uma maioria de respostas neutras ou de evasão, e muito poucas de aproximação. Os golfinhos pintados foram aqueles que registraram uma maior percentagem de respostas evasivas, mas também maior aproximação, surgindo esta espécies como a mais flexível em termos de interações com humanos. Registaram-se as estratégias utilizadas pelos operadores para aproximar os grupos de golfinhos de forma a largar os nadadores. As mais frequentes foram pôr o barco paralelo ao grupo, cortar o rumo do grupo colocando o barco transversalmente e entrar no meio do grupo. Independentemente da espécie, a estratégia de cortar o rumo aos grupos foi aquela que gerou mais comportamentos de evasão, levando a uma redução do tempo de permanência dos nadadores na água. Uma redução do tempo de interação nadadores-golfinhos foi também observada quando os golfinhos estavam a descansar ou em deslocação, e com grupos mais pequenos. Os operadores geralmente cumpriram a legislação em vigor em termos de número de nadadores na água e da duração máxima das interações, mas excederam o número de tentativas de largada por cada grupo. Com base nestes resultados, sugere-se que os regulamentos da atividade de natação com golfinhos incluam evitar a estratégia de "corte do rumo" dos grupos escolhidos para a atividade, evitar largar nadadores com grupos em descanso e evitar grupos que incluam recém-nascidos, sendo estes particularmente vulneráveis.

As mudanças comportamentais e a elevada percentagem de respostas de evasão detetadas durante as atividades, seja de observação que de natação, sugerem que, mesmo que este sector de turismo nos Açores seja ainda relativamente limitado, já estão a ocorrer perturbações. O ritmo de crescimento desta indústria sugere a necessidade de medidas de gestão que tenham em conta a importância da área para as várias espécies de golfinhos, revendo a atual legislação da natação nos termos descritos acima. Além disso, considera-se necessário um esforço de monitorização contínuo, especialmente para clarificar os patrões de residência dos golfinhos e assim avaliar melhor potenciais impactos cumulativos.

ABSTRACT

The cetacean diversity observed in the Azores accounts for around 30% of currently known cetacean species. This high level of diversity has supported the development of commercial recreational activities such as whale watching and swim-with-dolphin programs. Both operations are regulated by law, which is currently under revision. In order to produce effective management strategies and avoid detrimental impacts, an assessment of the populations targeted by such activities is imperative. This becomes even more critical in light of the poor, often absent, baseline information currently available for local populations. The short-beaked common dolphins (*Delphinus delphis*) is the most common species, encountered year-round, and thus is one of the most representative species in this industry. Other dolphin species such as the bottlenose (*Tursiops truncatus*) and the Atlantic spotted dolphin (*Stenella frontalis*) are also exposed to swim-with programs. Hence, the objectives of the present study are to (1) describe for the first time the normal undisturbed behavioural patterns of common dolphins, (2) measure behavioural changes resulting from whale watching (common dolphins), (3) investigate swimming-with-dolphins interactions (common, bottlenose and Atlantic spotted dolphins) and (4) provide suggestions for guidelines, especially the swim-with operations, which are considered more invasive and thus potentially have a greater impact.

Focal group follows and predominant group activity sampling was undertaken between 2013 and 2014 from a land-base station in São Miguel Island. The activity budget of common dolphins revealed that they use the area primarily for foraging and travelling. Travelling peaked during the summer months; foraging decreased around midday. Larger groups were observed during summer and during foraging. Common dolphins showed a variety of surface active behaviours such as breaches, porpoising, head and tail slaps when engaged in foraging, travelling and socializing, suggesting different functions of these behaviours depending on the context they are used in.

Common dolphins were found interacting with tour boats during 10% of their time, a relatively low percentage when compared to other common dolphin populations such as those in New Zealand. Nonetheless interaction with tourism activities revealed changes in the behavioural patterns of common dolphins, with less time spent foraging and more time socializing. The time to resume a preceding activity after a tour boat interaction was also affected, with dolphins taking longer to restart foraging and less time to re-engage in socializing. Similarly, the average foraging bout length was shorter in the presence of tour boats compared with control scenarios.

Boat-based sampling was conducted between 2013 and 2015 to assess the response of dolphin groups to swim-with programs. The three dolphin species observed showed mainly neutral or avoidance responses. The bottlenose dolphins showed higher neutral responses than the common dolphins, and Atlantic spotted dolphins tended to avoid and approach more often than the other two species, suggesting a higher variability in response to human activities. Among the three main strategies used to approach dolphin groups, intersecting the dolphin's path was the most disruptive method and more likely to result in avoidance behaviour and in shorter swimmer-dolphin interactions. Irrespective of species, the duration of swimmer-dolphin encounters was also shorter when dolphins were resting or travelling and when they were in small groups. Compliance with legal regulations was generally good except in the number of swim attempts per dolphin group. This averaged six whereas a maximum of only three attempts is allowed. Suggestions to improve the current legislation include not intersecting the path of dolphins when approaching groups, and avoiding swimming with resting groups and with groups which include new-borns, due to their particularly vulnerable nature.

Behavioural changes and the high avoidance responses detected in the three target species suggest that, although cetacean tourism in the Azores is still far from being considered a large industry, disruptive effects are already occurring. The likely increase in the number of tourists requires effective management that takes into account the importance of the area for dolphins and their susceptibility to tourism interactions. Enhancing monitoring efforts is also fundamental to clarifying site fidelity patterns and hence the potential for cumulative impact.

LIST OF FIGURES

Introduction

Methodology

Results

LIST OF TABLES

Methodology

Results

1. INTRODUCTION

Bottlenose, common and Atlantic spotted dolphins, and related tour activities: whale watching and swim-with dolphins

1. INTRODUCTION

1.1 Tourism impacts on wildlife: the special case of cetaceans

Non-consumptive anthropogenic activities such as hiking, boating and wildlife watching, have been found to have an impact on wildlife either by affecting the community abundance and diversity (e.g. Patthey et al. 2008), or by changing animal behaviour (e.g. Swarthout & Steidl 2001). The degree of such effects often depends on the frequency of the activity (Wheeler et al. 2009) and its timing and impact (Burger et al. 2004, Remacha et al. 2011). For instance, among wandering albatrosses (*Diomedea exulans*) at Marion Island, those approached more frequently by pedestrians recorded the highest proportion of nest failures (Wheeler et al. 2009), and the number of birds that could be observed in guided tours at a woodland area in central Spain increased when visitor groups were smaller (Remacha et al. 2011).

Recreational activities are known to affect the physiology (Zwijacz-Kozica et al. 2013, Hayward & Hayward 2009, McClung et al. 2004), activity state (Shaughnessy et al. 2008) and behavioural patterns (Hayward & Hayward 2009, Granquist & Sigurjonson 2014) of the wildlife involved. Lions (*Panthera leo*) in the Addo Elephant National Park, South Africa, increased the number of breaths per minute, a physiological reaction associated with stress, and exhibited disturbance behaviours such as standing, sitting, yawning and moving away when tourists were present. Conversely, in the absence of tourists relaxation behaviours such as grooming and rolling were more frequently recorded (Hayward & Hayward 2009). The endemic subspecies of chamois (*Rupicapra rupicapra tatrica*) inhabiting the Carpathian Mountains had a higher concentration of faecal cortisol metabolites, a measure of stress levels, at sites of high tourism disturbance (Zwijacz-Kozica et al. 2013). The presence of tourists also had an influence on the weight of fledging chicks of yellow-eyed penguins (*Megadyptes antipodes*), which was lower than that of chicks occupying an area with no tourist activity (McClung et al. 2004). Activity state disruption has been reported for fur seals, *Arctocephalus pusillus doriferus* and *A. forsteri*, which tended to decrease the probability of resting and increase that of moving away from their haul site at Montague Island, Australia, when the study boat approached the colony more closely (Shaughnessy et al. 2008). Avoidance behaviour from the haul site in the presence of tourists was also reported for common seals (*Phoca vitulina*) in Iceland, which also increased vigilance behaviour (Granquist & Sigurjonson 2014).

Among wildlife, cetaceans constitute an appealing taxonomic group for the general public leading to a speedy development of recreational activities such as observation and swim-with programs (O'Connor et al. 2009).

Commercial recreational activities including whale watching and swim-with-dolphins programs started in the 1950s in San Diego (Hoyt 2001) and in the late 1990s in New Zealand (Orams 2004), respectively. Since then, these activities have increased almost exponentially (O'Connor et al. 2009). Whale watching and swim-with-dolphins programs are regarded as an important source of revenue, especially for developing countries, where they constitute an economic opportunity for the local community (Hoyt 2001, Orams 2002, Wilson & Tisdell 2003, Cisneros-Montemayor et al. 2010, Buultjens et al. 2016). In addition, the educational potential of whale watching can enhance knowledge and conservation awareness (IFAW et al. 1997, Wilson & Tisdell 2003, Neil et al. 2003, Zeppel & Muloin 2008, Jacobs & Harms 2014, Johnson & McInnis 2014) and encourage a long term pro-environmental attitude among tourists (Ballantyne et al. 2011). However, some have suggested that, although there is educational potential in these activities, in practice they are still far effectively communicating conservation issues to increase biocentric attitudes (Russell & Hodson 2002, Corkeron 2006). Reasons for this include poor interpretation and a lack of structure for providing information to the public by tour guides as well as the different background and expectations of visitors (Russell & Hodson 2002, Stamation et al. 2007).

Parallel to these potential benefits, there is a strong concern about the impact of this industry on cetacean populations. Many studies have been conducted to understand how these activities could be detrimental (Lusseau 2003, Bejder et al. 2006a, Lusseau & Bejder 2007, Stensland & Berggren 2007, Courbis & Timmel 2009, May-Collado et al. 2012, 2014, Steckenreuter et al. 2012). The Whale Watching Sub-Committee of the International Whaling Commission's Scientific Committee regularly reviews such studies and summarizes new information. So far, eight reviews have been produced, of which the latest is Parsons & Scarpaci (2016).

As highlighted by Beale (2007), it is necessary to distinguish between short-term and long-term effects. The former is a response that can be assessed during operational activities. Long-term effects may only be revealed by long-term studies, which can provide life historical data to reveal any biological changes in the population studied. Example of short-term effects include changes in diving profile (Ng & Leung 2003, Williams et al. 2009, Stamation et al. 2010), path direction (Williams et al. 2002, Delfour 2007, Timmel et al. 2008, Stamation et al. 2010, Christiansen et al. 2011, 2013a), swimming speed (Williams et al. 2002, Morete et al. 2008, Williams et al. 2009), behavioural state (Williams et al. 2006, Dans et al. 2008, Arcangeli & Crosti 2009, Montero-Cordero & Lobo 2010), group cohesiveness (Nowacek et al. 2001, Bejder et al. 2006b, Valle & de Melo 2006, Steckenreuter et al. 2012), surface active behaviour (Delfour 2007, Morete et al. 2008, Noren et al. 2009, Cammareri & Vermeulen 2010), and vocalization rate (Gordon et al. 1992, Buckstaff 2004, Soto et al. 2006, Jensen et al. 2009, Markowitz et al. 2011). How and whether these effects are associated with a long-term impact may be difficult to establish. It has been suggested that they may lead to a decrease in energy uptake and/or increase in expenditure at the individual level, and therefore a decrease in individual fitness, which could result in population level effects (Williams et al. 2006, Lusseau et al. 2009).

1.1.1 Short-term effects

Whale watching

Changes in activity state occurring in the presence of boats are an example of short-term effect that have been reported in various studies (Williams et al. 2006, Stockin et al. 2008a, Lusseau et al. 2009, Christiansen et al. 2010, Steckenreuter et al. 2012). Feeding and resting are often regarded as critical activity states (Parsons 2012, Steckenreuter et al. 2012) and for which any changes in occurrence may affect individuals or populations. Since the activity budget influences the energy budget of individuals and populations (Lusseau 2004) it is expected that changes in behavioural activity lead to changes in energy balance and can be therefore used to indicate likely impacts.

A study by Lusseau et al. (2009) on orcas (*Orcinus orca*, Linnaeus, 1758) from the southern population in the North Pacific used land-based observations and time-discrete Markov-chain statistics to detect the transition between behavioural events in the presence and absence of boats. The study revealed that the orcas spent 20% less time foraging when boats were present. In another study of a northern orca population in the Johnson Strait, whales were found to reduce their foraging time and to delay their feeding bouts in the presence of boats. They also increased their time travelling by 12.5% (Williams et al. 2006).

Short-beaked common dolphins (*Delphinus delphis*, Linnaeus, 1758) from Whitianga and Hauraki Gulf, New Zealand, were reported to substantially decrease the likelihood of continuing to forage after a boat approached them (Neumann & Orams 2006, Stockin et al. 2008a, Meissner et al. 2015). Decreased time spent foraging was also reported in common bottlenose dolphins (*Tursiops truncatus* Montagu, 1821) off Australia (Arcangeli & Crosti 2009) and off La Maddalena

Archipelago, Sardinia, Italy (Pennino et al. 2016). In particular, dolphins off La Maddalena were never observed foraging and socializing when more than three boats were present.

Indo-Pacific bottlenose dolphins (*Tursiops aduncus*, Ehrenberg, 1833) off Zanzibar (Christiansen et al. 2010) and Australia (Steckenreuter et al. 2012) were also shown to spend less time foraging. Here a reduction of 66.5% in the time the dolphins spent feeding was recorded during encounters with tour boats (Steckenreuter et al. 2012). Regular disruption of feeding behaviour may lead to an increase in energy expenditure (Christiansen et al. 2011) and a decrease in energy acquisition (Christiansen et al. 2013b). However, in the study of Williams et al. (2006) energetic costs of whale watching interactions were calculated for orcas and estimated to be small, suggesting this is unlikely to be substantive, at least at low intensity boat traffic levels. The authors' concern in this case was disruption of feeding bouts and engagement in other activities than foraging, which could lead to a reduction in prey capture and subsequent reduced energy gain. Food resources are typically distributed in patches, and the time taken to locate them may be significant for whales and dolphins (Benoit-Bird & Au 2003). If the time spent foraging is further reduced by external disturbance, possible longer-term consequences could derive by higher investment required to search for a new patch coupled with a decrease in daily energy intake.

Resting is also affected by tourist operations. Observations of common bottlenose dolphins off Australia and Indo-Pacific bottlenose dolphins off Zanzibar showed a decrease in resting in the presence of boats (Arcangeli & Crosti 2009, Christiansen et al. 2010, Steckenreuter et al. 2012). Indo-Pacific bottlenose dolphins off Australia were never observed resting in the presence of dolphin-watching vessels and also spent less time socializing when the number of boats increased (Steckenreuter et al. 2012). By contrast, they increased the time for milling and travelling. The authors reported their concern that dolphins could be spending more energy and facing a decrease in prey capture efficiency due to feeding disruption. Common dolphins in New Zealand were also reported to reduce their resting time (Stockin et al. 2008a). Southern right whales (*Eubalaena australis*, Desmoulins, 1822) off Argentina were reported to double their resting time after boat exposure, while increased travelling during boat approaches (Cammareri & Vermeulen 2010).

The biological importance of resting behaviour is indicated by the fact that it persists, even though resting animals are at greater risk of predation due to reduced alertness and responsiveness (Lima et al. 2005, Lima & Rattenborg 2007). Resting is in fact essential for a variety of body functions including hormonal regulation, immunity, thermoregulation and metabolism. Sleep deprivation has been associated with cognitive impairment in rats (Rechtschaffen & Bergmann 2002, Tartar et al. 2006) and the necessity of resting is correlated to proper cellular function (Benington & Heller 1995, Inoué et al. 1995).

Another response often observed during encounters with vessels is a change in movements and swimming direction. Whale and dolphin groups (Williams & Ashe 2007, Timmel et al. 2008, Schaffar et al. 2009, Christiansen et al. 2011, 2013a) have been reported to become more erratic in their movements in the proximity of boats, adopting avoidance behaviour. The linearity of movements in humpback whales (*Megaptera novaeangliae*, Borowski, 1781) off New Caledonia decreased proportionally with an increase in the number of boats (Schaffar et al. 2009). Southern right whales have been reported to redirect their path direction during experimental encounters with boats and swimmers (Lundquist 2012). Minke whales (*Balaenoptera acutorostrata*, Lacépède 1804) in Iceland tended to adopt a convoluted path in the presence of whale watching boats (Christiansen et al. 2011, 2013a). In contrast, reported changes in movement patterns among fin whales (*Balaenoptera physalus*, Linnaeus 1758) in the Mediterranean Sea showed an increase in linearity and speed in the presence of boats (Jahoda et al. 2003). Responses to human disturbance have been related to anti-predator behaviour (Frid & Dill 2002). If this is the case, cetaceans might be expected to react to whale watching vessels as they would in the presence of a predator. Baleen whales have been described as fight or flight species depending on the strategy adopted to avoid predators, either choosing to face them or to escape at high speed (Ford & Reeves 2008). The strategy adopted would be linked to their morphology, with Balaenidae species and one Balaenopteridae (the humpback whale) relying on their robust body and higher manoeuvrability to compensate for their reduced ability to flee. Other more streamlined Balaenopteridae, on the contrary, might use their swimming speed to escape from predators (Ford & Reeves 2008). This could explain the behaviour adopted by southern right, (Lundquist 2012), humpback (Schaffar et al. 2009) and fin whales (Jahoda et al. 2003), but not that of minke whales (Christiansen et al. 2011, 2013a), which would be expected to adopt a similar response to fin whales. The slower species would therefore choose to keep and amplify the irregularity of their tracks to confound the potential predator, whereas the faster species would increase the linearity of their movements to benefit from their ability to flee. Williams and Ashe (2007) reported that in the presence of few boats male orcas off British Columbia adopted a convoluted path, whereas when the number of boats increased further, the linearity of the whales' track increased. Killer whales are the fastest species among cetaceans, reaching 30 knots (Lang 1966), so following a straight path would allow them to advance faster than if they swim in a non-linear pattern. In another study, Williams et al. (2009) recorded a series of behavioural events including path direction, respiration rate, swim speed and surface-active behaviour of orcas in relation to the number and distance of vessels. Data were collected using a theodolite from land, on two different sites along the Washington coast, and analysed using Generalized Additive Models where both anthropogenic and natural variables were considered. The presence of boats influenced all variables in a non-linear manner. The direction of movement became more erratic as boats approached the whales, and more linear when the number of boats increased, as found in the previous study. Inter-breath intervals were reported to increase in the presence of 1 to 6 boats, but decrease when the number of boats was higher. Surface-active behaviour also increased when few boats started approaching, but decreased when boats came closer (Williams et al. 2009).

The increase in breathing synchrony observed in bottlenose dolphins in the presence of boats off Moray Firth, Scotland, was also suggested to be an anti-predatory strategy where animals engaging in synchronous behaviour may reduce individual vulnerability by decreasing their likelihood of being predated (Hastie et al. 2003). Changes of group cohesiveness have also been considered a defence strategy against predators. Guiana dolphins (*Sotalia guianensis*, Van Bénéden, 1864) have been reported to form tighter groups in the presence of boats at a distance of 180m and show maximum cohesion when boats were in the 100-20m range (Valle & de Melo 2006).

If responses to disturbance represent behaviour adapted to avoiding predation, then different species, possibly different gender and age classes, and different contexts (e.g. number of boats, type of boats or type of manoeuvring) may explain the variety of behaviours reported and the discrepancies found in many studies addressing the same variables in relation to boat disturbance. An example is the change in diving profile. Humpback whales off New Caledonia (Schaffar et al. 2009) and Hawaii (Green & Green 1990), and Guiana dolphins off Brazil (Valle & de Melo 2006), make longer dives in the presence of whale watching boats, while common minke whales off Iceland (Christiansen et al. 2011) reduce their diving time instead. Hence, multiple aspects need to be taken into account when trying to identify the complexity of response behaviours.

Few studies have focused on the effects of whale watching operations on the vocalization rate. As cetaceans are highly vocal and rely on sound for communication, navigation and foraging, any changes in vocal output might be of biological importance. Male humpback whales in a breeding ground in Brazil have been studied using pop-ups, underwater recording devices positioned on the seafloor and retrieved on command, to record their songs in the presence of tourist boats (Sousa-Lima & Clark 2009). Vocalization rates were analysed before, during, and after exposure. Additional data collected included distances between whales and boats, spatial orientation, and swimming speed. Some individual singers were found moving away from vessels and stopped singing without resuming it for at least 20min. Other males were recorded continuing to sing but moving away when boats were at less than 4km distance (Sousa-Lima & Clark 2009). Sperm whales (*Physeter macrocephalus*, Linnaeus 1758) have been reported to increase the duration of the first pause between clicking bouts in the presence of whale watching boats (Gordon et al. 1992, Markowitz et al. 2011). They also tended to delay the start of clicking after fluke up, although results in this respect were not significant and high inter-individual variability was recorded (Markowitz et al. 2011). The authors suggested that the prolonged duration of the first silence could be related to a passive monitoring behaviour by the sperm whales, which might be listening to the vessels in the attempt to detect their movements (Markowitz et al. 2011).

Orcas increased the duration of their calls in the presence of whale watching boats along the Washington coast (Foote et al. 2004). Beluga whales (*Delphinapterus leucas*, Pallas, 1776) progressively reduced their calling rate, showed repetition of specific calls, and increased the mean frequencies from 3.6 kHz to 5.2-8.8 kHz when vessels were in their proximity (Lesage et al. 1999). Bottlenose dolphins off Namibia were reported to shift upwards the frequency of the vocalizations in the presence of one or more boats (Heiler et al. 2016). Individuals of the same species off Florida have been reported to increase their whistle rate when boats approached (Buckstaff 2004). The author explained this increase in vocalization rate as a possible means of gathering members of the group in a socializing context or to compensating for the increased levels of background noise. Other studies have also commented on the possibility of a reduction in communication due to masking noise (Erbe 2002, Erbe et al. 2016, Jensen et al. 2009, Pine et al. 2016).

Highly social species like the delphinids, may suffer from reduced communication when exposed to noise. Mother and calf pairs as well as adult individuals engaged in mating behaviour could be forced to modify their vocal behaviour, increasing their vocalization rate and/or their source level. Erbe (2002) modelled boat noise levels and proposed that fast boats could be heard by orcas at 16km distance, mask their vocalization at 14km and influence their behaviour at distances of 200m. A temporary hearing loss could occur at 450m distance. Although these results are not deriving from actual data and their potential cannot be confirmed, understanding these parameters can help supporting operations management and the development of more effective guidelines to mitigate such effects.

However, responses to human interference may be of a completely different nature, as reported in studies where groups of dolphins have been observed swimming towards the vessels or not displaying any visible changes in their activity. For this reason, some authors distinguished among positive, neutral and negative reactions (Gregory & Rowden 2001, Pereira et al. 2007, Araujo et al. 2008, Hashim & Jaaman 2011). The terminology used, though, has to be treated carefully when interpreting results. While the "negative" response is quite evident in terms of disturbance, with dolphins clearly avoiding boats, a response deemed “positive” might not necessarily be advantageous to either individuals or populations. Approach behaviour towards oncoming vessels gives an impression of lack of disturbance is usually understood as a positive response. Clearly in this case, the dolphins do not perceive the boats as a potential predator and might approach them for various reasons, including the opportunity to exploit the hydrodynamics created by a moving vessel (Williams et al. 1992). However, if disturbance involves the disruption of a current activity and consequently influences the dolphins’ energetics, then such situations could have a negative impact. Dolphins engaged in a particular activity may stop in order to bow-ride, reducing the time used for important activities.

A “neutral” response occurs when dolphins continue to be engaged in pre-contact activities without any apparent modification of behaviour. A lack of obvious aversive visible reaction, though, does not necessary mean a lack of impact. It has been suggested (Gill et al. 2001, Beale & Monaghan 2004, Bejder et al. 2009) that behavioural responses to disturbance may differ depending on the condition of individuals. Favourable states include abundant and easily accessible food resources, availability of resting sites and, in general, a variety of high quality options. On the contrary, having few alternatives and limited resources may contribute to low quality conditions, which could induce behavioural choices defined by physiological requirements that override possible disturbances. Hence, individuals responding physically or acoustically might be only those that can “afford” it energetically and can thus explore alternatives. This also means that responsiveness can change over time depending on resources and condition.

Swim-with-dolphins

Short-term effects have been also reported during swim-with wild dolphins operations, although the number of studies for these activities is lower than those investigating “regular” whale watching. Such programs should raise greater concerns, as the interactions involved are more invasive. Their boat manoeuvres are more intrusive than those used for just observing the dolphins as they occur at closer distances in order to allow swimmers to enter the water in the proximity of the animals. The way swim-with-dolphins is performed varies among areas. In Australia, several techniques are used to approach groups of dolphins. These include (1) swimmers floating at the surface attached to each other by the waist while a guide with an underwater scooter pushes the dolphins towards them, (2) swimmers holding “mermaid lines”, 15-meters-long ropes positioned to the rear of a slowly moving boat, and (3) swimmers placed in a boom net attached to the rear or in front of a boat (Zeppel 2007). In other areas (e.g. New Zealand, Constantine & Baker 1997, Neumann & Orams 2006, Martinez et al. 2011 and in the Azores, personal observation), swimmers are left floating free after the boat approaches a pod of dolphins. In the Azores tourists are equipped with snorkelling gear but without fins (Figure 1.1).

Figure 1.1 Swim-with-dolphins operations in the Azores. Swimmers are solely equipped with snorkelling gear.

In New Zealand, three different techniques are used to approach a group of dolphins during swim-with operations: the “line abreast” approach where boats move parallel to the dolphins, the “in path” approach where boats first move parallel to the group and then stop in front of it, intersecting their path of travel, and the “around the boat” strategy where the boats are stopped while dolphins swim around it (Constantine & Baker 1997, Martinez et al. 2011).

Studies have documented that boat manoeuvring affects the degree of disturbance. Hector’s dolphins (*Cephalorhynchus hectori*, Van Bénéden, 1881), bottlenose dolphins and common dolphins showed avoidance behaviour more frequently when the “in path” type of approach was used (Constantine & Baker 1997, Martinez et al. 2011). The use of mermaid lines in the Gulf of St. Vincent, Australia, by contrast, seemed to minimize inappropriate approaches by the swimmers towards the dolphins, which as a consequence did not show changes in group cohesiveness (Peters et al. 2012). In this study the boat operator performed a parallel approach, considered less invasive than other strategies (Constantine 2001, Scarpaci et al. 2003). The encounters may also involve repeated approaches with the same group, which can generate responses to swimmers that may change throughout the tour (Neumann & Orams 2006). For instance, in New Zealand common dolphins were reported to have diverse responses towards swimmers, changing from a neutral behaviour to an interested one after consecutive encounter attempts (Neumann & Orams 2006). Dolphin group size and their age composition have also been reported to influence reactions during swim-with-dolphins operations. Smaller groups were found to interact with swimmers less than larger groups, and juveniles approached more frequently than adults (Constantine 2001, Neumann & Orams 2006, Peters et al. 2012). From a conservation perspective, it would be constructive to encourage and further investigate the least invasive types of approach used during operations.

1.1.2 Long-term effects

Whale watching

Induced changes in behavioural states may have important implications for the survival of individuals and populations. Foraging is considered biologically crucial to allow energy gain and maintain health, while socializing is fundamental for ensuring mating opportunities. External activities that regularly interfere with usual behavioural patterns may lead to physiological effects on individuals and to a gradual alteration of the viability of cetacean populations (Hastie et al. 2003, Lusseau & Bejder 2007). Bejder et al. (1999) suggested that disturbance is likely to lead to cumulative rather than acute effects.

Some authors have highlighted the potential for the stress response to pose potential risk for cetaceans (Wright et al. 2009, Rolland et al. 2012). Stress is a physiological response triggered in particular situations, such as during predation, to promote the survival of the individual. It has an immediate action and the physiological changes involved tend to return to baseline after the condition has passed. When resumption of normal conditions does not occur, a state of chronic stress results. Consequences reported for non-marine mammal species are a weakened immune system, a higher probability to contract diseases and the potential for endocrine disorders (Romero & Butler 2007, Wright et al. 2009, Parsons 2012). Repeated or prolonged encounters, over time, may result in chronic stress (Barr & Slooten 1999).

Few convincing studies exist of the long-term effects of tourist operations on cetacean populations (Lusseau 2004, Bejder et al. 2006a, Weinrich & Corbelli 2009). Probably the clearest example concerns a population of bottlenose dolphins in Shark Bay, Australia (Bejder et al. 2006a). In this area an extensive database on dolphin behaviour, distribution and demographics had been collected since 1984, well before the first commercial dolphin-watching operations which started in 1993. A second commercial operator received the permit in 1998. The large dataset extending over decades allowed comparisons to be made before and during dolphin-watching operations and between sites with high rates of interaction and sites with no or very low levels of operations (control). When comparing periods of tourism with one single operator with periods without tourism activity, no difference was found in dolphin abundance per km^2. However, when the comparison included two operators, a decrease in dolphin abundance of 14.9% per km^2 was detected. When comparing the control site with the tourism site, an increase in dolphin abundance of 8.5% per km^2 was found, suggesting that the decrease recorded did not reflect a decline of the population at local level, but rather a decline restricted to the tourism site, where more sensitive individuals may have been displaced. Within the same population of bottlenose dolphins, females experiencing higher tour boats exposure decreased their reproductive success compared to the less-exposed females, another example of effect at population level (Bejder 2005). Clearly a study like this one can provide a useful support to policy makers in management decisions. This case in particular was followed by a government decision to reduce the number of licenses from two to one and to introduce a moratorium on research permits (Higham & Bejder 2008).

Using a database of a 26-year period (1980-2006), Weinrich & Corbelli (2009) investigated the biologically significant effects of commercial whale watching on reproductive and calf survival rates of humpback whales in Canadian waters. Mother and calf pairs were identified using photo-identification methods. Only females of at least 8 years old were included in the analysis as this is the age at which they reach sexual maturity. Exposure time and number of boat-whale interactions were the variables used to explore the effects using logistic regression analysis. The authors do not report any evidence of the effects of boat interaction in relation to time of exposure or number of interactions for female humpback whales and their calves. Conversely, a positive relationship between whale survival and whale watching boat exposure was found. This was explained by the authors as likely a coincidental effect linked to prey availability and distribution. Whales chose the study area to feed on the abundant sand lances (*Ammodytes* spp.) and their survival rates would have been related to this resource and not to the whale watching boats, which would likely visit the area where they know whales occur. The authors nevertheless reported that the humpback whale population in the North Atlantic is growing at a lower rate with respect to other populations e.g. in the Southern Hemisphere. They therefore suggested a precautionary approach, due to the potential cumulative stress.

Another way of measuring the biological significance of behavioural change is to calculate the energetic costs of the behavioural responses (Williams et al. 2006, Yazdi 2007). Bottlenose dolphins in Chile were found to be affected by boats closer than 100m. Their presence induced a decrease of feeding, resting, and socializing and an increase of both slow and fast travelling. The avoidance strategy was estimated to have a cost of 324 kJ per hour, corresponding to 1/3 of the energy budget used in fast swimming (Yazdi 2007).

When databases are less comprehensive, it is still possible to approach the issue with a long-term perspective. Courbis and Timmel (2009) studied the surface-active behaviour of spinner dolphins (*Stenella longirostris*, Gray, 1828) in relation to boat traffic in Hawaii over a four-month period in three study areas. Results were then compared to long-term studies from the 1980s and 1990s reporting frequency of surface-active behaviour of the dolphin population within one of those three study areas. Overall, the authors reported a decrease in dolphin aerial activity and an increase in boat traffic. Changes in distribution within the bay were also observed and explained by the authors as a possible sign of displacement due to traffic. Although this study did not find any confirmed evidence of impact, the approach nevertheless allowed the detection of behavioural trends over time.

Swim-with-dolphins

Long-term studies addressing swim-with-dolphins operations have been investigated less often with only two published studies currently available. Constantine (2001) made observations spanning four years and used these to explore trends in behavioural response. Bottlenose dolphins in Bay of Islands, New Zealand, were followed during dolphin tour operations on 1994-1995 and 1997-1998. Comparisons of dolphin behaviour towards swimmers between years showed an increase in avoidance responses from 22% to 31%, in conjunction with a decrease from 48% to 34% of successful interactions, defined as dolphins approaching within 5m of swimmers. The encounter rate of the endemic species Australian bottlenose dolphin (*Tursiops australis,* sp. nov.) decreased by 12.8% over a period of 15 years (Filby et al. 2014). Concurrently, groups approached by the swim operators in more recent years were more likely to include calves, suggesting that operators responded to the decrease in encounter rate with an opportunistic strategy, in spite of regulations exempting groups with calves from swim-with-dolphins programs (Filby et al. 2014). Further investigations of swim-with operations to better understand dolphin-human interactions and long-term effects should be undertaken.

1.1.3 The conservation perspective

The choice of either leaving or staying in an area in response to human disturbance is species- and individual-specific and can lead to an alteration of community and population structure (Caro & Sherman 2011). From a conservation perspective however, the ultimate question will be whether commercial operations affect the fitness at individual and population levels, with changes in reproduction or survival rates as a result (Gill et al. 2001).

It is important to recognise that responses triggered by human activities will not necessarily result in reduced fitness (Blumstein & Fernandez-Juricic, 2010), just as lack of response is not necessarily synonymous with lack of impact. Being able to detect the circumstances and type of stimuli which activate a process of physiological disturbance that can affect the demography of a cetacean population is a real challenge. Stressors may be delayed in their expression and consequent physiological responses could arise at levels of disturbance which would not necessarily trigger a behavioural reaction (Holmes et al. 2005). Deriving estimates of energetic costs may help to indicate whether human activities are posing a threat for cetacean populations (Williams et al. 2006, Yazdi 2007).

With respect to this, Population Consequences of Disturbance (PCoDs) and Population Consequences of Acoustic Disturbance (PCADs) frameworks have been recently developed to assist with the analysis and interpretation of data. They aim to help evaluate impacts on populations incorporating both acute and chronic effects of disturbances in the modelling framework (Lusseau et al. 2012, Christiansen & Lusseau 2015a, Pirotta et al. 2015). These frameworks identify the processes by which behavioural changes due to disturbances may affect vital rates. A mathematical model developed for each process is used to investigate disturbance scenarios for individual vital rates and to determine its consequences at population level (New et al. 2014, King et al. 2015). Data on distribution, habitat preferences and reproductive history of individuals are needed to be incorporated in the model (New et al. 2014, Pirotta et al. 2015). This approach could provide an aid in the development of management decisions for conservation purposes.

Similarly, a good knowledge of local population status, survival rates, habitat use and behavioural ecology is essential for issuing *ad hoc* management measures (Bejder et al. 2006a). Unfortunately, such data are available for very few cetacean populations. In the Azores, for instance, despite various studies (e.g. Silva et al. 2003, 2014, Hartman et al. 2014, 2015) with only one long term addressing the ecology and social structure of Risso's dolphins (*Grampus griseus,* G. Cuvier 1812) in Pico Island (Hartman 2014), knowledge of cetacean populations is still too poor to be incorporated in the above mentioned models and to be used to inform management decisions. There is therefore a critical need to increase such knowledge for the majority of cetacean species.

This lack of information should call for a precautionary approach when dealing with management choices. If biologically significant changes in a given population may take time to become detectable and can only be measured where adequate data are available, then an alternative approach would be to reduce as far as possible the short-term effects. It would also be important to bear in mind that serious impacts can occur even when measurable behavioural responses may seem modest.

1.2 Cetaceans tourism in the Azores

1.2.1 The Azores Archipelago

The Azores are nine volcanic islands located in the central North Atlantic Ocean and on the Mid-Atlantic Ridge (N 39°13 W 29°36). They are usually divided into three groups: Western, one including Corvo and Flores; Central, including Pico, Faial, São Jorge, Terceira and Graciosa; and Eastern, with São Miguel, the largest island, and Santa Maria. As typical of oceanic islands they are characterized by steep slopes and reduced island-shelves (Sala et al. 2015). The sea surface temperature ranges between 15°C in winter and 27°C in summer (Martins et al. 2007). Although warm temperate waters are usually known to be oligotrophic, the Azores seem to be a hot-spot in biodiversity (Sala et al. 2015). Such richness is understood to have been driven by the complex bathymetry, such as the presence of many seamounts which support the formation of circulation patterns allowing that allow particles to be maintained *in situ* without much dispersion (Sala et al. 2015). The great biodiversity is reflected at different levels of taxa, including cetaceans. So far 28 species, around 30% of the currently known cetacean species (Committee on Taxonomy 2016), have been reported. This great local diversity encouraged the development of whale watching tourism in the Azores.

1.2.2 The tourism activity

Whale watching in the Azores started in Pico Island in the early 1990s with one operator and recorded 468 tourists in 1993 (Silva 2013, Bentz et al. 2015). It has since developed to involve 24 companies on four out of the nine islands of the Archipelago (Pico, Faial, Terceira and São Miguel), with a total of 59 boats. Seven companies in São Miguel are allowed to operate on the island and run 20 boat licenses. Vessels used include semi-inflatable boats (RIB), inboard motor boats and catamarans spanning from a minimum capacity of 12 to a maximum of 93 passengers (Regional Directorate for Tourism, Azores Government pers. comm.). Operations in São Miguel are mostly concentrated off the southern coast, departing mainly from Ponta Delgada and Vila Franca do Campo harbours. However, occasional tours are now also starting to extend to the northern coast of the island. One operator was established in 2014 in Mosteiros to the west coast (Figure 1.2). A characteristic of the whale watching activity in the Azores is the presence of a *vigia,* a lookout, who locates cetaceans from land and directs the tourist boats to the area of the animals. *Vigias* were used in the past in the Azores during whaling to specifically target sperm whales (Clarke 1954, Prieto et al. 2013) and constitute nowadays a unique technique within commercial operations around the world. The presence of a lookout enhances the success of tours, guaranteeing almost 100% of cetacean sightings.

Two types of tours are offered by the companies, whale watching and swim-with-dolphins. Both operations are regulated by the Regional Decree 9/99/A, revised in 2003 (Decreto Legislativo Regional 1999 and 2003), last modified in 2004, and currently under revision. Guidelines for whale watching include aspects such as the approach methods and speed, distance from the animals, and duration of the encounters. Swim-with-dolphins guidelines cover the maximum number of swimmers entering the water at a particular time, the maximum duration of each swim attempt, and the maximum number of swim attempts per dolphin group.

On average two up to four trips daily are scheduled by the operators, each trip lasting 2.5-3h, with the exception of few operators performing trips lasting up to 6h. The main season occurs between April and October, with a peak in July and August. During the boreal winter (December, January, February), tours are drastically reduced due to sea state conditions and lower tourist demand. The Azores is still far from being a mass tourism destination. Compared with other countries (e.g. Canada and USA, where whale watchers in 2008 exceeded 1 and 4 million respectively, O'Connor et al. 2009) whale watching activities cannot be identified as a large industry. In 2013, for instance, the number of tourists engaged in whale watching and swim-with dolphin tours reached approximately 59,000 (Bentz et al. 2015). This is a very important point in terms of impact studies, and the fact that the activities have not reached high levels can serve as comparison to accompany the evolution of the business and direct it in a sustainable path. However, in 2015 the number of tourists increased by 30% in relation to the mean for previous years (SREA 2016). This increase is likely due to a recent opening of low cost air transport. It is expected that the number of tourists (and thus of whale watchers) will continue to rise, making it imperative to monitor its effects.

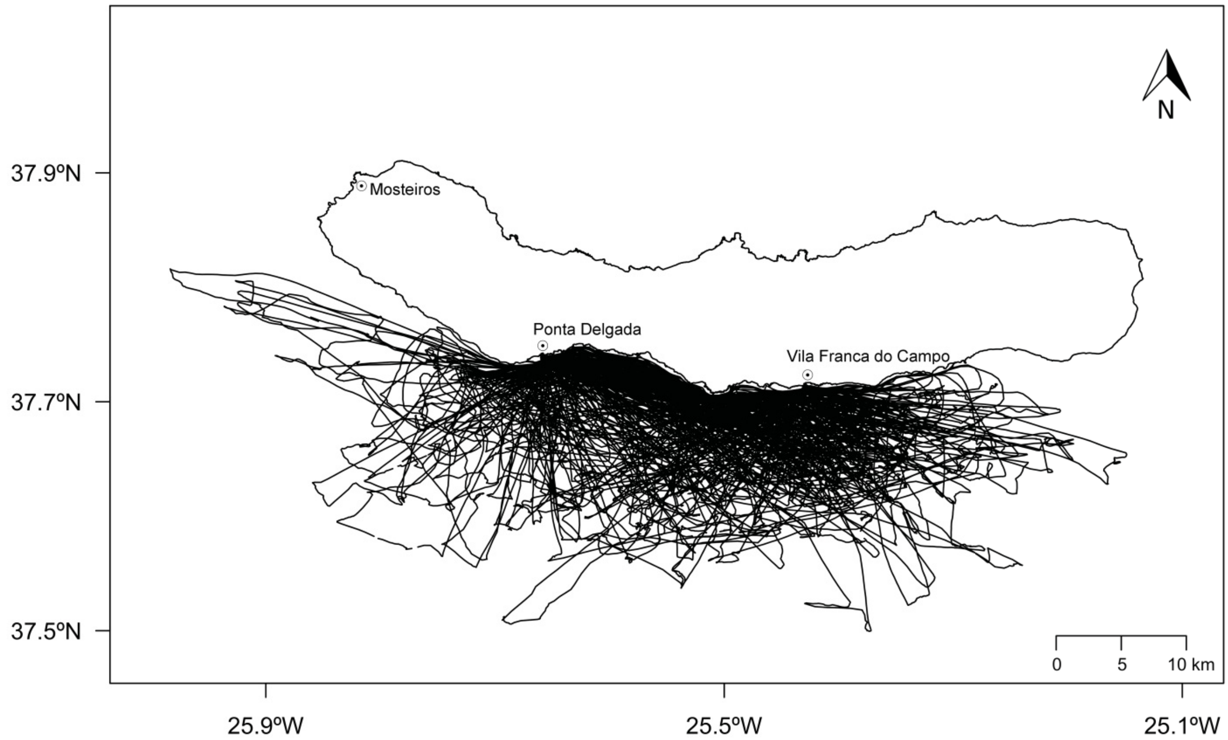


Figure 1.2 Overview of the area most used for commercial activities off the south coast of São Miguel Island, Azores. Black lines are tracks of whale watching boats during 2014 and 2015 seasons departing from the two main harbours, Ponta Delgada and Vila Franca do Campo

1.2.3 Target species

Virtually all cetaceans occurring in the Azores are targeted by whale watching operations. They include species observed year-round, migratory species as well as occasional visitors, entailing a diversified range of encounters (Visser et al. 2011a, Silva et al. 2013, Silva et al. 2014). Large migratory baleen whales (e.g. blue whales, *Balaenoptera musculus*, Linnaeus 1758; fin whales and sei whales, *B. borealis,* Lesson 1828) are mostly observed during spring. Conversely, sperm whales, especially females and juveniles (Gordon & Steiner 1992), short-beaked common, bottlenose, and Risso's dolphins can be observed year-round (Silva et al. 2014). Atlantic spotted dolphins (*S. frontalis,* G. Cuvier 1829) occur in the area between summer and autumn (Silva et al. 2003) when sea water temperature is highest.

Some species are preferred targets for whale watching operators, namely the sperm whale and, in spring, baleen whales. Dolphin species, especially *Delphinus*, provide reliable sighting success within the tourism operations given their high encounter frequency rate. Swim-with-dolphins tours rely on all species except the striped dolphins (*Stenella coeruleoalba,* Meyen 1833), which are less cooperative due to their elusiveness and fast swimming behaviour. Risso's dolphins are also only occasionally targeted by tour operators in São Miguel Island, due to the high elusiveness of this species (Filipe Ferreira, lookout, pers. comm.). However, groups of Risso's dolphins in Pico are targets for swim-with dolphins tours (Hartman et al. 2014). This difference can be explained by the possible different use of the coastal areas where tourism occurs. Risso's dolphins in São Miguel generally form small elusive groups whereas operator prefer other, more conspicuous species such as common dolphins and Atlantic spotted dolphins, which gather in large groups (Filipe Ferreira pers comm.). Conversely, in Pico Island, Risso's dolphins are often encountered in large groups including females and calves, suggesting that the coastal area is important for nursery (Hartman et al. 2014). Based on these findings a recent proposal has been made for the regional decree that excludes Risso's dolphins from the list of the species that may be approached for swim-with dolphins operations. Overall among dolphins, common, bottlenose and Atlantic spotted dolphins account for most daily tour operations.

Common dolphin

The taxonomy of the common dolphin has been controversial since the species was first described by Linnaeus in 1758. In 1994, two sympatric forms, the short-beaked and the long-beaked common dolphins, *D. delphis* and *D. capensis* (Heyning & Perrin, 1994), were described as genetically distinct. More recently, further molecular studies (Cunha et al. 2015) questioned that classification and urged a revision of the current classification. Another form of short-beaked common dolphin inhabiting the Black Sea has been described as subspecies (*D. d. ponticus*, Amaha 1994). The great variability common dolphins display in terms of coloration, size and shape might be the main reason why their classification has been so uncertain. Common dolphins have a widely distributed, occurring in all oceans from tropical to cool temperate waters, including the Azores (Perrin 2009). They are also found in closed waters such as Mediterranean and Black seas. Common dolphins can be observed both nearshore (Bearzi et al. 2003, Pierce et al. 2010) and offshore (Cañadas & Hammond 2008, Silva et al. 2014) preferring steep slopes and upwelling areas where foraging opportunities are enhanced (Evans 1994, Oviedo et al. 2010). Thus, the development of coastal anthropogenic activities could interfere with their viability. Indeed, despite being globally assessed as "Least Concern" due to their wide distribution and overall abundance (Baillie & Groombridge 1996), localized threats do exist. The populations inhabiting the Alborán Sea and the eastern part of the Mediterranean basin, for instance, saw a sharp decline in the last decade due to fishing interactions (Bearzi et al. 2003, 2008) and for this reason are classified as "Endangered". Moreover, despite the wide distribution of this species, only a few studies focus on activity budget: Neumann (2001a) and Stockin et al. (2009) for New Zealand, and Filby et al. (2013) for

Australia. Studies in the Mediterranean have focused mainly on distribution and habitat modelling rather than on behavioural patterns (Canãdas & Hammond 2008).

In the Azores common dolphins may be observed associated with other species during foraging, mostly with Atlantic spotted and striped dolphins (Clua & Grosvalet 2001, Quérouil et al. 2008). Calves are observed year-round (unpublished data, MONICET database), while peaking in spring-summer, as shown in the results section 3.3., and as reported in other common dolphin populations of temperate waters (Westgate & Read 2007, Stockin et al. 2008b). *Delphinus,* like other small delphinids, tend to form large aggregations and to exhibit conspicuous behaviour (Ferguson et al. 2006). Information about local population size, site fidelity and activity budget is still missing. This lack of information is notable especially in the light of the increasing interest in tourism in the Azores. Cetacean populations, which are being exploited as living resources for tourist reasons, could be better managed with basic knowledge about their behavioural and ecological patterns.

Bottlenose dolphin

Another species for which taxonomy is controversial is the bottlenose dolphin. Currently there are three confirmed species: *T. truncatus*, *T. aduncus* and *T. australis*, the latter recently confirmed as a species (Charlton-Robb et al. 2011). The Black Sea population is a subspecies (*T. t. ponticus*) and in the North Atlantic two ecotypes of bottlenose dolphins are recognized: the coastal and the offshore forms, which differ in terms of size, shape, ecology and genetics (Reeves et al. 2003). In the Azores it is still not clear whether both forms occur and whether they show distinctive habitats preferences, given that oceanic islands are characterized by reduced island shelves. In this respect, one study focusing on genetic analysis on both alive and stranded specimens, reported that bottlenose dolphins in the Azores lacked a population structure and were similar to the offshore form. Due to such high gene flow among individuals, the authors suggest that the bottlenose dolphins of the North Atlantic be considered a single conservation unit (Quérouil et al. 2007).

Bottlenose dolphins have a wide distribution, being found in tropical and temperate waters as well as both nearshore and offshore, over continental shelves and oceanic areas. They are probably the most studied dolphin species, possibly due to their predominantly coastal range, including bays and estuaries which they enter for foraging, and because of their residency patterns, which in some areas have allowed long-term monitoring (Bearzi et al. 2009, Bossley et al. 2017). Globally they are considered a “Least Concern” species, although some local populations are listed as “Vulnerable” and “Endangered”. Due to their tendency to occur in coastal areas, as well as their high level of adaptability, they may be easily exposed to anthropogenic impacts (Balmer et al. 2011). For instance, bottlenose dolphin populations from coastal Georgia were studied in relation to the presence of persistent organic pollutants, those ranging closer to the pollutant point source were found to be heavily polluted (Balmer et al. 2011). Despite the current limited information about the bottlenose dolphin population off São Miguel, the regular occurrence of small groups in the coastal area of the main harbour in Ponta Delgada, suggests their potential exposure to human activities.

Atlantic spotted dolphin

The Atlantic spotted dolphin is found only in the Atlantic Ocean, occurring seasonally in the Azores. It is observed mostly in offshore continental waters (e.g. Bahamas, Herzing 1997), but may be also observed in deep oceanic waters and around oceanic islands (Silva et al. 2003). Besides some localized long-term monitoring programs (e.g. Bahamas), Atlantic spotted dolphins, especially those inhabiting pelagic waters, are poorly known and their conservation status is therefore listed as “Data Deficient” (Hammond et al. 2012). Groups tend to be mixed for age and sex and groups size is large (Silva et al. 2003). When they mix with other species like the common dolphin groups tends to be even larger (Quérouil et al. 2008). Seasonal variations in their occurrence have been reported off Florida coasts, where higher density coincided with the cool season (Griffin & Griffin 2004). In contrast, in the Azores Atlantic spotted dolphins are observed during the warmest months, although their seasonality still needs to be further investigated.

1.3 Aim and objectives

The aim of this study was to gain an understanding of the effects that tourism activities in São Miguel might be having on the local dolphin individuals and populations to provide suggestions for improving practices and promote the long-term sustainability of commercial operations. For this, the effects of the two most common tourist activities (observation and swimming) on the behavioural patterns of dolphins were investigated. *D. delphis*, the most common species, was chosen as the target species to investigate baseline behavioural patterns and boat interactions. Effects of swim-with-dolphins operations were also investigated on the bottlenose and the Atlantic spotted dolphin.

Why is it important to assess the behavioural patterns of a species?

The study of behavioural patterns establishes the link between organisms and the environment in which they live. In particular the activity budget of a species, which is a form to describe behaviour, provides insights into its natural history and may also help researchers to understand the habitat use of a population. An activity performed predominantly in a specific area is an indication of the suitability of that area for that activity. Therefore, populations occupying different habitats are likely to show differences in activity budgets (Ellwanger & Gould 2011). Activity budgets demonstrate temporal patterns, both diurnally and seasonally (Engel & Young 1992, Massé & Côté 2013) and also across the life stages of an individual and between sexes (Prates & Bicca-Marques 2008, Shanee & Shanee 2011, Lövy et al. 2013, Ferretti et al. 2014, Kour et al. 2014). The time spent on a particular activity may depend on environmental factors, e.g. more time could be dedicated to foraging when food resources are scarce or more difficult to find. Conversely, if an area is suitable for a specific activity, then that activity may be more often seen in that location. For example, spinner dolphins (*Stenella longirostris,* Gray 1828) are reported to use Hawaiian bays as a resting site. They enter bays in the early morning and depart in late afternoon for foraging in offshore waters (Danil et al. 2005, Delfour 2007). Group size may also affect activity budgets (Isbell & Young 1993). Living in a group has potential benefits such as reduced predation, enhanced foraging and reproduction success, as well as increased efficiency in defence strategies. However, group living can also result in increased competition for resources, increased potential for predation, and decreased reproductive opportunities (Gowans et al. 2007). Thus, a number of factors seem to be implicated in characterizing the activity budget of a species, which in turn may explain a number of environmental and ecological aspects, as well as informing on the suitability of a given area for a specific behaviour.

Changes in activity budgets have also been used to infer anthropogenic impacts. For instance, in the above mentioned spinner dolphin population, the increased number of swimmers and kayakers in the area was deemed to cause a decrease in dolphin’s resting time (Danil et al. 2005, Courbis & Timmel 2009).

Why can common dolphins be good indicators of tour boat effects?

Common dolphins often approach moving boats (Neumann & Orams 2006), which could result in repeated tour boat encounters throughout the day, potentially leading to cumulative impacts (Barr & Slooten 1999, Parsons 2012). So far, behavioural effects of tour boats on common dolphins are only known for the New Zealand population. In the Hauraki Gulf, dolphins reduced the time spent foraging and resting (Stockin et al. 2008a) and delayed the time to resume foraging when in the presence of tour boats. Similarly, in Bay of Plenty, dolphins reduced their time foraging (Meissner et al. 2015). Although the overall activity budget was not affected, dolphins in Mercury Bay tended to increase travelling in the presence of boats. Smaller groups were also more likely to avoid boats (Neumann & Orams 2006). In the Azores, the only studies addressing the impact of tour boat activities have been on the local population of sperm whales (Magalhães et al. 2002) and Risso's dolphins (Visser et al. 2011b). Sperm whales off Pico and Faial islands were found to change speed and increase surface behaviour when operators violated the code of conduct (Magalhães et al. 2002). Risso's dolphins off Pico Island shifted the daily time range allocated for rest during the high traffic season, tending to rest and socialize less in the presence of more than 5 boats (Visser et al. 2011b).

With the increasing pressure of tourism on living resources it becomes even more important to increase our knowledge of the behaviour and ecology of local populations, and in particular for those which are daily exposed to the boats presence, like the common dolphin.

Why is it important to investigate swim-with operations and its effects in the Azores?

In the Azores swim-with-dolphins programs started in combination with whale watching tours, with tourists partaking in swim with dolphins activities in an opportunistic manner. As this activity became more popular and offered additional economic revenue, dedicated swim-with-dolphins tours began to be offered. Operators may target specific groups when there is the opportunity to choose among species, group size associated with activity state, or distance from the harbour. For instance, Atlantic spotted and bottlenose dolphins tend to be preferred over common dolphins, while large gatherings of surface feeding common dolphins are preferred over smaller ones. A shorter distance from the harbour is also preferred over groups occurring far out (Filipe Ferreira, tour company lookout, pers. comm.).

The fact that multiple species are targeted in the same area is unique compared with what occurs in New Zealand and Australia, where dolphin operators mostly focus on a single species, the prevalent one for their area, e.g. bottlenose dolphins in Gulf of St. Vincent (Peters et al. 2012) and Port Phillip (Scarpaci et al. 2000, Filby et al. 2014), Australia; Hector's dolphins in Akaroa Harbour (Martinez et al. 2011) and Porpoise Bay (Bejder et al. 1999), common and bottlenose dolphins in Bay of Islands (Constantine 2001) and Mercury Bay (Neumann & Orams 2006), dusky dolphins in Kaikoura (Markowitz 2012), New Zealand.

Within the local legislation for swim-with-dolphins activities no specific guidance is given on how to approach dolphin groups; "the type of approach as well as the distance to the group is left to the exclusive responsibility of the skipper, based on the evaluation of the dolphins' behaviour and the sea state" (Decreto Legislativo Regional 1999, 2003). There is, however, a limitation on the number of swim attempts per group of dolphins (3) and the number of swimmers per swim attempt (2). The duration of each swim episode is limited to a maximum of 15 minutes. A recent proposed amendment of this legislation included a limit of only one swim-with-dolphins boat at the time per group of dolphins, and no swim attempts to be made in the presence of whale watching boats. Moreover, at the first sign of disturbance from the dolphins, the swimmers should return to the boat and no more swim attempts are allowed. The legal definition of "disturbance" is a horizontal and/or vertical displacement of the group or part of it.

To better manage tourist operations and to minimize their potential effects, guidelines are fundamental. However, to be able to issue effective guidelines it is imperative to know the effects of the activity and which of its aspects are the most critical, especially because these can be species and habitat dependent.

In this context, the specific objectives of the present study were:

1. To describe the normal undisturbed behaviour of common dolphins off São Miguel Island focusing on the activity budget and its temporal variation.
2. To assess potential behavioural changes of common dolphins resulting from tour boat interactions. Results were then used to interpret potential long-term effects of biological importance.
3. To describe the swim-with-dolphins activity in the Azores, to evaluate the respective behavioural responses of common, bottlenose and Atlantic spotted dolphins and to provide suggestions for improved practices.

2. METHODOLOGY

Early morning light embracing the Ilhéu (Islet) of Vila Franca do Campo, São Miguel. View from the land station in Ponta Garça

2. METHODOLOGY

The high sighting frequency especially of dolphin species, in the Azores allows relevant data to be collected in a relatively short period. Moreover, in this location cetaceans occur relatively close to shore, facilitating their observation from land. Land-based studies of marine mammals are relatively rare compared with boat-based studies, yet have the advantage that observation can take place without interference, an important point for behavioural studies (Giacoma et al. 2013). This becomes even more critical when evaluating the effects of interactions with vessels. For the purpose of the present study, data were collected both from land and from boat. The land platform provided the advantage of not being part of an interaction scenario, while the boat platform allowed to collect more specific data concerning dolphin-swimmer interactions. The project was carried out in collaboration with two whale watching companies operating in São Miguel. Such collaboration established a link between science and the local tourism, with the aim of supporting its development on a sustainable way. Specifically, during land-based data collection, extra support was given by the lookout of one of the whale watching companies, whereas boat-based data were collected on-board tour boats during swim-with operations.

2.1 Study areas

Given the two components involved, land-based and boat-based, the study area differed within each field methodology. The land-based study site was located on the southern coast of São Miguel Island (N37°42’ W25°22’) covering an area of 150° with a radius of ca. 9km from the observation point located in Ponta Garça at 93m above sea level. The bathymetry of the area is characterized by relatively steep slope within few kilometers from Ponta Garça towards the east of the Island (Figure 2.1). The area covered approximately 6% of the total area used by the whale watching companies departing from Ponta Delgada and Vila Franca do Campo. Daily whale watching and swim-with-dolphins activities are run throughout the year, and are more frequent between April and October. Other recreational private boats and commercial activities such as scuba diving also take place in the area, but mostly close to shore where dolphins are less frequent.

The boat-based methodology encompassed a larger area. As whale watching companies in the Azores rely on their own lookouts located on land to detect cetaceans, operations at sea can cover different areas for different companies. To overcome this, and to cover the area used for the activity as much as possible, two whale watching companies departing from two different harbours located on the south coast of São Miguel Island (N 37º39’, W 25º26’), were chosen (Figure 2.2).

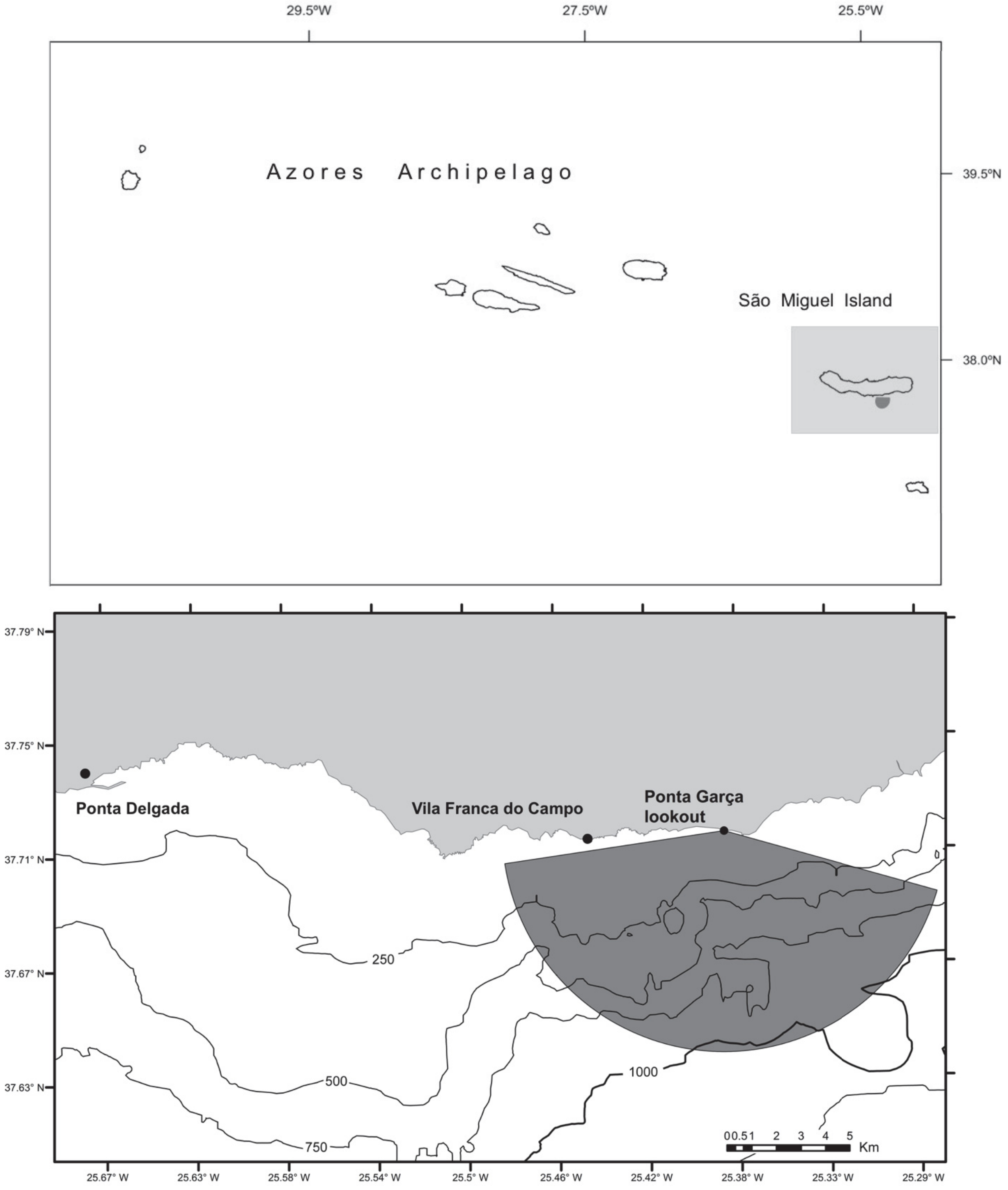


Figure 2.1 Study area covered for data collection starting from the observation point in Ponta Garça (N37º42'50.76", W25º22'23.16"), São Miguel Island.

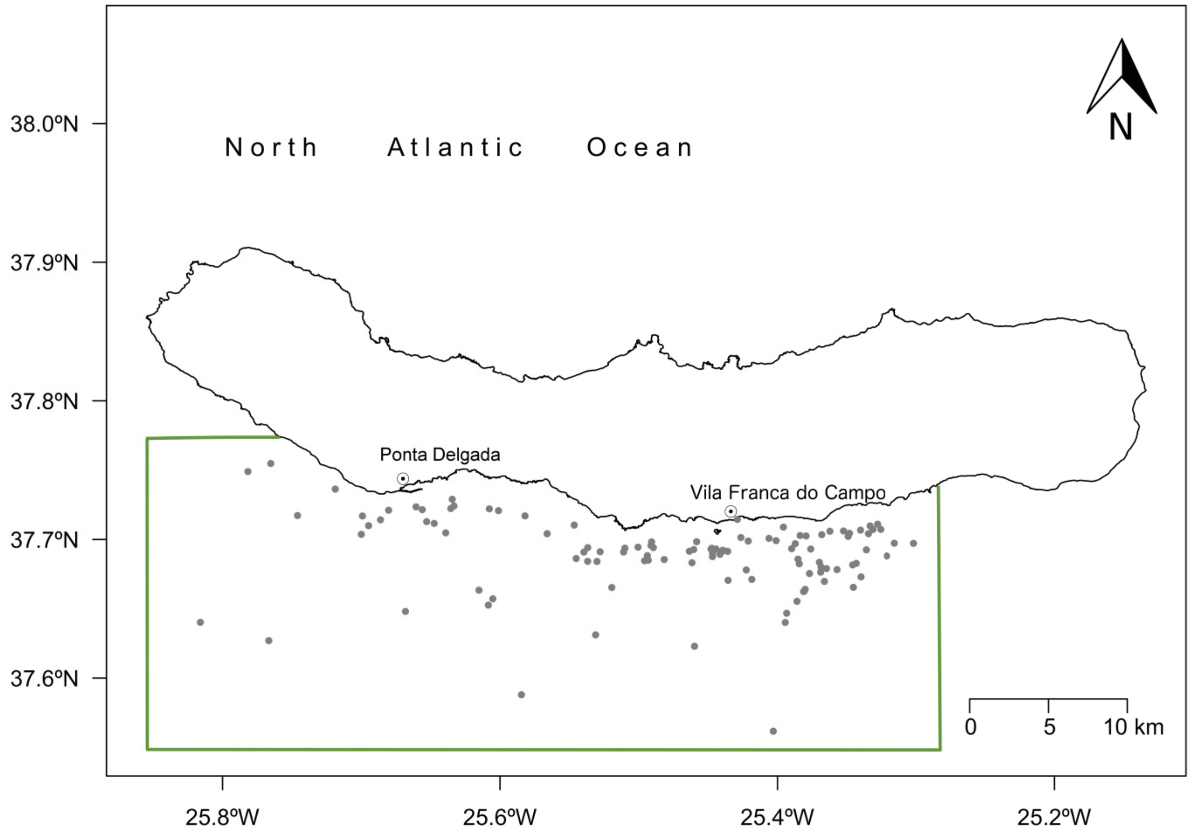


Figure 2.2 Study area of the boat-based data collection and dolphin groups encounters (grey dots) during swim-with-dolphins operations starting from the two main harbours, Ponta Delgada and Vila Franca do Campo on the south coast of São Miguel Island.

2.2. Data collection

2.2.1 Baseline behavioural patterns of common dolphins

To address the first objective, field data were collected from the land station. A team of one observer and one data recorder performed dedicated watches from 0800 to 1700h in good sea state (Beaufort ≤3) and visibility (> 10Km) conditions from July to September 2013 and April to October 2014. Data were collected using Steiner 15x80 binoculars placed on a stationary support for increased stability. The support enabled a 360° rotation, allowing the ocean to be smoothly scanned across the entire angle of observation (Figure 2.3). Co-aligned with the binoculars was a digital camera (Canon EOS 40D, zoom lenses 90-300mm) to record visual data (Markowitz et al. 2011). The images were used to assess the distance of dolphin groups from the shore. Audio information was also recorded to assist in later analysis, especially with dolphin detection within each photo frame. A calibration object (Figure 2.4) of known size was located at 5m distance from the observation station and served to calibrate the camera's focal length (Gordon 2001).

Given the fission-fusion nature of common dolphin groups and the distance at which observations were carried out (Neumann 2001a, Stockin et al. 2009), focal group follows (Altmann 1974, Mann 1999) were preferred over focal individual follows. Moreover, the elevation at which observation occurred provided a good vantage point to oversee the entire focal group (Martinez 2010). The first focal follow of the day was always of the dolphin group first encountered during scan sampling and thus was less dependent on group size or behaviour. Subsequent encounters were selected based on direction and distance from the original group, so as to reduce the chance of autocorrelation (Cecchetti et al. 2017).

Figure 2.3 Land-based data collection from the station in Ponta Garça during the seasons 2013-2014 off the south coast of São Miguel Island (left, photo by E. Madeira). The wooden support enabled binoculars to rotate and adjust up and down during focal follows (right, photo by A. Cecchetti)

Predominant group activity sampling was defined as the behaviour in which more than 50% of individuals were engaged during sampling. A group was defined as individuals at 100m radius from a central individual (Irvine et al. 1981), typically engaged in the same activity and showing the same direction of movements (Shane 1990). Data were collected until the focal group was lost from sight or left the area and when the distance no longer allowed reliable data collection. Hence, samples included only reliable and consistent data.

An instantaneous sampling technique with 2min intervals was used to record four categories of activity: foraging, travelling, socializing and low activity (detailed description given in Table 2.1). The low activity state included resting and milling combined, given the distance from shore at which observations took place. Although resting and milling are distinct states, both are characterized by low active surface behaviours, therefore misperception could occur when observing at distance. Milling is regarded as a transitional behaviour between other states and lacks any apparent biological significance (Neumann 2001a, Stockin et al. 2009).

Figure 2.4 Stick used to calibrate the focal length of the camera during focal follows. Located at 5m distance from the stationary support, it shows three different measures accounting for camera adjustments (left). Example of camera shot during a focal follow (right).

A continuous sampling technique was chosen for recording active surface behavioural events. These tend to be underestimated with the instantaneous sampling technique because the duration of an event is often shorter than the recording interval (Martin & Bateson 2007). Active surface behavioural events included four categories: breach, porpoising, head-slap and tail-slap (a detailed description is given in Table 2.2). In 2014, breach, head-slap and tail-slap rates data were also collected. Behavioural observations of common dolphins were always performed by the same observer (AC) to avoid inter-individual variability. A data recorder entered data in real time using the free application Epicollect+ (version 1.5, Imperial College London, http://www.epicollect.net/) for data storage. Epicollect+ is a user-friendly application, designed to facilitate data collection. It allows the creation of a personalized project by building an input form using a drag and drop interface. Once the form has been created it can be used via web or mobile devices, and saved data can be later accessed online and downloaded for analysis (Figure 2.5).

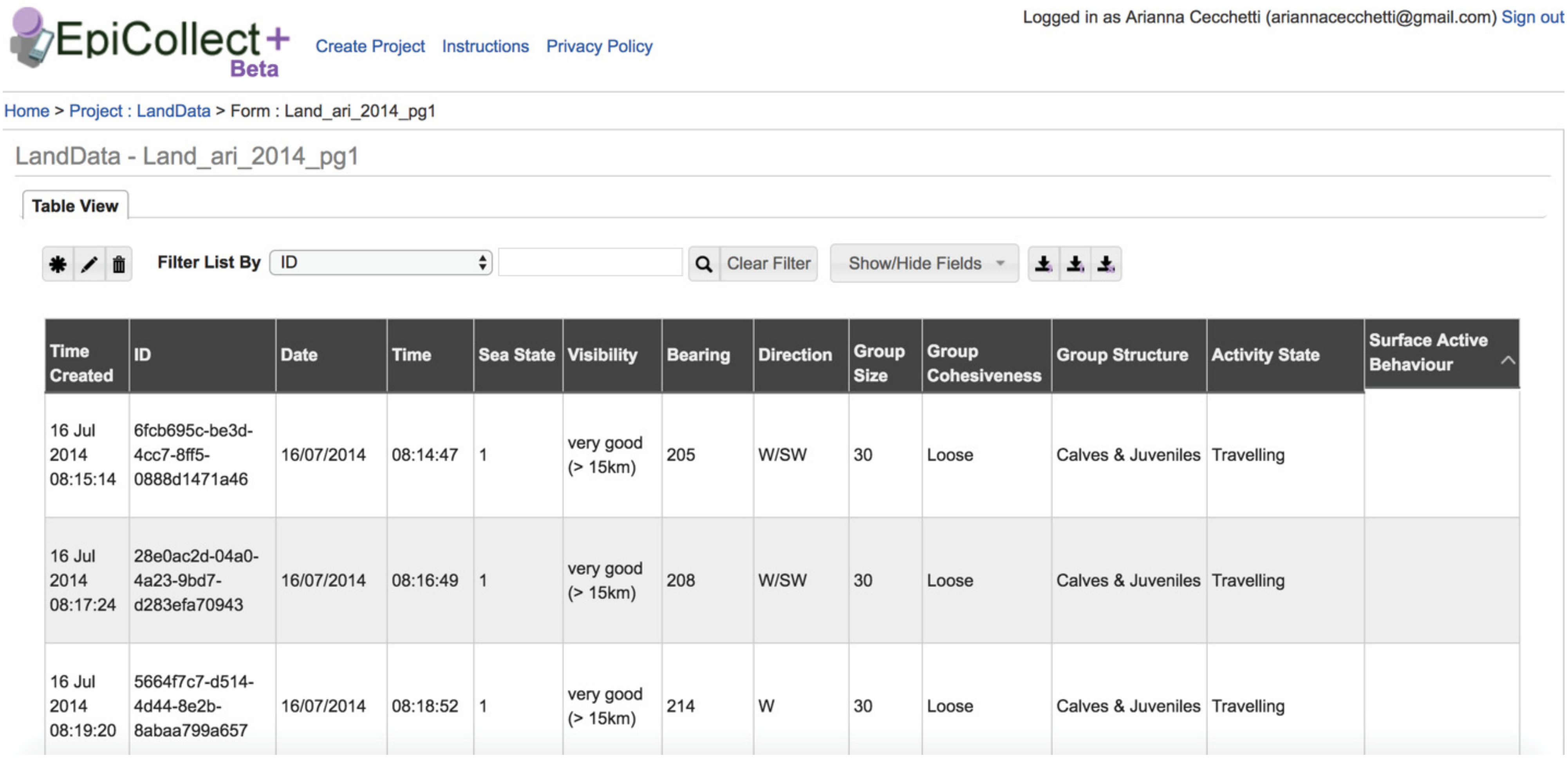
The data recorder also assisted with searching for dolphin groups between observation sequences in order to prevent observer fatigue. Additional search support was given by the whale watch lookout operating from the same station. This additional observation support further reduced the risk of resampling the same groups and the associated issue of pseudo-replication (Cecchetti et al. 2017).

Table 2.1 Definitions of behavioural categories considered in the present study, from Neumann (2001a) and Stockin et al. (2009).

Activity state	**Definition**
Foraging	This category includes also feeding and is defined as individuals engaged in coordinated directional movements and prolonged dives in the attempt to pursue and capture prey. Cohesiveness of the group varies often during foraging/feeding activity. Changes in heading and circling movements can be observed. When actual feeding occurs close to the surface, aerial activity is observed. Seabirds can be associated with feeding dolphins.
Low activity	Generally slow movements and absence of active surface behaviour. It includes circling movements or absence of forward propulsion (motionless). Close distance range between individuals and regular surfacing patterns are observed. Recurrent re-direction headings can be observed.
Travelling	Movement of an individual or group following a consistent track over time.
Socializing	High frequency of active surface events such as breaching, head slapping, and tail slapping concerning at least two individuals (mother-calf excluded). Chasing and body contact is observed.

Table 2.2 Definitions of active surface behavioural events used in the present study, adapted from Weaver (1987) and Bearzi et al. (1999).

Behavioural events	**Definition**
Breach	Individuals jumping out of the water, either with half body or total body. Breaches can be single or in series.
Porpoising	Individuals leaping repeatedly out of the water with the whole body during fast swimming.
Head slap	Individuals hitting their head on top of the sea surface generating a V-shaped water splash. The head and rostrum is often pointing sideway.
Tail slap	Individuals hitting once or repeatedly their tail on top of the sea surface.



Time Created	ID	Date	Time	Sea State	Visibility	Bearing	Direction	Group Size	Group Cohesiveness	Group Structure	Activity State	Surface Active Behaviour
16 Jul 2014 08:15:14	6fcb695c-be3d-4cc7-8ff5-0888d1471a46	16/07/2014	08:14:47	1	very good (> 15km)	205	W/SW	30	Loose	Calves & Juveniles	Travelling	
16 Jul 2014 08:17:24	28e0ac2d-04a0-4a23-9bd7-d283efa70943	16/07/2014	08:16:49	1	very good (> 15km)	208	W/SW	30	Loose	Calves & Juveniles	Travelling	
16 Jul 2014 08:19:20	5664f7c7-d514-4d44-8e2b-8abaa799a657	16/07/2014	08:18:52	1	very good (> 15km)	214	W	30	Loose	Calves & Juveniles	Travelling	

Figure 2.5 Example of the online tabular format of data collected in the field using Epicollect+. Data are ready to be downloaded in excel format for analysis

2.2.2 Effects of tour boats on common dolphins' behaviour

To address the second objective and investigate the effects of tour boats on the behavioural patterns of common dolphins, data were also collected from the land station using the methodology described previously. In addition to dolphin behavioural data, however, the presence of boats was also recorded. Specifically, when a tour boat was approaching a group of dolphins its manoeuvres were assessed in the light of the local whale watching guidelines (Decreto Legislativo Regional 1999, 2003). During each encounter the type of approach, the speed and the encounter duration were recorded. The manoeuvring of the boat with respect to the dolphin group was classified into 3 categories: parallel and behind, to the front, and transversal, whereas the speed of the boat was noted as idle, equal to or exceeding that of the dolphins. The encounter duration was calculated as the sum of 2min intervals the boats were interacting with the dolphin group. An interaction was defined as boats intentionally slowing down and stopping or continuing to move nearby a group of dolphins. When a tour boat was performing swim-with dolphins, compliance could not be assessed given the lack of specifications in terms of approach measures and maximum encounter duration within the local guidelines (Cecchetti et al. 2017).

2.2.3 Swim-with-dolphins operations and dolphins' response

To fulfil the third objective, data were collected during swim-with-dolphins operations between the summers 2013 and 2015. Typically, each company carried out viewing and swim with dolphins' activities separately. Up to three swim-with trips occurred daily per company. Each trip included one or more *group encounters*, during which the boat approached a group of dolphins and attempted to place clients in the water (*swim attempt*). If successful, a swim attempt led to a *swim episode* in which one or more clients were released in the water with the suggestions from the operators to minimize as much as possible any noise and sudden movements that might disturb the dolphins.

Group focal scan sampling was used (Altmann 1974, Mann 1999) to examine the dolphins' response to the activity. Data collected included the initial behavioural state, the group size best estimate and the presence of calves and/or newborns, the type of boat placement, the number of swimmers and their placement relative to the dolphin group. Data were collected for all dolphin species approached. Boat-based data collection allowed the distinction between resting and milling behaviours, although the latter was never observed during swim-with operations.

Hence, behavioural states were defined in four categories, three of which were the same described for the land-based data collection: foraging, travelling and socializing (Table 2.1). The fourth, resting, was defined as "dolphin groups usually tight, exhibiting slow movements up to absence of forward propulsion, regular surfacing patterns and absence of active surface behaviour".

A calf was defined as an individual of approximately one-half or less in size than an adult and consistently associated with an adult (Fertl 1994). Newborns were defined as individuals showing visible foetal folds, consistently associated with an adult (Shane 1990).

Recordings of the time swimmers entered the water and re-boarded the boat allowed the duration of each swim episode to be calculated. When the swimmers entered the water, a scan was performed to record the dolphins' response, defined after Martinez et al. (2011) as: 1) *neutral*, dolphins did not show any apparent change of behaviour; 2) *avoidance*, dolphins changed their path direction or dived away from the swimmers or increased their speed and either changed direction or dived; 3) *approach*, at least one dolphin of the group changed direction and swam within 5m of at least one swimmer.

2.3. Data analysis

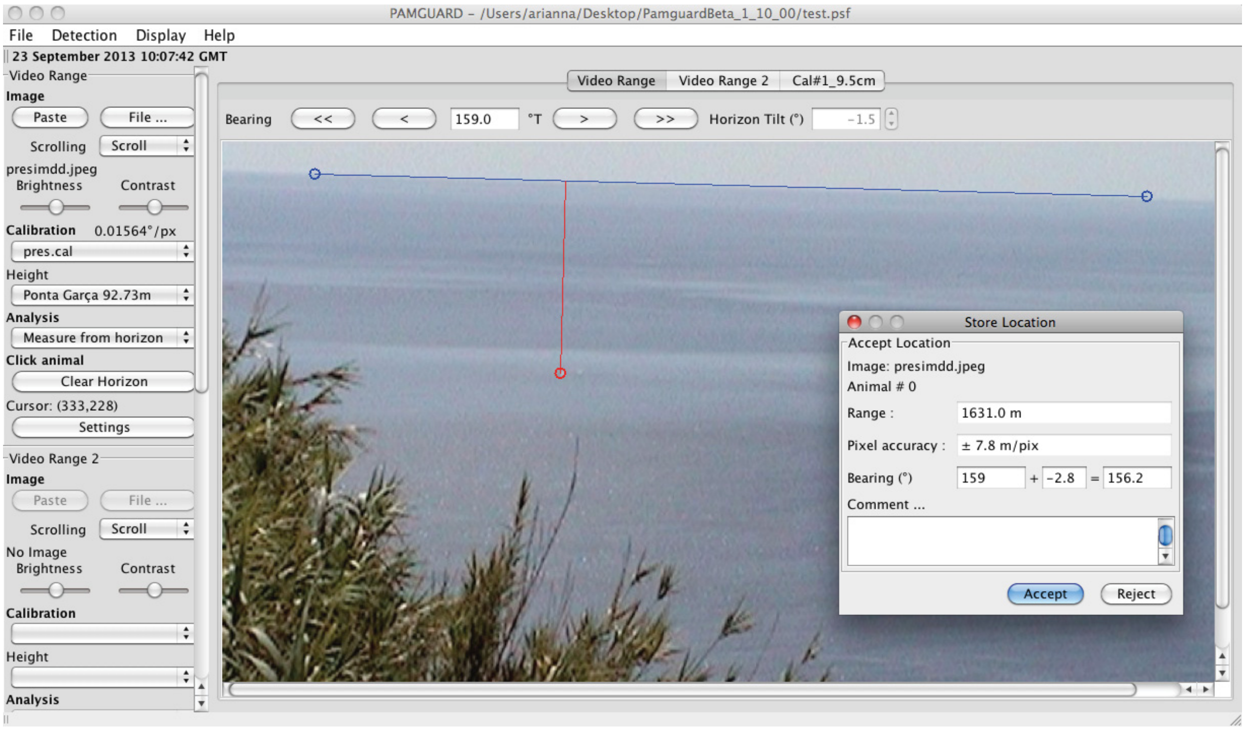
2.3.1 Baseline behavioural patterns of common dolphins

Visual data (images) were downloaded at the end of each day and archived by date and time to be subsequently selected for analysis based on sharpness and dolphin detection. The simultaneous presence of animals and horizon within the frame was necessary for calculating the distance ranges. Hence, images where only animals were detected without the referee point of the horizon were discarded. Distance of dolphin groups from shore were calculated using the PamguardBeta 1.0 software (Figure 2.6). Mathematical functions following the method described by Gordon first (1990, 2001) and Leaper and Gordon (2001) later, and integrated into the programme, made it possible to perform the analysis using bearing, calibration and observer height measures.

Land-based behavioural data were organized in time blocks to test for temporal behavioural differences: early morning (0800-1014), late morning (1015-1229), midday (1230-1444) and afternoon (1445-1700). Three boreal seasonal periods were used for analysis: Spring (April-May), Summer (June-July) and Autumn (August-September). Winter months were not considered due to frequent bad weather conditions, which did not allow the collection of data.

The time spent in each activity state was calculated from the 2min interval samples and added for all the sightings (Neumann 2001a). A bootstrap resampling analysis with replacement was then carried out to generate 1,000 samples for each time block for monthly and daily activity budgets, which were used to perform a post hoc analysis. Bootstrap has the advantage of being a simple and effective statistical tool that provides an estimate of the variability of the sample's mean. Replacement implies that a data point can occur more than once or can be omitted in the bootstrap dataset, increasing the probability that the generated samples are different from the original one (James et al. 2013).

Active surface behavioural data relative to breach and head slap rates were analysed with a hurdle model. Hurdle models allow data with excess of zero counts and overdispersion to be analysed, and provide separate equations for the zeros and non-zero data (Mullahy 1986). In a first step, both positive and zero data are included in a binomial model, in this case performance or non-performance of a behavioural event. The second step takes into consideration the positive data, running a count data model, either following Poisson or a negative binomial distribution, i.e. how many behavioural events occurred (Mullahy 1986). An Aikake Information Criterion (AIC) was used to help decide between the use of a Poisson and a negative binomial model. Tail slap rates were analysed due to low sample size. All statistical analysis was performed in R (version 3.1.1). R packages used included bootstrap, resample, chron, flexclust, GAD, geosphere, PMCMR, pscl and sp.


PAMGUARD – /Users/arianna/Desktop/PamguardBeta_1_10_00/test.psf

23 September 2013 10:07:42 GMT

Video Range

Image: presimdd.jpeg

Scrolling: Scroll

Calibration 0.01564°/px

pres.cal

Height: Ponta Garça 92.73m

Analysis: Measure from horizon

Cursor: (333,228)

Video Range 2

Image: No Image

Scrolling: Scroll

Bearing 159.0 °T

Horizon Tilt (°) -1.5

Store Location

Accept Location

Image: presimdd.jpeg

Animal # 0

Range : 1631.0 m

Pixel accuracy : ± 7.8 m/pix

Bearing (°) 159 + -2.8 = 156.2

Comment ...

Figure 2.6 Example of distance range calculation with PamguardBeta. The blue line indicates the measure is taken using the horizon as referee point.

2.3.2 Effects of tour boats on common dolphins' behaviour

Group-focal follows were used to calculate control and interaction sequences based on the absence or presence of tour boats which were either observing or swimming with a group of dolphins (Cecchetti et al. 2017). Other boats which were not specifically targeting the dolphins were not considered in the interaction scenarios. This decision was taken because of the limited spatial and temporal occurrence of vessels in the area and because the aim of the study was to focus only on tourism activities.

Considering the nature of data collected, namely the high dependence between consecutive 2min intervals within a sequence, Markov chains analysis was chosen, because it enables the dependence of an event on the preceding ones to be assessed (Guttorp 1995). Specifically, first-order Markov chains analysis, where a succeeding state is only dependent on the immediately preceding one, was applied to derive transition probabilities between mutually exclusive behavioural states. The Markov-chains approach requires the creation of a transition matrix, which is then compared to a model of expected probabilities. In this case two-way contingency tables were created for both control and interaction scenarios using preceding and succeeding states within each focal follow (Lusseau 2003). A transition was tallied in a control table when no tour boat interaction occurred between two samples; for cases where there was an interaction the transition was tallied in the interaction table. Boat arrivals or departures are typically ambiguous times when it is not clear whether a transition is to be considered within a control or interaction sequence (Lusseau 2003). In such instances, a conservative approach was followed (Meissner et al. 2015), and transitions that occurred between two samples after an interaction were removed (Lusseau 2003, Stockin et al. 2008a, Meissner et al. 2015).

Transition probabilities for control and interaction chains were calculated by:

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

where i is the preceding behavioural state and j is the succeeding behavioural state (ranging from 1 to 4, the total number of states observed and included in the analysis), a_{ij} is the number of transitions observed from state i to state j and p_{ij} is the transition probability from i to j in the Markov chain. A two-tailed Z-test for proportions was then used to compare each control transition with its interaction counterpart (Fleiss et al. 2003).

The activity budget of control and interaction scenarios was derived from the left eigenvector of the dominant eigenvalue of the transition matrices (Lusseau 2003) using the Excel add-in PopTools (version 3.0.3, CSIRO www.cse.csiro.au/poptools). Control and interaction activity budgets were then compared with a two-tailed Z-test and 95% CI were calculated (Cecchetti et al. 2017).

For each activity state within each scenario, the time to resume a given activity after a change occurred was calculated by:

$$E(T_j)=1/\ \pi_j$$

where $E(T_j)$ is the number of transitions to return in the initial state j and π_j is the steady-state probability of each activity in the chain. The steady-state probability means that after several transitions, the system tends to stabilize and the probabilities won't be much different from one state to the other. The number of transitions were then multiplied by 2min intervals length to give the time taken by dolphins to resume the activity *j*.

Following Lusseau (2003), the average bout length for each activity state in control and interaction scenarios was derived from the mean of the geometric distribution of p_{ii} (Guttorp 1995):

$$t_{ii}=1/1-p_{ii}$$

where p_{ii} is the probability to stay within the same activity state *i*. The average bout lengths of each activity within both scenarios was then compared with a Mann-Whitney test.

Given the potentially repeated exposure of dolphins to tour boats throughout the whole season, the cumulative activity budget was calculated following Lusseau (2003), Christiansen et al. (2010) and Meissner et al. (2015) using the following formula:

Cumulative budget = (*I* x interaction budget) + (*C* x control budget)

where *I* is the proportion of time common dolphins spend with interacting tour boats and *C* is the proportion of time dolphins spend without interacting tour boats (hence $C=1-I$). *I* is 0 if there is no interaction with tour boats, and in this case the cumulative budget is equivalent to the control budget. In the opposite case, when interaction with tour boats is constant, *I* is 1 and the cumulative budget equals that of the interaction budget (Cecchetti et al. 2017).

The cumulative activity budget of control and interaction scenarios were then compared for each activity state with a two-tailed Z-test for proportion. The difference between the Z-test p-values of control and cumulative budgets were used to explore the effects of boat traffic intensity on cumulative budget (Cecchetti et al. 2017).

2.3.3 Swim-with-dolphins operations and dolphins' response

To investigate whether encounter frequency of different dolphin species and their mean group sizes reflected their relative abundance or was instead driven by a subjective preference of the operators, data collected during swim-with-dolphins operations were compared, using a Chi-square, with observations from an opportunistic open database (MONICET, www.monicet.net). This database is compiled from regular whale watching activity and covers a larger area. The presence of calves/newborns between the two datasets was not compared for the incomplete data available within the whale watching database.

Dolphins' response to swimmers was analysed with a Generalised Estimating Equation (GEE) model for multinomial responses. This model is suitable for analysis of population response estimates rather than those of individuals. Is is an alternative to Markov-chains in that it overcomes the dependency issue by taking it into account through specifying a working correlation structure (Zeger & Liang 1986). The exchangeability time ("time.exch") correlation structure, recommended for nominal responses (Toulomis 2015), was chosen. The full model contained the three-levels response variable (neutral, avoidance and approach) and five explanatory variables: species, group size, behavioural state, boat placement and presence of calves/newborns. The model was then rerun excluding non-significant explanatory variables. Similarly, a GEE model with exchangeable correlation structure was applied to explore the duration of swim episodes with the same five explanatory variables. In the exchangeable correlation structure, the within-cluster observations (in this case the group encounter) are assumed to be equally correlated. This structure was preferred over the first-order autoregressive structure, which assumes that correlations are a function of time, i.e. correlation of successive swim attempts would decrease over time, and that measurements are equally spaced in time. This was not the case in the present study, as sampling depended on the activity and therefore intervals between swim attempts were not standardised. The "swimmers placement" variable was not included due to its high collinearity with boat placement. This latter was chosen instead, given that boat approaches could already elicit a reaction prior to swimmers entering the water. Thus, the dolphins' response would be linked mainly to the operator behaviour and only secondarily to swimmers' placement. Moreover, understanding which type of approach triggers the highest avoidance response would be more helpful in that rules of best practice regarding boat manoeuvres would be easier to control than swimmers behaviour. The number of swimmers was also not included in the model due to its low variability, as legislation stipulates that two is the maximum number of swimmers entering the water at the time. Only the most frequent factor levels of "boat placement" and "swim episode duration” were included in the models. The goodness of fit between nested models and the Quasi-AIC (QIC) tests were used to select the best models. Data were also analysed based on the current legislation and its most recent proposal to account for compliance of the legislation. All analyses were performed in R using geepack and multgee packages.

3. RESULTS

Surfacing common dolphin

Socializing common dolphins next to a tour boat

Tourists getting ready to swim with bottlenose dolphins

3. RESULTS

3.1 Baseline behavioural patterns of common dolphins

3.1.1 Field effort

Common dolphin behavioural data were collected on 83 days, corresponding to 599 hours of effort. A total of 249 groups of dolphins were observed: 64 in 2013 and 185 in 2014. Days with no dolphin groups sighted accounted for 16% of the total (N=83). Group size ranged from solitary individuals to several hundreds, with a median of 30 individuals.

3.1.2 Distance from shore

The mean distance from shore at which groups of dolphins were recorded was 1,623m (min=45m, max=5,341m, median=1,417m, n=459). Sea state and visibility did not affect the distance at which dolphin groups were observed (r_s=-0.028, p=0.549 and r_s=0.026, p=0.578 respectively). No significant differences in group distance from shore were found on a daily scale, but the monthly variation was significant (Figure 3.1, KW: H=45.69, df=5, p=<0.0001), although it only ranged between 500m and 1km. Dolphins observed in June tended to be more distant from the shore than those observed in April (p=0.00016), May (p=0.038), July (p=0.0057) and September (p<0.0001). In May and August dolphins were found farther from shore than in April (p=0.03742 and p=0.02347, respectively).

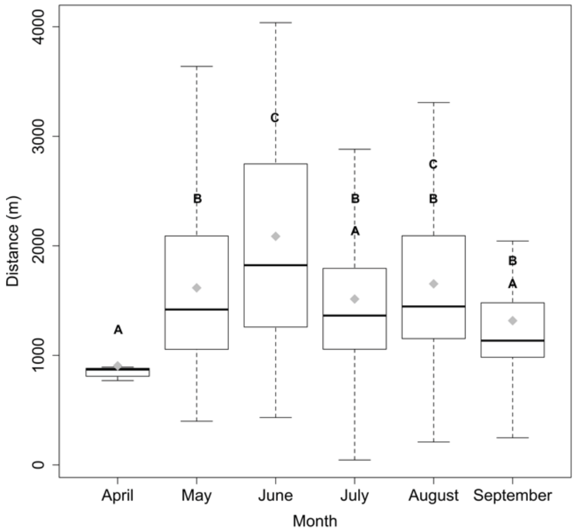


Figure 3.1 Distances from shore of dolphin groups per month. Different letters indicate significant differences between variables. Grey dots represent mean values, horizontal lines within the box the median, and whiskers the standard errors.

3.1.3 Activity budget

Overall, travelling was the most frequent activity (40%, N=2266), followed by foraging (32%), socializing (16%) and low activity (12%). A difference between the survey years was recorded (X^2_3=133.17, p<0.0001, N=2266): foraging was the most frequent activity in 2013 (48%, N=664) and travelling the most frequent in 2014 (46%, N =1602) (Figure 3.2).

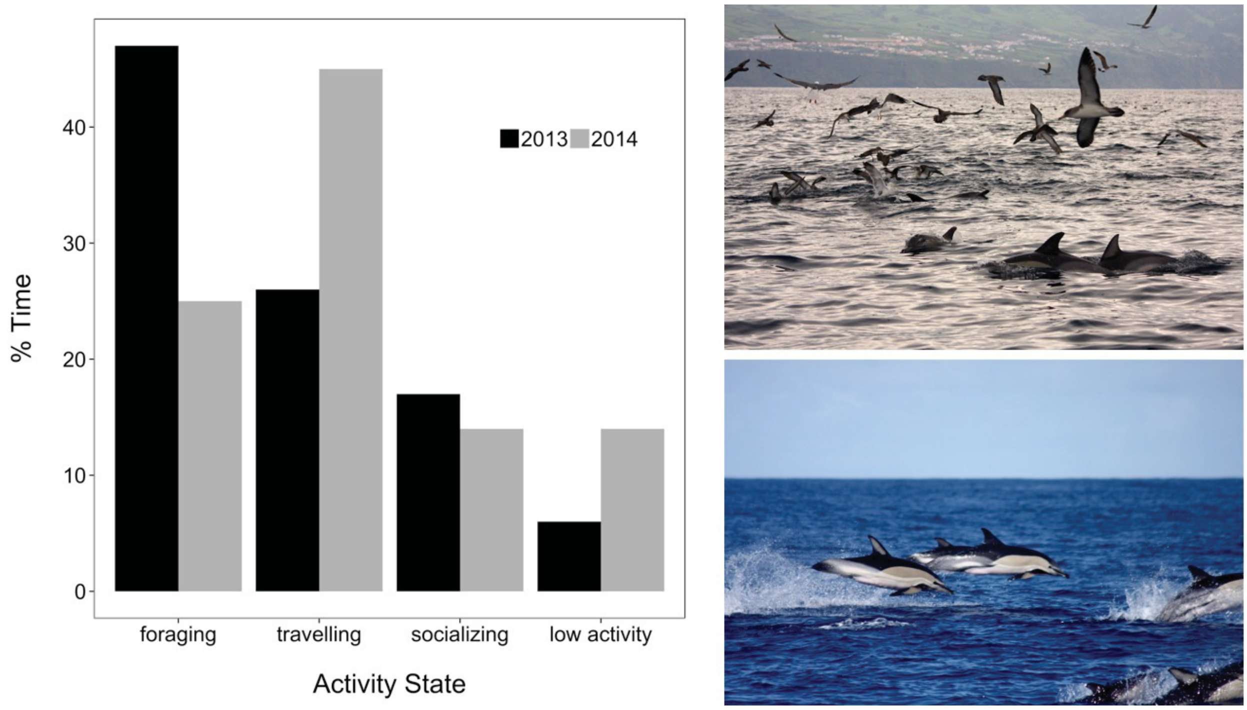


Figure 3.2 Activity budgets of common dolphins during 2013 and 2014 seasons off São Miguel Island. Photos show foraging common dolphins in associations with Cory's shearwaters and yellow-legged gulls (top) and porpoising dolphins during fast travelling (down).

Activity budget, measured from bootstrap samples, differed significantly between the four daily periods (X^2_9=103.2335, p<0.0001) and the three seasons (X^2_6=55.458, p<0.0001). Post hoc analysis showed that throughout the day, all activity states besides socializing during midday and afternoon, were significantly different (p<0.0001). They were also significantly different (p<0.0001) between all seasons except for foraging between June-July and August-September. At midday, the low activity state was at its highest, contrasting with the reduced foraging activity (Figure 3.3a). Along the three seasons, foraging increased, whereas travelling showed an inversed trend from socializing and low activity (Figure 3.3b).

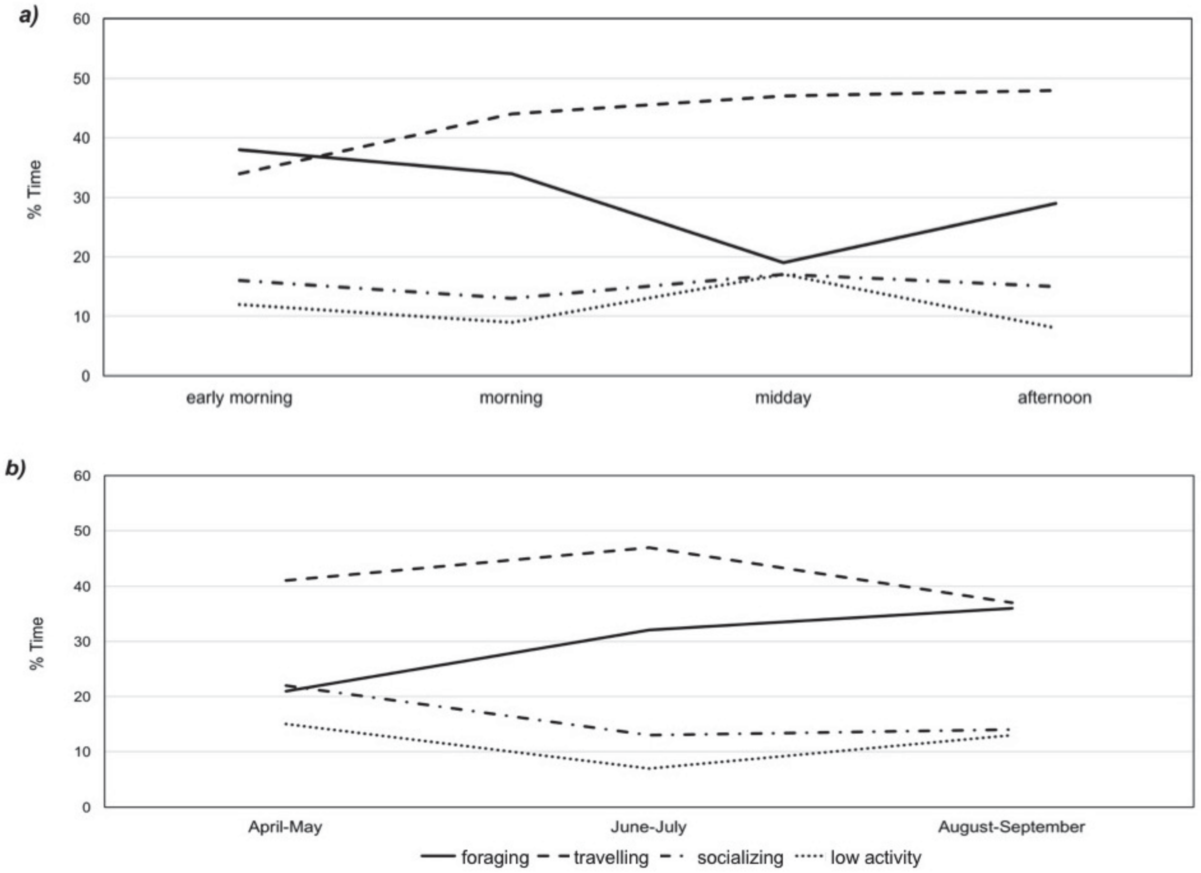


Figure 3.3 Breakdown of the activity budget of common dolphins by day (a) and seasons (b) off São Miguel Island, Azores.

3.1.4 Group size

Group size varied with activity states (KW H=15.3, df=3, p-value=0.001, n=631, Figure 3.4). The post hoc test showed that foraging groups were significantly larger than low activity groups (p=0.004). Similarly, socializing and travelling groups were significantly larger than low activity groups (p=0.006 and p=0.020, respectively).

Within each activity state, group size varied significantly between months (Figure 3.5). Post hoc comparisons showed that group size of foraging dolphins in May was significantly smaller than in July and August (p=0.008 and p=0.021, respectively). Groups of socializing dolphins were larger in July and August in comparison with June (p=0.020 and p=0.029, respectively) and September (p<0.0001). Moreover, groups in May were larger than in September (p=0.034). When comparing travelling dolphins, the group size was larger in July with respect to April, May or September (p=0.002, p=0.020 and p<0.0001). Dolphin groups engaging in low activity were larger in July than in September (p=0.017).

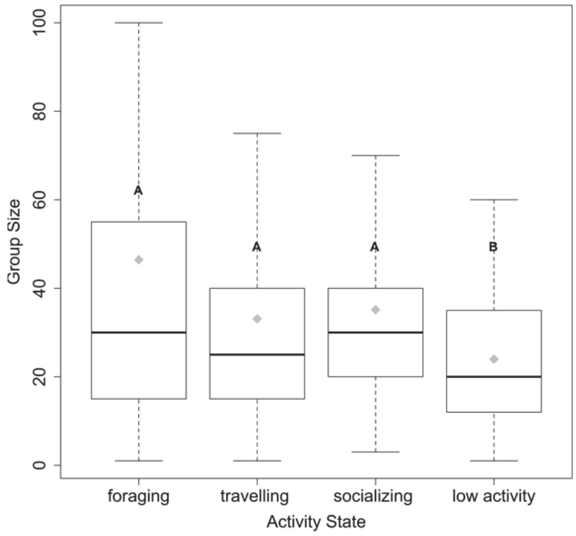


Figure 3.4 Common dolphin group size in relation to activity state. Different letters indicate significant differences. Grey dots represent mean values, horizontal lines within the box the median and the whiskers the standard errors.

3.1.5 Active surface behaviour

Porpoising dolphins (143 events) were mostly engaged in travelling (46%) or foraging (43%). Dolphins whose activity was low were never observed porpoising. Breaches (366 events) were most frequent during foraging (49%) and socializing (27%), whereas head slaps (132 events) were observed more during travelling (46%) and foraging (30%), followed by socializing (20%). A negative binomial distribution was chosen over a Poisson (breach rate: AIC(NB)=2300, AIC(P)=2382; head-slap: rate AIC(NB)=1404, AIC(P)=1452). A maximum of twelve breaches per 2min interval were recorded, with one to three breaches per 2min interval being the more frequent breach rate observed. Hurdle model analysis showed that breaching rate was smaller when dolphin groups were engaged in travelling ($p<0.0001$) or in low activity state ($p<0.0001$).

Thirteen head slaps per 2min interval was the maximum rate recorded, while the highest frequency was one to three head slaps per 2min interval. Head slaps were also recorded less frequently for low-activity groups ($p<0.001$). Within groups performing head slaps, those engaged in foraging and travelling were significantly ($p<0.001$) more likely to perform them.

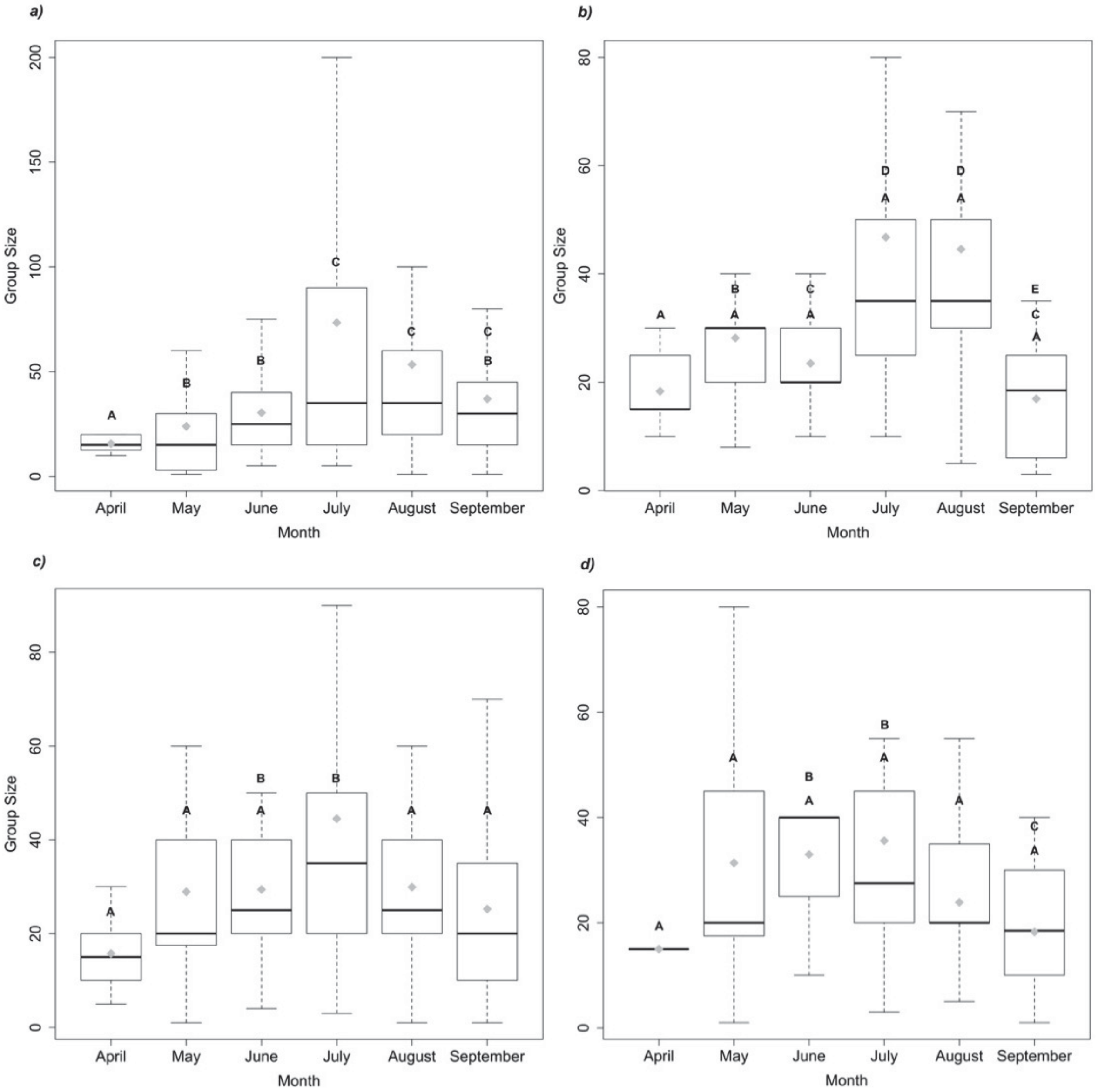


Figure 3.5 Variation of group size for each activity state among different months, a) foraging, b) travelling, c) socializing, d) low activity. Different letters indicate differences as per post-hoc test. Different scales used for clarity. Grey dots represent mean values, horizontal lines the median, and the whiskers the stadard errors.

3.2 Effects of tour boats on common dolphins' behaviour

3.2.1 Field effort

Data were collected between July 2013 and October 2014 over 83 days, which corresponded to 599 hours of effort, of which 157 were spent in focal follows. During the study period, a total of 154 control and 25 interaction sequences were recorded, giving a total of 3,357 control and 419 interaction transitions respectively. The mean duration for control sequences was 46min (median=36min, SD=17.12, range=14 to 215min), whereas the mean duration for interaction sequences was 34min (median=32min, SD=33.9, range=14 to 78min). Of the 25 interaction sequences, 11 involved whale watching only, 7 swimming-with-dolphin activities only, and a further 7 sequences included both activities simultaneously (Cecchetti et al. 2017). Most of the sequences involved only one tour boat interacting with a dolphin group (79% of transitions, N=419) up to a maximum of three (4% of transitions, N=419).

3.2.2 Effects of boat interactions

Both control and interaction scenarios reported a higher transition probability between the same activity state (Figure 3.6). The presence of tour boats had a significant effect on three state transitions: foraging to socializing (Z=5.15, p<0.001), travelling to socializing (Z=2.14, p=0.032) and travelling to foraging (Z=2.26, p=0.023). When boats were interacting with the dolphins, foraging to socializing increased from 0.3% to 4.8% and travelling to socializing increased from 7% to 12%; conversely, travelling to foraging decreased from 4.9% to 0.7% (Figure 3.7).

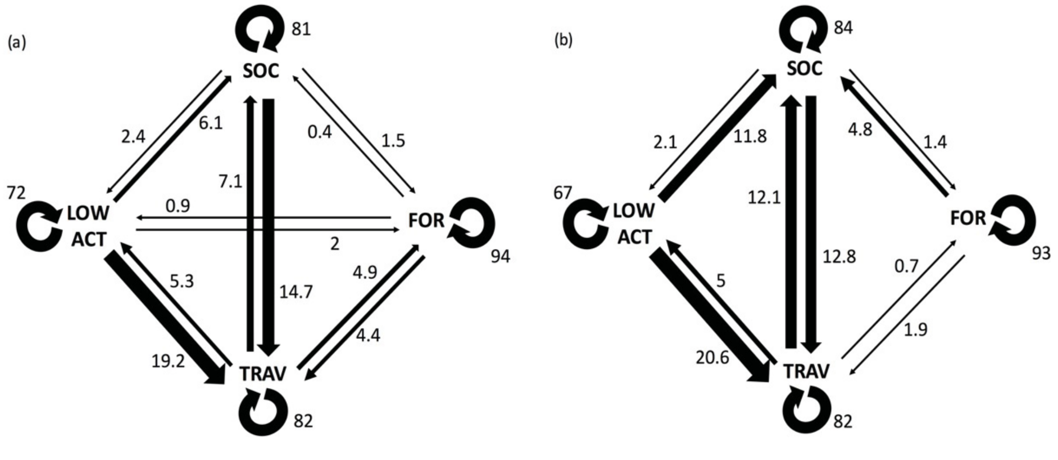


Figure 3.6 Transition probabilities calculated for both control (a) and interaction (b) scenarios. Thicker arrows refer to transition with higher probabilities. Values are percentages (from Cecchetti et al. 2017).

When comparing activity budgets in control and interaction situations (Figure 3.8), socializing and foraging differed significantly, with dolphins engaging more in socializing (39% *versus* 17%, Z=6.822, p<0.001) and less in foraging (12.4% *versus* 38%, Z=3.78, p<0.001) when boats were present. In the presence of tour boats, low activity state decreased (9.6% to 8.6%) whereas travelling increased (35% to 39%).

When calculating the time to resume a preceding activity, control and interaction scenarios differed once again. Foraging dolphins took 10.8min longer to return to their initial state when interacting with tour boats. Similarly, dolphins engaged in low activity took 2.2min longer, whereas socializing dolphins took less time (6.5min shorter) to return to their initial activity (Table 3.1).

During interaction with tour boats the average bout length increased 13% for socializing groups (V=1658.5, p<0.0001), but decreased 15% for foraging (V=2994.5 p<0.0001) and low activity groups (V=1420, p<0.0001), and by 3.1% for travelling dolphins (V=4945.5, p<0.0001)(Table 3.2).

The interaction time analysis suggests a potential cumulative impact when socializing and foraging dolphins interact with tour boats 44% and 48%, respectively, of the time (Figure 3.9). During the study period, dolphin groups were observed spending only 10.5% of their time interacting with tour boats.

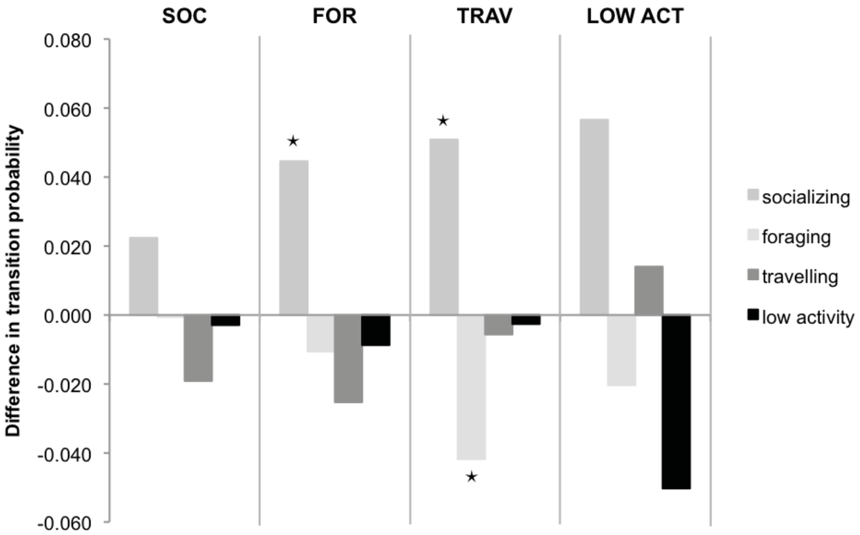


Figure 3.7 Effects of boat interactions on activity state transitions, based on differences in transition probabilities. The graph is divided into four parts delimited by vertical lines and representing a preceding activity state. Bars indicate succeeding activity states. Those marked by ★ are significantly different. Negative values indicate that the transition of the control chain is superior to that of the interaction chain (from Cecchetti et al. 2017).

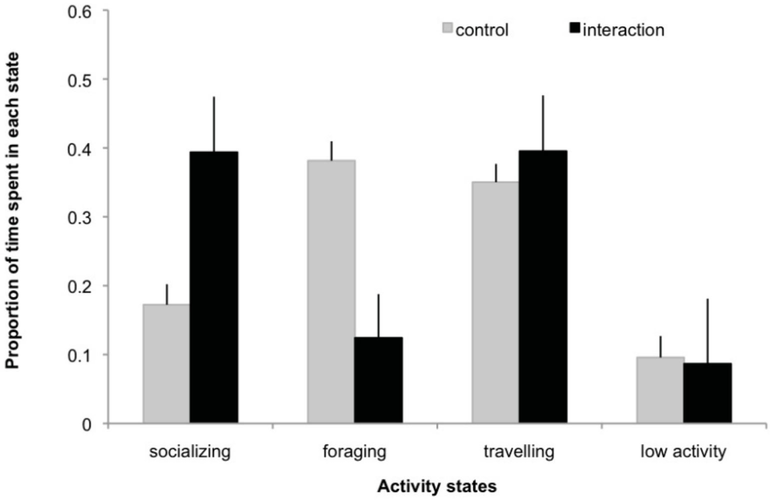


Figure 3.8 Time dolphins spent in each activity state during control and interaction scenarios. Error bars represent 95% confidence intervals (from Cecchetti et al. 2017).

Table 3.1 Probabilities of staying in a particular activity state (π_j), relative average number of time units $E(T)_j$ taken to return to an activity state after boat approached and time needed to return to that activity state. Control/Interaction values are reported

Activity state	π_j	**E(T$_j$)**	**Resumed time activity state**
Socializing	0.172 / 0.393	5.8 / 2.53	11.6 / 5.079
Foraging	0.381 / 0.124	2.62 / 8.04	5.24 / 16.08
Travelling	0.350 / 0.395	2.85 / 2.52	5.7 / 5.05
Low activity	0.095 / 0.086	10.4 / 11.5	20.87 / 23.08

Table 3.2 Average bout length t_{ii} *(minutes) for each activity state in both control and interaction scenarios (from Cecchetti et al. 2017).*

Activity state	t_{ii}	
	Control	**Interaction**
Socializing	5.39	6.13
Foraging	17.6	14.8
Travelling	5.76	5.58
Low activity	3.66	3.09

3.2.3 Compliance with whale watching guidelines

Overall, whale watching tour boats complied with guidelines for approaching and manoeuvring around dolphins (compliance observed on 90.4% of 197 occasions). Breaches of guidelines occurred when boats approached the group either transversally, to the front, or moved in the middle of the pod, or exceeded the dolphins' speed when close to the group. Moreover, in 27% (N=18) of cases, encounters exceeded the established maximum time limit of 30min, with encounters lasting between 2 and 53min (mean=22.67; SD= 14.97; median=19).

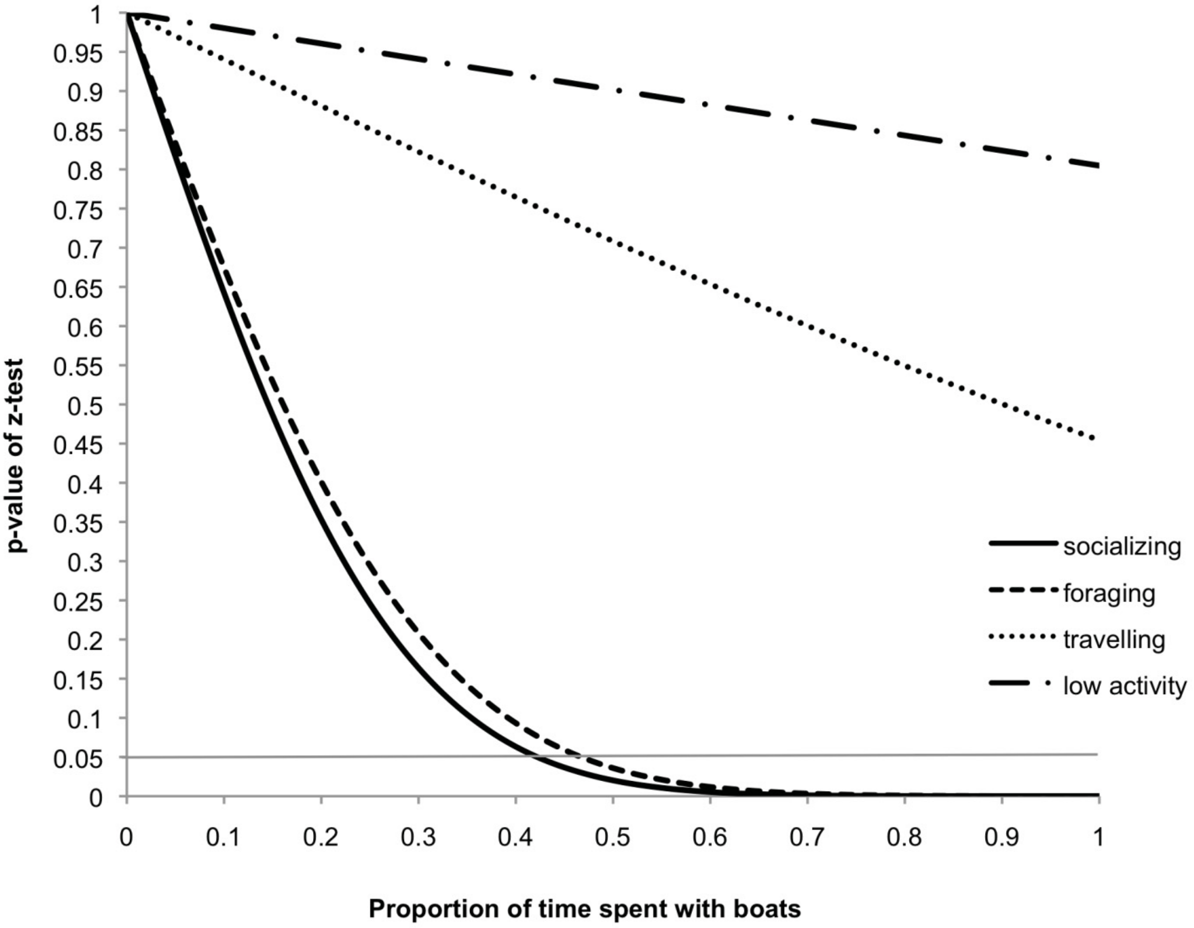


Figure 3.9 Effects of tour boat traffic intensity on common dolphin activity budget. Z-test p-values of the difference between cumulative and control budgets. The grey horizontal line indicates the level of significance set at $p<0.05$ (from Cecchetti et al. 2017).

3.3 Swim-with-dolphins operations and dolphins' response

3.3.1 Target species and approach techniques

Data were collected on 135 trips run over 104 days between 2013 and 2015. A total of 225 independent group encounters was recorded. Only one trip resulted in no dolphin encounters. Common dolphins (Dd) were approached on 110 occasions, bottlenose dolphins (Tt) on 62 and spotted dolphins (Sf) on 34. Risso's dolphins were approached only three times. Mixed species groups of common with spotted or bottlenose dolphins were also approached (12 and four times, respectively). No statistical analysis was carried out using data from mixed groups or for Risso's dolphins because of the small sample sizes.

The frequency of approaches to groups of different species was not significantly different from their group sighting frequency in the overall whale-watching trips, as recorded in the larger MONICET database (N swim-with dataset=206, N whale watching dataset=1265; Dd: X^2=0.0861, df=1, p=0.769; Tt: X^2=0.3125, df=1, p=0.576; Sf: X^2=1.1108, df=1, p=0.291). Operators selected smaller groups for swim attempts: the median group size of approached dolphin groups was significantly smaller than that recorded in the whale watching database. Calves and newborns were present in the majority of the swim attempts (Table 3.3).

Table 3.3 Differences between group sizes of dolphins approached for swim operation (SWD) and those recorded during regular whale watching (WW). Group size is given as median (1st interquartile, 3rd interquartile). Percentage of calves and newborns observed during swim operations are reported for each species. Dd = D. delphis, *Tt =* T. truncatus, *Sf =* S. frontalis.

		Group size			
	% calves	**SWD**	**WW**	***U***	***p***
Dd	72	17.5 (10-30) n= 110	30 (15-50) n= 658	41528.5	<0.001
Tt	52	15 (10-25) n= 62	20 (10-40) n= 355	12941	0.012
Sf	79	30 (17-46) n= 34	50 (30-80) n= 252	5257.5	<0.01

Only in 1% of cases did the dolphins approach the boat. Five different approach techniques were generally used by the skippers to approach and release the swimmers (Figure 3.10). The *in path* strategy was the most frequently used (50%, N=1367): the boat would move parallel to the group at first, then accelerate in order to pass ahead of it and quickly position itself transversal to their track. The second most frequent (35%, N=1367) type of approach was the boat moving and stopping *parallel* to the group of dolphins. During 9% (N=1367) of approaches, the boat would pass through the group and stop *in the middle* of it. Other less frequent strategies used were approaching and placing the boat *to the front* of the group (4%, N=1367) or *to the rear* (1%, N=1367). In less than 1% (N=1367) of cases the boat remained *stationary* near the dolphins long enough to allow a second swim turn. Swimmers entered the water mostly to the front (50.7%, N=1355), parallel (35.2%, N=1355) or in the middle (11.22%, N=1355) of the group. In a few cases they were placed behind the group (1.4%, N=1355) or were particularly far from it, which meant they had to swim to get to the group (1.4%, N=1355).

The use of approach strategy varied between species. The *in path* was mostly used to approach bottlenose dolphins (43%, N=683), whereas both the *in the middle* (65%, N=129) and *parallel* (61%, N=472) strategies were used mostly to approach common dolphins. Spotted dolphins were approached with equal percentages of all techniques. Approach strategies varied significantly as a function of group size for common and spotted dolphins (Dd: *KW*=20.162, df=2, p<0.001, Sf: *KW*=14.0502, df=2, p<0.001). A post-hoc Dunn's test showed that for these two species, the *in the middle* approach was used significantly more frequently with the larger groups (p<0.01, Figure 3.11).

3.3.2 Compliance with regulations

Compliance with current and proposed regulations is reported in Table 3.4. The median number of swimmers entering the water during each swimming episode was two, which is the number established by the current regulation. However, in 23% of the episodes, three or more (up to seven) swimmers were in the water concurrently. Mean duration of swim episodes was 2min, regardless of the species. This includes the time required to place the swimmers in the water and return them to the boat. Regulations stipulate a maximum of three swim attempts per dolphin group, but the median number observed was 6, and 67% of the groups were approached 10 or more (up to 23) times. Only 12 swim attempts (N=1367) were not followed by the release of swimmers in the water.

The new regulations under discussion propose that at the first sign of disturbance, swimmers should return to the boat and no further swim attempts should be made. I considered avoidance reactions as a sign of disturbance, and found that only 29% of the encounters followed this rule. Compliance with respect to the number and activity of the boats interacting with the dolphin groups could not be investigated as information was not available for all samples.

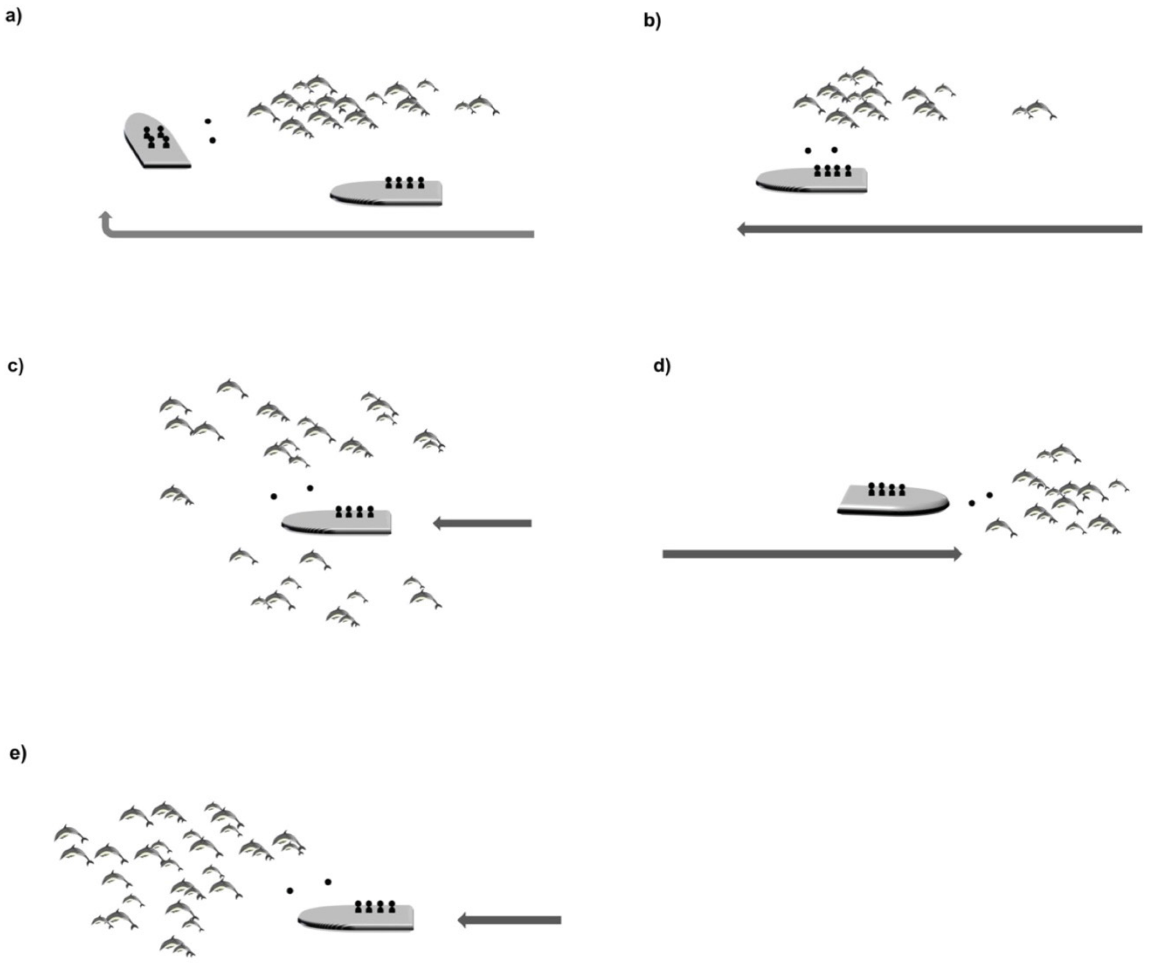


Figure 3.10 Boat placement strategies used to approach dolphin groups in the Azores: a) in path, b) parallel, c) in the middle, d) to the front, e) to the rear.

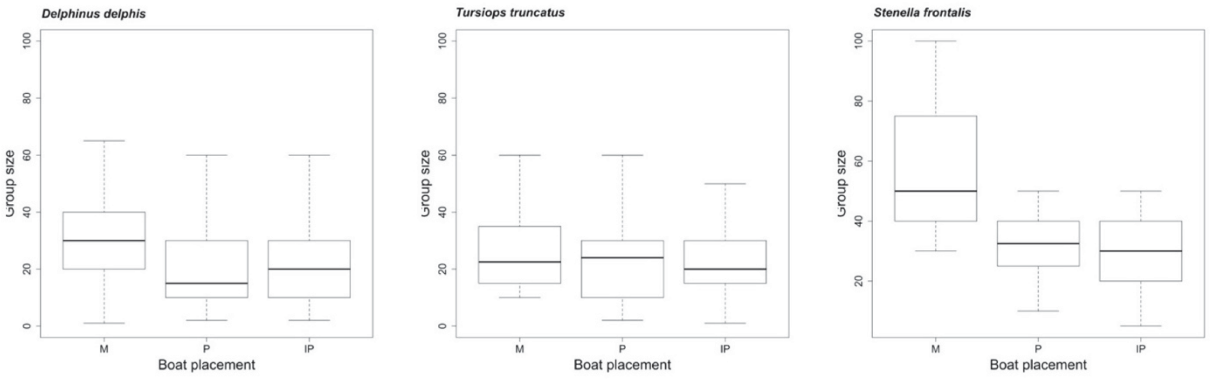


Figure 3.11 The three most frequent boat placement strategies as a function of dolphins group size for each species. M= in the middle, P= parallel, IP= in path. Horizontal lines are medians, vertical lines are the range of values, and boxes are the interquartile ranges.

Table 3.4 Compliance with current and proposed (*) guidelines during swim-with-dolphins operations between 2013 and 2015 off São Miguel Island, Azores.

Rule	Set Value	Median	Maximum	Compliance
Nr swimmers in the water	2	2	7	77%
Nr swim attempts with one group	3	6	23	33%
Duration of swim episode	15	2	15	100%
Stop interaction on avoidance*	-	-	-	29%

3.3.3 Effects of swim-with-dolphins operations

The overall dolphin response of the three species to the swimmers was either avoidance (50%, N=1354) or neutral (48%). Only in 3% of cases did the dolphins approach the swimmers. Atlantic spotted dolphins showed a high degree of avoidance (52%), but also the highest percentage of approach (10%, Figure 3.12a).

The GEE model for multinomial responses showed three variables significantly related to dolphin response: species, behavioural state and boat placement (Table 3.5). In particular, a neutral response to an approach was more likely for *Tursiops* than for *Delphinus* (Figure 3.12a). Groups of resting dolphins were less likely to respond in a neutral way than socializing groups were (Figure 3.12b). Avoidance responses were more likely when the boat intersected the dolphins' path than when it stopped in the middle (Figure 3.12c).

Table 3.5 GEE model for multinomial responses with time exchangeability correlation structure (time.exch). N = neutral, Av = Avoidance. Approach was taken as reference for the response variable. References for the explanatory variables are Dd *for species,* in the middle *for boat placement and* socializing *for behavioural state.*

Parameters	**Coefficient estimate**	**Standard error**	**z**	***p***
beta01	3.2087	0.6839	4.69	<0.001 ***
Species				
Sf: N	-1.0202	0.9001	-1.13	0.257
Tt: N	1.4949	0.7530	1.99	0.047 *
Boat placement				
Parallel: N	0.3651	0.5589	0.65	0.514
In path: N	1.3924	0.7759	1.79	0.073
Behavioural state				
Foraging: N	0.0237	1.0432	0.02	0.982
Travelling: N	-0.8044	0.8764	-0.92	0.359
Resting: N	-1.1568	0.5349	-2.16	0.031 *
beta02	2.8709	0.6550	4.38	<0.001 ***
Species				
Sf: Av	-0.6729	0.8936	-0.75	0.451
Tt: Av	1.2178	0.7551	1.61	0.107
Boat placement				
Parallel: Av	0.2643	0.5031	0.53	0.599
In path: Av	1.5136	0.7262	2.08	0.037 *
Behavioural state				
Foraging: Av	-0.3205	1.0011	-0.32	0.749
Travelling: Av	-0.1126	0.8520	-0.13	0.895
Resting: Av	-0.8512	0.5323	-1.60	0.110

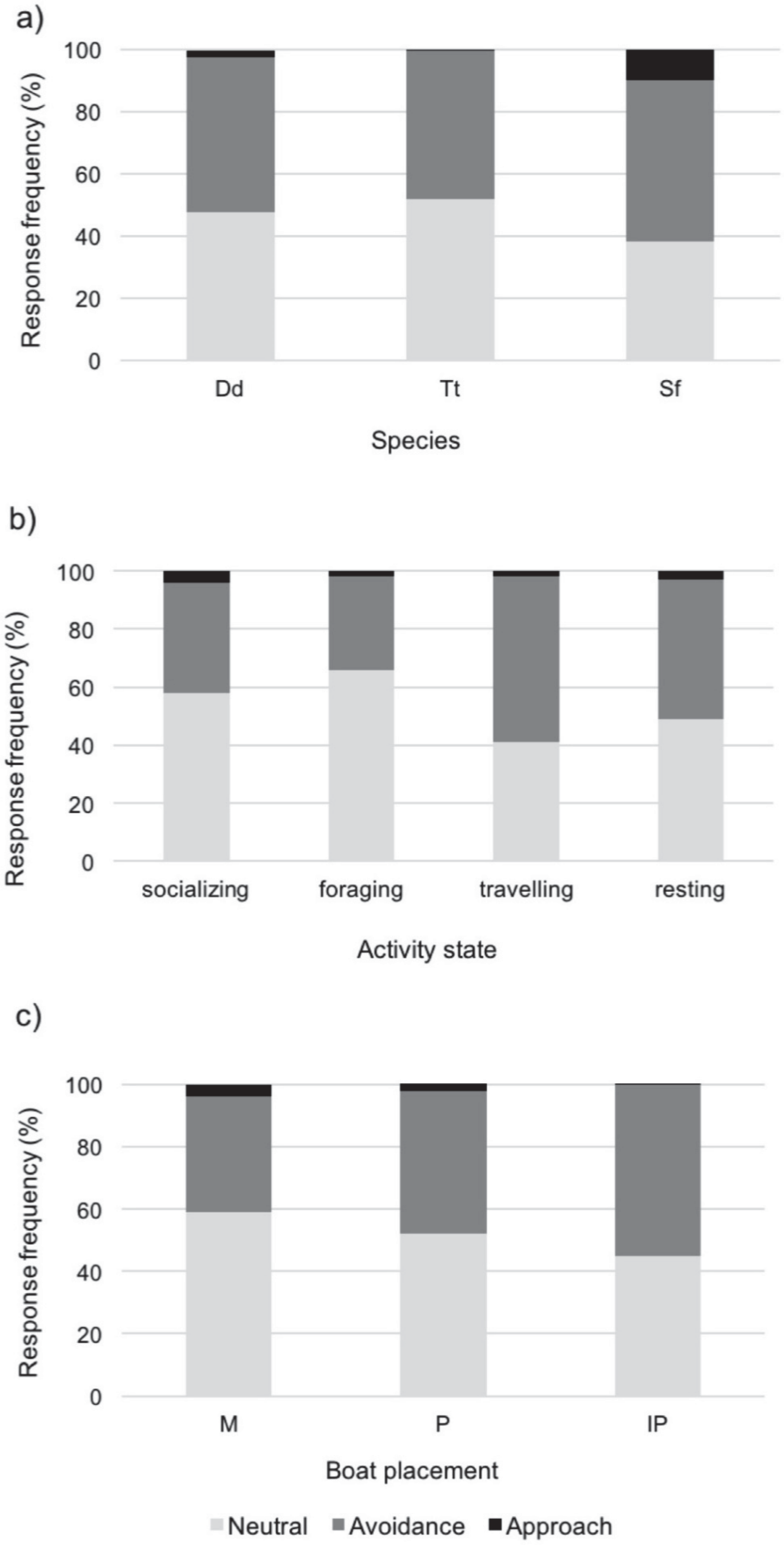


Figure 3.12 Dolphins response during swim-with dolphins operations in relation to species (a), behavioural state (b) and boat placement (c). Dd = Delphinus delphis, Tt = Tursiops truncatus, Sf = Stenella frontalis; M = in the middle, P = parallel, IP = in path.

Three of the five explanatory variables had significant effects on the duration of the swim episodes: group size, behavioural state and boat approach technique (Table 3.6). Swim episode duration tended to increase with larger groups (Figure 3.13a). When the boat was placed in the path of the group of dolphins the duration of the swims was shorter than when it was placed in the middle (Figure 3.13b). Foraging groups also resulted in longer swim episodes than travelling or resting dolphins (Figure 3.13c).

Table 3.6 GEE model with exchangeable correlation structure. References for the explanatory variables are socializing *for behavioural state and* in the middle *for boat placement*

Parameter	**Cofficient estimate**	**Standard error**	**Wald**	***P***
Intercept	2.54014	0.19277	173.63	< 0.001***
Group size	0.00454	0.00181	6.30	0.0121 *
Behavioural state				
Foraging	0.47078	0.22641	4.32	0.0376 *
Travelling	-0.42777	19.12	0.09783	<0.001***
Resting	-0.37697	0.12528	9.05	0.0026 **
Boat placement				
Parallel	-0.26337	0.15115	3.04	0.0814
In path	-0.44053	0.16163	7.43	0.0064 **

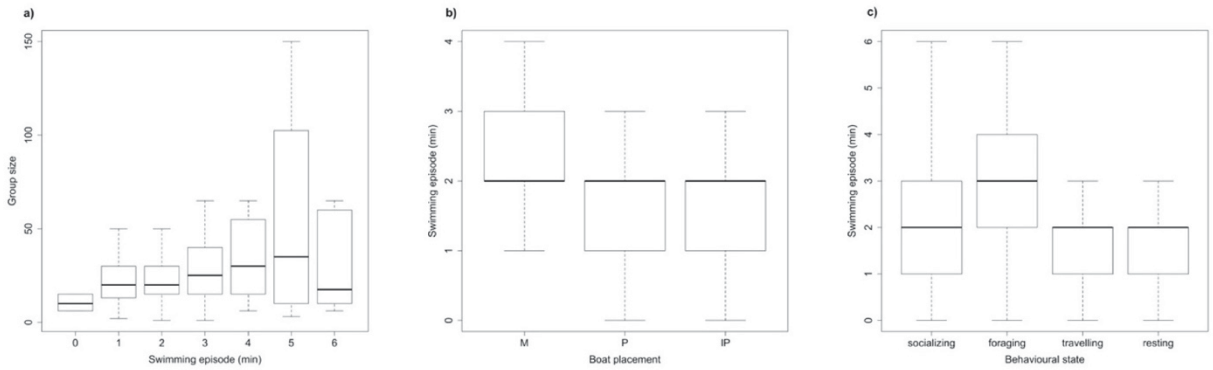


Figure 3.13 Swim episodes' duration in relation to group size (a), boat placement (b) and behavioural state (c). M = in the middle, P = parallel, IP = in path. Horizontal lines are medians, vertical lines are the range of values and boxes are the interquartile ranges.

4. DISCUSSION

Juvenile Atlantic spotted dolphin leaping off Vila Franca do Campo, Azores

4. DISCUSSION

The main aim of this study was to assess the effects of tourism on the behavioural patterns of dolphin populations off the Azores so as to provide baseline knowledge about both dolphin behaviour and the anthropogenic impact on such behaviour. Here, I discuss in detail each objective.

4.1 Baseline behavioural patterns of common dolphins

4.1.1 Distance from shore

Common dolphins in the Azores were found closer to shore during April and September than in other months. Seasonal movements of this species have been associated with prey distribution, particularly fish, the most important diet item (Brophy et al. 2009). In South Africa the migration of pilchards (*Sardinops ocellatus,* Pappe 1854) seems to play a fundamental role in dolphins' distribution. Pilchards represent an important food resource in this area, especially for pregnant females with high energy requirements (Cockroft & Peddemors 1990). Similarly, common dolphins in New Zealand were reported to occur more inshore in winter and spring time and further offshore during summer and autumn (Neumann 2001b, Neumann & Orams 2005, Dwyer et al. 2016). In this case, the authors suggested a correlation with sea surface temperature, which affected prey distribution. In the coastal areas of the Azores, common dophins are known to feed on blue jack mackerel, *Trachurus picturatus*, Bowdich 1825 (Clua & Grosvalet 2001). However, horizontal seasonal movements of the blue jack mackerel around the Azores are currently unknown. Moreover, the area surveyed from land was relatively small and other distribution patterns may occur at a larger scale throughout the day or over a season. Further investigation with respect to both common dolphin and prey distribution would allow a better understanding of dolphin seasonal occurrence in the waters off São Miguel and, ideally, would clarify potential distance patterns from shore.

4.1.2 Activity budget

Dolphins in the present study spent most of their time travelling, followed by foraging. Travelling can be associated to prey search on a larger scale, when groups engage in searching for suitable but dispersed patches for foraging (Benoit-Bird & Au 2009, Spitz et al. 2012). Food availability and distribution are considered the most important factors determining an animal's activity budget (Bertolino et al. 2004, Hanya 2004, Filby et al. 2013), with other activities undertaken only after metabolic energy has been guaranteed (Doenier et al. 1997, Neumann 2001a). Large-scale movements, however, entail correspondently high energetic costs, and are therefore expected to be undertaken only when important.

In the Gulf of St. Vincent, Australia, the time allocation to these activity states was the inverse, with common dolphins engaging predominantly in foraging and less in travelling (Filby et al. 2013). These authors suggested that the higher percentage of time allocated to foraging was likely due to the favourable conditions of the area, which present high prey availability. A similar situation was also reported for common dolphins (*Delphinus* spp.) in Santa Monica Bay, California (Bearzi 2003) and in the Hauraki Gulf, New Zealand (Stockin et al. 2009). In all cases, the populations examined were observed within enclosed areas, whereas the habitat of the present study is open ocean. In this respect, Gowans and colleagues (2007) hypothesized that where resources are spatially and temporally predictable, dolphins occupy relatively small areas, whereas in more open unstructured environments and where resources are spatially and temporally unpredictable, dolphins tend to travel more, forming larger groups that facilitate cooperative foraging and defence strategies.

The hypothesis that the activity budget of common dolphins in the Azores is influenced by the spatial and temporal dynamics of their prey (e.g. Benoit-Bird & Au 2003) is corroborated by the observation that, in 2013, dolphins were observed mainly engaged in foraging, whereas in 2014 they were mostly travelling. Common dolphins may feed on a variety of species (Ohizumi et al. 1998, Silva 1999, Doksæter et al. 2008, Meynier 2008a) although high-quality species are preferred to compensate for high metabolic costs (Spitz et al. 2010, 2012). The diet of common dolphins has been reported to vary between seasons and years depending on prey availability (Meynier et al. 2008b). Such variability may also reflect the type of foraging dolphins engage in. For example, in 2013 most feeding occurred close to the surface, as evidenced by the association with flocks of seabirds, especially Cory's shearwaters (*Calonectris borealis,* Cory 1881) (Clua & Grosvalet 2001). On the contrary, in 2014 the association of seabirds with foraging dolphins was less frequent. In such cases dolphins may have been feeding at greater depth, possibly targeting different prey like mesopelagic fish (Doksæter et al. 2008).

The larger group sizes observed in 2013 are also consistent with a possible variation in prey availability between the two years (Johnson et al. 2002). Higher availability of pelagic fishes in 2013 could have led to the larger gatherings observed, which occurred also in association with other species (mainly Atlantic spotted dolphins). As the availability of food resources influences foraging competition, multi-species associations cooperating in herding schooling fish are an indirect cue on the abundance and accessibility of resources (Gowans et al. 2007). The comparative difficulty of finding food in 2014 could have influenced the formation of smaller groups.

Temporal variability of the activity budget was also noted at the lower scales of month and day. Dolphins were most likely to engage in socializing in April-May. Reproduction in temperate populations of common dolphins is seasonal, peaking between spring and summer, as opposed to tropical waters where no seasonality exists (Westgate & Read 2007, Murphy et al. 2005, Danil & Chivers 2007). This timing would allow calving during the more favourable sea conditions. An early summer period allocated to foraging and taking care of young could explain the decrease of low activity behaviour in June and July. Low activity behaviour was higher at midday, suggesting recovery from the higher energetic activity of foraging in the early morning. Similarly, Filby and colleagues (2013) reported an increase of resting in the early morning for common dolphins in the Gulf of St. Vincent, which they suggested was a likely consequence of nocturnal foraging bouts.

4.1.3 Group size

A clear difference in group size was observed between the activity states. The largest groups and the highest variability in group size was associated with foraging, reflecting the higher behavioural flexibility and plasticity of dolphins when engaged in this activity (Stockin et al. 2009). Conversely, dolphins engaged in low activity behaviour were found in the smallest groups, which is consistent with observations for resting and milling common dolphins in New Zealand (Stockin et al. 2009) and resting dusky dolphins (*Lagenorhynchus obscurus,* Gray 1828) in Argentina (Degrati et al. 2008).

Overall, dolphin groups were larger during the summer months, for all activity states. These results suggest that independent from the frequency of each activity during these months, dolphins gather in larger groups, possibly as consequence of the higher number of calves and newborns (Bearzi et al. 1997, Schaffar-Delaney 2004, Azevedo et al. 2005, de la Brosse 2010). Little is known about the social structure of common dolphins, and contrasting findings give rise to further perplexity. Genetic studies from stranded common dolphins in the North Atlantic suggest little evidence for relatedness within a group, with possible dispersal of juveniles of both sexes from the natal unit and consequent formation of non-breeding groups (Mirimin 2007, Viricel et al. 2008). Thus, their social structure may be characterized by a high degree of fission-fusion dynamics, leading to temporal associations based on the activity they are engaged in, and on the availability and distribution of their prey (Aureli et al. 2008, 2012). However, another study focusing on southern Australian free-ranging common dolphins found that genetic relatedness of male individuals was greater within than between groups of dolphins, and that maternal kinship could play a role in shaping their social structure (Zanardo et al. 2016).

4.1.4 Active surface behaviour

Results of surface-active events are consistent within the definition of behavioural categories observed. As surface behaviours imply high energy costs, dolphins engaged in low activity were consistently less likely to breach, porpoise or head slap. Conversely, dolphins were often observed breaching during socializing as this behaviour is regarded as linked to mating (Shane et al. 1986, Weinrich et al. 2001). However, breaches were also observed during surface feeding when it occurred in large groups, which involve cooperative behaviour. Likely they represent part of a complex communication repertoire that is useful in cooperative feeding strategies (Würsig & Würsig 1980, Gallo-Reynoso 1991). The same behaviour can be adopted within different contexts, which in turn would help to understanding its function (Lusseau 2006a). When travelling, dolphins were less likely to breach. In this case, dolphins are moving in a specific direction so a breach could act as an interruption. Breaching while in transit can be observed if dolphins are engaged in a mixed activity, namely socializing/travelling (Bearzi et al. 1999). On the contrary, porpoising was more often observed during travelling and foraging, as in this case the aim of such aerial behaviour is to enhance the forward movement (Weihs 2002, Gallo-Reynoso 1991). Head slaps were also mostly observed during travelling and foraging, and could be used as cues to direct the group in one specific direction, maintaining cohesion and facilitating the movements.

4.2 Effects of tour boats on common dolphins' behaviour

The behavioural patterns of common dolphins off São Miguel Island, Azores, were found to be affected by the presence of tour boats interacting with them: dolphins spent less time foraging and more time socializing, and took longer to resume foraging after a tour boat interaction.

Feeding is biologically important, and any disruption occurring in the process of acquiring metabolic energy may pose a risk to the wellbeing - even the survival - of individuals, leading to possible consequences at population level (Christiansen et al. 2011, Christiansen et al. 2013a). A reduction in time spent foraging implies a possible reduction in feeding rate, although it is not always possible to confirm the success of foraging bouts to account for such relation. Furthermore, oceanic delphinids are often reported to feed mostly at dusk and during the early hours of the morning (Neumann 2001a, Ringelstein et al. 2006, Pusineri et al. 2007, 2008), which is when whale watching activities do not occur. Disruption of foraging during daylight hours might therefore have a limited impact on the total daily foraging budget. Within this study, dolphins foraging during daylight hours were often associated with diving Cory's shearwaters, a sign that feeding was occurring (Martin 1986). Moreover, the presence of bait-balls was often observed and reported by whale watch operators during their encounters with foraging common dolphins. Hence, although information about common dolphins feeding at night off São Miguel is presently missing, foraging bouts during daylight hours offer a good indication of feeding, similar to those reported in the Hauraki Gulf, New Zealand (Stockin et al. 2009). Common dolphins are likely to have high metabolic costs due to their small size and active swimming habits (Spitz et al. 2010). Furthermore, food availability in oceanic habitats is typically patchily distributed, implying the need for considerable searching movements to locate the best resources (Benoit-Bird & Au 2003). Common dolphins, like other small delphinids, reportedly use costly foraging techniques involving highly coordinated movements in order to gather bait-balls and enhance the feeding success (Gallo-Reynoso 1991, Neumann & Orams 2003, Benoit-Bird & Au 2009, Vaughn et al. 2010). These movements are dependent on acoustic and visual detection of their prey (Gallo-Reynoso 1991). The presence of manoeuvring boats nearby could hinder such foraging techniques (Guerra et al. 2014, Pirotta et al. 2015).

Other studies have shown the potential for foraging disruption by tour boats in a number of cetacean species (Williams et al. 2006, Dans et al. 2012, Steckenreuter et al. 2012). For instance, foraging common dolphins in New Zealand were reportedly affected by commercial tourism boats: reducing time spent in this activity and delaying their feeding bouts (Stockin et al. 2008a, Meissner et al. 2015). Given the high site fidelity of the dolphin population in the

Hauraki Gulf, these short-term effects could well lead to longer-term effects, a major concern for this particular population (Stockin et al. 2008a, Hupman 2016). Conversely, common dolphins in Bay of Plenty were reported to have lower site fidelity. However, their coastal occurrence during the summer breeding period, matching the peak of tourism activity, is a case for concern (Meissner et al. 2015). Common dolphins in the Azores are observed year-round, and no information is available about their site fidelity. However, the regular presence of calves during summer months is reason for concern, as this is also the time tourism activities are more intense.

Transitions from foraging to socializing and from travelling to socializing were observed to increase when common dolphins were visited by tour boats. Socializing behaviour facilitates the access to, and maintenance of, resources. This enables better cooperation during group foraging, increases protection from predators and enhances reproductive success (Silk 2007, Schülke et al. 2010). Thus, it is important for the survival of individuals and the health of populations. Socializing involves a variety of behaviours and includes play and copulation. The limitation in being able to distinguish among functions makes the results more difficult to interpret, especially given the likelihood that socializing in the presence of boats *versus* control scenarios could have been qualitatively different. Socializing dolphins often engage in aerial behaviours, which may function as a means of communication. The presence of tour boats interacting with dolphins may trigger an increase in their surface-active behaviour, a possible strategy to improve communication and to counteract disorientation and noise perturbation (Lusseau 2006b, Noren et al. 2009). From a metabolic perspective, these findings are open to two possible interpretations: dolphins cannot have been seriously affected by the presence of tour boats because they still engage in high energy expenditure activities such as socializing, or the impact is serious because dolphins are shown to increase their energy costs by engaging more in socializing while not gaining energy as a consequence of foraging disruption. However, as reported by Holmes and colleagues (2005) stress levels do not always result in explicit effects as these may be delayed. Therefore, interpreting immediate reactions classified as either “positive” or “negative” would not be straightforward. As mentioned in the Introduction, an example is given by bow-riding behaviour, which is often considered as a “positive” reaction since it implies attraction rather than evasion. However, if dolphins are engaged in a particular activity, the fact that they stop it to bow-ride may result in a reduction of the time used for the initial activity. On the other hand, a reaction considered negative may not necessarily lead to long-term effects if it lacks biological significance (Blumstein & Fernández-Juricic 2010).

Effects of non-consumptive activities, such as cetacean tourism, have been regarded as cumulative rather than catastrophic (Bejder et al. 1999). In the present study the cumulative effects on foraging and socializing dolphins were predicted to occur above 48% and 44% of tour boat exposure, respectively. Common dolphins in São Miguel spent about 10% of their daytime interacting with tour boats. Given that this is below the calculated threshold and also low compared with other populations (e.g. 28.9% in Hauraki Gulf, New Zealand, Stockin et al. 2008a, 21% Bay of Plenty, New Zealand, Meissner et al. 2015), this proportion of time could potentially allow for recovery between interactions (Christiansen & Lusseau 2014). However, it should be noticed that the study area is only a small portion of the coast of São Miguel used by tour boats, which may indicate that dolphins daytime exposure to tour boats may be higher, at least between April-October, i.e. during the peak of whale watching operations. It is difficult to estimate the potential for cumulative effects without site fidelity and population size data of common dolphins in the Azores.

Generally, within the sequences recorded, tour operators complied well with the guidelines, but were sometimes seen breaching the approach or time limit regulation. During the majority of the encounters only one boat at the time approached the dolphins, although as many as three boats were also recorded near a dolphin group, three being the maximum limit set by the guidelines. When guidelines were violated, no additional change in dolphin activity state was recorded. Further monitoring, possibly including a larger area, would provide a larger interaction sample size allowing for more detailed insights. In a study relying on a larger dataset, Bentz et al. (2015), found that in the Azores the limit of 3 boats was exceeded in over 20% of cetacean encounters. Future studies could also use other proxies for disturbance such as direction patterns and breathing rates (Hastie et al. 2003, Lusseau 2006b) to better understand dolphin-boat interactions.

4.3 Swim-with-dolphins operations and dolphins' response

4.3.1 Species and group selection

Three dolphin species were the most targeted for swim-with-dolphins operations off São Miguel, Azores: the common, the bottlenose and the Atlantic spotted dolphin. That these were also the species most observed in the general activity suggests that the choice of approaching any of them is more likely reflecting their occurrence rather than a specific preference from the tour operators. In particular situations, however, other factors such as the distance from the coast can have priority over species selection. For instance, the regular occurrence of a small group of bottlenose dolphins outside of Ponta Delgada could easily lead companies departing from there to select this species.

Small resident populations targeted by tourism activities may be vulnerable to cumulative impacts (Markowitz 2012), and this could ultimately lead to displacement or even impacts on reproductive rates (Lusseau 2005, Bejder et al. 2006a). Monitoring the impact of swim with dolphins activities should take into consideration that some particular groups of animals may be targeted more intensely than the general population and may require specific management measures to limit cumulative impacts.

4.3.2 Effects of swim-with-dolphins operations

The analysis of dolphin's response to swim-with operations in the Azores revealed a high degree of neutral or avoidance reactions, and a very low approach rate for all three species. Atlantic spotted dolphin had the highest avoidance rates, followed by the common dolphin, while bottlenose dolphins were more frequently neutral in their responses. In a similar study, Constantine & Baker (1997) also noted that common dolphins tended to show more avoidance responses than bottlenose dolphins. Specifically, it was reported that, per encounter, the likelihood of swimnming with bottlenose dolphins was 41% compared with 27% for common dolphins.

Atlantic spotted dolphins tended to have the highest avoidance but also the higher approach rate, suggesting this species is the most variable in terms of responses. This would need to be further investigated, possibly with a larger sample size.

The presence of calves and newborns was not significantly related with dolphins' response towards swimming activities. Nonetheless, the vulnerability of calves in relation to vessels is well documented (Stone & Yoshinaga 2000, Martinez & Stockin 2013, Dwyer et al. 2014) given their naïve nature. National swim-with-dolphins regulations in New Zealand and Australia, for instance, forbid boats to approach groups that include calves (Neumann & Orams 2006). In this respect, it would be useful to further investigate this matter, considering, for instance, the proportion of calves and newborns per group and distinguishing these two age classes.

For all species, the resting behavioural state was associated with fewer neutral responses than socializing and with a tendency for higher avoidance responses. Duration of swim episodes was also reduced when dolphins were resting and travelling than when they were socializing. This is consistent with observations on bottlenose dolphins off Port Phillip, Australia, which also showed a high degree of neutral responses from groups of individuals that were socializing and high avoidance when resting (Filby et al. 2014). As resting is fundamental for proper brain and cellular function (Rechtschaffen & Bergmann 2002, Tartar et al. 2006, Benington & Heller 1995, Inoué et al. 1995), a decrease in resting may affect the physiology and metabolism of an individual.

An example of impact derived from resting disruption has been reported for Hawaiian spinner dolphins, which use in-bay waters with sandy substrates to rest during the day and predominantly travel when outside the bays (Tyne et al. 2015). The presence of snorkelers, scuba divers and kayakers (Danil et al. 2005, Courbis & Timmel 2009) resulted in altered resting patterns among the spinner dolphins (Courbis & Timmel 2009), which are unlikely to be replaced outside the bays where protection is lacking (Tyne et al. 2015). Common dolphins in the Azores have been observed resting and engaging in lower energetic activities during the midday time range. This information would be useful to address this information when making management decisions.

The *in path* strategy generated the greatest percentage of avoidance reactions. It also resulted in the lowest proportion of approaches by the dolphins. Other studies have reported similar results for bottlenose, common and Hector's dolphins (Scarpaci et al. 2003, Martinez et al. 2011, Filby et al. 2014). In the Azores, and in contrast with other areas, this was the approach technique more frequently used by tour operators. This may reflect the fact that in the Azores the legislation does not specify how the operators should approach the dolphin group, unlike guidelines issued in other areas. For instance, in New Zealand and Australia, the parallel approach is mandatory because it was found to be the least disturbing for dolphins (Martinez et al. 2011, Filby et al. 2014). Conversely, in this study, dolphins were less disturbed by the *in the middle* approach, possibly because it was used especially when groups were larger as it occurs when dolphins are feeding close to the surface or socializing. One of the functions of large groups is to increase protection from predators (Inman & Krebs 1987). Thus, because responses to human disturbance have been compared to anti-predator behaviour (Frid & Dill 2002), individuals in large groups would likely react less strongly to the potential threat. Larger groups have in fact been reported to approach swimmers and boats more frequently (Constantine 2001, Neumann & Orams 2006, Peters et al. 2012). Groups of spinner dolphins smaller than 25 individuals were observed avoiding Maku'a Beach, Hawaii, if the number of swimmers was high (Danil et al. 2005), and swimmers in Mercury Bay, New Zealand, had a higher chance of longer interactions with common dolphins when groups were larger than 50 individuals (Neumann & Orams 2006). In the present study, large group size was also related to increased duration of swim episodes, which is in line with the suggestion of lower perceived risk for dolphins when gathered in larger numbers. Nevertheless, an *in the middle* approach still needs to be considered rather invasive if dolphins are gathered in large numbers when foraging. As previously reported, foraging activity may be disrupted by tour boat presence (Cecchetti et al. 2017).

4.3.3 Compliance with regulations

Operators complied fully with the maximum duration of each swim episode expressed in the regulations. In fact, the mean duration of swim episodes was only 2min for all species. However, this result appears to be determined by the avoidance response of dolphins rather than the operator choice. A short interaction time is usual for common dolphins, which have been shown to be one of the least receptive species for swim-with tourism (Neumann & Orams 2006) when compared to dusky (8-9min, Markowitz et al. 2009) and Hector's dolphins (25min, Martinez et al. 2011). However, in the Azores bottlenose and spotted dolphins exhibited similar levels of receptivity to common dolphins. It is noteworthy however, that bottlenose dolphins were the ones most often approached with the most disturbing strategy (*in path*), compared with the other two species. Habituation and sensitisation due to cumulative experience of anthropogenic activity has been reported for some dolphin populations (e.g. Markowitz et al. 2009, Constantine 2001). Whether the bottlenose dolphins occurring out of Ponta Delgada harbour have developed some degree of tolerance is hard to tell at this stage, and further investigation is warranted.

Most of the operators followed the legislation for the number of swimmers simultaneously in the water, but compliance with the number of swim attempts was low (33%). Regulations indicate three as a maximum number of times swimmers can be released into the water per group of dolphins. To try to ensure customer satisfaction, operators likely increase the number of simultaneous swimmers or the number of swimmer releases, when they find a more receptive dolphin group. It would be useful to investigate further the relative impact of the number of swimmers *versus* the number of attempts to approach the group. Neumann & Orams (2006) reported that common dolphin encounters were longer if the number of swimmers did not exceed five. However, Hector's dolphins in Porpoise Bay did not show any avoidance reaction towards swimmers, whereas boats led to initial attraction followed by neutral and eventually avoidance or equivocal behaviours (Bejder et al. 1999). In the Azores, operators usually made a large number of swim attempts, with little account for the reaction of the dolphins, and often not complying with existing and proposed regulations. This likely reflects the low success of interactions and is a way to counteract the short time dolphins stay in the presence of swimmers. In some cases, however, more swim attempts could have resulted from a lower avoidance rate from the dolphins group. Clearly, regulation in this area is premature without a reference to current practices and, ideally, to data on the impact of the different alternatives.

A definition of group must be specified in the issuing legislation, in order to apply the proposed guidelines regarding the number of boats interacting with each group at any moment, and the type of activity they are engaged at. For instance, a group which is dispersed and includes many subgroups could be perceived by the operators as many different groups, hence the need for standardize such definition. Within the dolphin ecology literature there are various definitions for groups. These are based on *distance* between individual, being such distance variable among authors (e.g. 100m rule, Irvine et al. 1981; 5 body-length rule, Smolker et al. 1992; 10m rule, Acevedo-Gutiérrez & Stienessen 2004), on *behavioural state* and on *direction of movement* (Shane 1990). The presence of a qualified on-board naturalist or marine biologist guide may facilitate the evaluation of such circumstances and decrease the potential for misapplication of the law.

5. CONCLUDING REMARKS

Group of bottlenose dolphins with a tour boat in the background

5. CONCLUDING REMARKS

In this section I review the main findings and, based on the knowledge acquired, I provide management recommendations in the context of conservation. The study limitations are also discussed and suggestions for future work are provided.

5.1 Main conclusions

In the Azores, the tourism sector is growing and particular attention is now being paid to whale and dolphin watching activities (Bentz et al. 2015). Swim-with-wild-dolphins, where human-dolphins interactions are more invasive than the mere observation, is also becoming popular and could well expand. The sustainability of these activities requires that they should not have significant negative impacts on the animals targeted, especially on the long-term viability of populations. In order to evaluate impacts, knowledge of the baseline behaviour of the target species is essential. However, in the Azores, as little is known about the behaviour of most dolphin species, filling this gap was considered essential. In addition, a first assessment of the effects of tourism on local dolphin populations was made.

The common dolphin is a wide ranging species (Perrin 2009) and the most frequently sighted dolphin in many areas, including the Azores (Silva et al. 2014). However, only few studies are available concerning its behaviour (e.g. Neumann 2001a and Stockin et al. 2009). To fill this gap, the activity budget of this species and its temporal variation were studied. Common dolphins' activity budget showed inter-annual, monthly and diurnal variations. Dolphins overall engaged primarily in travelling and foraging. Cooperative foraging was mostly observed during the first survey season (2013) where large gatherings were recorded in association with other species, such as Atlantic spotted dolphins and Cory's shearwaters. During the second season (2014), dolphins were mostly travelling, and foraging groups were smaller, suggesting either a lower availability of prey or different prey species leading to different foraging strategies. Dolphins were also mostly engaged in travelling and foraging during summer and autumn whereas socializing predominated in spring. The high proportion of groups including calves and newborns during swim-with operations likely reflects this increase in socializing during spring. Other temperate water populations of common dolphins have their peak calving period in spring and summer when water temperatures are more favourable for the youngest components of the group (Stockin et al. 2009). Diurnal patterns showed a decrease in foraging during midday, coinciding with an increase in low activity. Group size of common dolphins was larger in summer and during foraging, whereas dolphins in the low activity behavioural state were observed in smaller groups as reported in other populations (Stockin et al. 2009). Common dolphins displayed a variety of active surface behaviours including breaches, porpoising and head slaps. All three categories were observed when animals were thought to be foraging, while travelling animals showed porpoising and head slap events. Surface events are likely used as means of non-vocal communication (Gallo-Reynoso 1991), which would be especially advantageous during cooperative foraging and travelling to maintain group cohesiveness. The high variability found in common dolphin behavioural patterns may well reflect patterns in prey availability driven by oceanographic conditions (Santos et al. 2013). These results provide the first baseline information which could be useful for understanding potential responses of this species to environmental changes and anthropogenic disturbances.

In this latter context, common dolphin behaviour was investigated in the presence of tour boats to measure changes in behaviour. Applying Markov chain analysis allowed comparison of behavioural transition probabilities in both control (no tour boats present) and interaction (tour boats present) scenarios. Common dolphins decreased their time spent foraging and increased their time socializing, whereas the time to resume foraging and socializing increased and decreased, respectively, when boats were present. The potential long-term impact of a reduced foraging budget could be reduced energy inputs (Christiansen et al. 2013b). Interpreting the long-term effects of increased socializing is less straightforward. Given that socializing is a costly activity, the potential for increasing energy expenditure is one possibility, although it may also suggest that dolphins were had sufficient energy and therefore were not affected. The current level of exposure of common dolphins to tourism in the Azores seems to be lower than that for populations in New Zealand (Meissner et al. 2015). However, given that the activity budget observed in the present study is primarily composed of travelling and foraging, results indicating a reduction in foraging need further consideration. Common dolphins may respond to changes in environmental parameters and prey distribution in a flexible way, but tourism could still represent a concern especially in the context of impact accumulation (Barr & Slooten 1999). In the present study, the cumulative impact may not be a concern, but could be in the future if the daily exposure to tour boats were to increase.

A more invasive activity such as swim-with-dolphins already demonstrated less flexible responses by the local dolphin populations. All three main species targeted by this activity showed high degree of neutral or avoidance responses. Bottlenose dolphins recorded significantly more neutral responses than common dolphins, while Atlantic spotted dolphins demonstrated highest plasticity. The most disturbing strategy used by the skippers to approach dolphin groups was the *in path* technique. This was also the technique most commonly adopted, especially with bottlenose dolphins. This strategy is forbidden in other countries, such as New Zealand, where similar greater avoidance rate related to this type of approach has been reported (Martinez et al. 2011, Filby et al. 2014). Swim episodes lasted on average 2min for all species, and were shorter when dolphins, irrespective of species, were travelling or resting. The activity budget of common dolphins revealed that they mostly engage in low activity during the midday range (12:30h-14:44h). This suggests that groups approached during the afternoon tours (typically starting at 13:00) may experience higher disturbance. Operators showed low compliance with existing regulations on the number of swim that should be attempted, usually exceeding the maximum of three permitted attempts per dolphin group.

5.2 Management recommendations

In light of the predicted future tourism increase in the Azores, it is highly likely that there will be an intensification of recreational activities with cetaceans. Hence, short-term effects and potential long-term effects need to be addressed by 1) restricting the number of boats approaching individuals or groups, 2) banning the *in path* strategy used within the swim-with-dolphin programs, 3) avoiding swimming with resting groups or groups including newborns. To reduce the crowding effect around animals, and hence to minimize the short-term effects highlighted in this study, the number of boats operating should be reduced by, for instance, adopting larger boats. Reducing the number of vessels manoeuvring around individuals or groups also allows a reduction in underwater noise, a known concern for cetaceans (Pine et al. 2016). Additionally, a moratorium on granting further licenses until further research has shown that this would not be harmful, seems a pragmatic precautionary measure. During swim-with-dolphins operations, intersecting the pathway of dolphin groups to release swimmers in the water should be avoided. Establishing as mandatory the *parallel* approach and permitting the *in the middle* strategy exclusively for very large and dispersed groups, would ensure dolphins have the space, and hence the option, to stay or leave of their own will. Resting groups are more susceptible to disturbance, given that their alertness decreases in this state (Miller et al. 2008). This was reflected in the shorter duration of human-dolphins interactions. Newborns are more vulnerable than any other age class component, given their reduced swimming abilities (Shoele & Zhu 2015). Hence, more invasive approaches such as those used during swim-with-dolphins should be avoided in these cases.

The importance of continuous monitoring and of long-term studies to identify the impacts that may derive from tourist activities cannot be overstated. A continuous effort to monitor cetacean populations in the Azores is therefore recommended, especially with respect to distribution, life history and behaviour. When continuous monitoring is not feasible, research efforts should be performed at least at regular intervals in order to identify trends in population dynamics.

Collaboration with the whale watching companies provides opportunities for long-term monitoring at relatively low cost. The example has been set by the MONICET platform (http://www.monicet.net), which brings together several companies from different islands to collect, store and render accessible information on cetacean distribution and photo-identification. Operating since 2009, the MONICET database can be used for research purposes as it has been shown in this study, and constitutes a recognized management tool as it was the case for the Marine Strategy Framework Directive (Carreira 2016).

The participation of the companies in research is also seen not only as a way to enhance the opportunity to create long-term datasets (e.g. Hupman et al. 2014), but also as a parallel tool to increase environmental awareness. This is especially important for the swim-with-dolphins program, which in contrast to whale watching tours where information is provided to researchers and the public, is merely a commercial activity. The potential benefits attributed to whale watching in providing education and building conservation awareness for the public (Wilson & Tisdell 2003, Zeppel & Muloin 2008) could be enhanced if companies were directly involved in the process of acquiring a better knowledge of the populations they are exploiting as living resources. Moreover, any impact on cetacean populations is a risk to the long-term viability of the business itself.

5.3 Future research

The present project would have benefited from a larger study area, especially for the land-based component. For instance, collecting data from two land stations would have provided a wider picture of the current dolphin-tourism interactions in São Miguel. Tour operators in fact, operate across all the south coast of the Island, with the areas close to the two main departure harbours being more frequently visited. However, limited funds and human resources prevented the setting up of more than one land station. This limitation can be overcome in future research where either a different area could be considered and compared with the present results, or when funding would allow it, more land stations could be set up simultaneously. Interpretation of results could have also benefited if data obtained during swim-with operations could have been complemented with that collected from land. However, due to the "last minute" nature of the activity, whereby lookouts may suddenly change the dolphin group to which they direct the boat, it was not possible to collect pre-activity data for most events. This approach could nevertheless be attempted in future research, where more land stations might be involved and more groups monitored simultaneously to increase the likelihood of being targeted for the swim-with activity.

In the Azores, the network of *vigias* used for detecting animals at sea to direct the tour boats to whales and dolphins could be utilised for research, thus enhancing land-based studies. An example of successful long term study on a Macaronesian island is provided by a 6-year study conducted in the Canary Islands from 2004 to 2010 (Arranz et al. 2013). Here, beaked whales were monitored from shore and their distribution and habitat selection were modelled with respect to environmental variables. The occurrence in Azorean waters of deep-diving species relatively close to shore and of more coastal groups, such as the bottlenose dolphins off Ponta Delgada, should allow ecology and behavioural data to be collected. In addition, information on the interactions with human activities could be collected, as was done in this present study.

In light of the results of this study, future research should focus specifically on detailing seasonal movements and site fidelity patterns of dolphin species in the Azores, with special attention to the three species that are the most targeted within the local tourism industry. Bottlenose and common dolphins are observed all year-round off São Miguel and although their relative abundance does not at present raise concern for their conservation status, common species are nevertheless considered essential for the wellbeing of the ecosystems (Gaston & Fuller 2008). It is mostly the role of a species, rather than its abundance, that characterizes the effects on ecosystem functioning when a decline or loss of that species would occur (Gaston & Fuller 2008, Boyero et al. 2006). Moreover, marine mammals as top predators are often used as indicators of marine-ecosystem dynamics, and the health of their populations is related with the preservation of the health of the whole marine ecosystem (Boyd et al. 2006).

Photo-identification data constitute an effective and low-cost tool to acquire data on population size, population dynamics, social organization, movements and residency patterns. This is essential for understanding the extent tourism is affecting the same groups or different ones over time, leading to diverse conservation implications. Photo-identification data, which are currently available only for bottlenose and Risso's dolphins, could be extended to common and Atlantic spotted dolphins. Although the common dolphin is a poorly marked species, it has been shown that information derived from individually identified common dolphins in Greece and New Zealand generated estimates of abundance and site fidelity (Bearzi et al. 2011, Hupman 2016), useful as baseline knowledge to interpret outcomes from a conservation perspective.

Another step in terms of assessing the effects of tourism activity would be to focus on the acoustic impact. The possibility to get an insight into the acoustic behaviour of cetaceans in São Miguel would provide an extra support in the development of the conservation measures to apply. Cetaceans are highly vocal animals and background noise has been reported to have adverse effects on their behaviour, potentially affecting their reproductive success (Sousa-Lima & Clark 2009). In this context other species besides those investigated in this study could be also targeted. Acoustic studies are particularly appropriate for sperm whales, given their diving patterns and hence the lower time spent at surface. The assessment of the tour boats effects on other species would provide a wider picture of the local tourism impact on cetacean populations. Monitoring of ambient noise and local boat traffic is fundamental to keep track of areas of intense and low operation. Quantifying the noise levels of whale watching vessels and monitoring them across time, for instance, would provide an appreciation of the development of the activities taking place in a specific area. They could also be used to predict level of disturbance and potential impact for targeted species (Erbe 2002). Similarly, boat traffic data could provide a picture of low and high intensity of operations and could be related with population distributions. An accessible way to collect these data would be to provide vessels with GPS loggers, giving detailed tracks of daily operations. During the present study, boats tracks from two companies were experimentally recorded (Introduction, Figure 1.2) providing an idea of the occurrence of the operations in the south coast of São Miguel. Ideally, data should span several years so as to provide information on the development of operations in terms of geographical range. For instance, recently some companies started to visit the north shore of São Miguel although on an irregular basis.

To further improve the current legislation for swim-with-dolphins activities, it is important to get a better evaluation of the effects of the number of boats, of swim attempts and of swimmers to be able to advise on the least disruptive way in which this activity could be conducted. More details on the effects of presence and number of calves would also help in defining the best practices for this activity. Moreover, monitoring compliance with regulation is fundamental in that it would provide indirect information on regulations effectiveness when linked with new impact assessments.

Lastly, the perspective of clients participating in these tourism programs is important. Research should investigate their satisfaction especially in relation to conservation and education aspects.

Recent studies have addressed this social aspect and found that tourists often show interest in the welfare of animals and can become more environmentally committed after experiencing whale watching programmes when they involve a certain level of education (e.g. Andersen & Miller 2006). Such biocentric attitude would provide companies with feedback for improving the quality of their products and indirectly influence their level of compliance (Filby et al. 2015, Bentz et al. 2016) and, ultimately, the overall sustainability of the activities.

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