

Short-term effects of tourism on the behaviour of common dolphins (*Delphinus delphis*) in the Azores

ARIANNA CECCHETTI¹, KAREN A. STOCKIN², JONATHAN GORDON³ AND JOSÉ M.N. AZEVEDO¹

¹Biology Department, cE3c – Centre for Ecology, Evolution and Environmental Changes/Azorean Biodiversity Group, University of the Azores, 9501-801 Ponta Delgada, Azores, Portugal, ²CMRG – Coastal Marine Research Group, Institute of Natural and Mathematical Sciences, Massey University, North Shore Mail Centre, Private Bag 102 904, Auckland, 0745, New Zealand, ³SMRU – Sea Mammal Research Unit, Scottish Ocean Institute, University of St. Andrews, St. Andrews, Fife KY16 8LB, UK

*Short-term measures of behavioural responses of cetaceans to tourism operations have been used in many studies to interpret and understand potential long-term impacts of biological importance. The short-beaked common dolphin (*Delphinus delphis*) is the species most frequently observed in the Azores and constitutes an important component of the marine mammal tourism industry in this region. This study investigated the potential effects of tour boats on the behaviour of common dolphins off São Miguel, Azores, with particular focus on the changes in activity budget and the time required to resume activities after a tour boat interaction. Behavioural data were collected from land using a group focal-follow methodology. Markov chains were applied to analyse control and interaction sequences and to assess behavioural transition probabilities in both scenarios. In the presence of tour boats, dolphins significantly reduced the time spent foraging and increased the time engaged in other high energy activities. Dolphins also took significantly longer to resume feeding after an interaction occurred. The average bout length varied significantly between control and interaction scenarios, with foraging bouts being shorter during tour boats interactions. The results presented have management implications since feeding is a biologically critical activity. Disruption of foraging behaviour could lead to a decrease in energy intake for this population. With cetacean tourism likely to increase in the future, a precautionary approach to issuing new licences is advisable and any expansion would warrant an appropriate monitoring programme.*

Keywords: short-beaked common dolphin, *Delphinus delphis*, whale watching, impact, Markov chains, Azores

Submitted 30 October 2015; accepted 4 April 2017; first published online 25 May 2017

INTRODUCTION

Whale watching has increased significantly since its inception in the late 1950s, with many countries now relying on its economic benefits. In particular, developing countries see this tourism sector as an appealing option (Hoyt, 2001; Wilson & Tisdell, 2002; Cisneros-Montemayor *et al.*, 2010). Another benefit from this activity is its potential educational role in enhancing knowledge and conservation awareness (Jacobs & Harms, 2014; Johnson & McInnis, 2014). However, there are also concerns about the potential impacts of this activity on individual cetaceans and populations, especially where individuals are resident or show high site fidelity with the potential for cumulative daily disturbance by tour boats.

Various studies have been conducted to understand how tourist activities could be detrimental for cetaceans (Lusseau & Bejder, 2007; Stensland & Berggren, 2007; Courbis & Timmel, 2009; May-Collado *et al.*, 2012). Short-term effects from boat exposure have been reported in a number of such studies. Behavioural responses include changes in dive behaviour (Ng & Leung, 2003; Williams *et al.*, 2009; Stamation *et al.*,

2010), path direction (Timmel *et al.*, 2008; Stamation *et al.*, 2010; Christiansen *et al.*, 2011, 2013), swim speed (Williams *et al.*, 2002, 2009; Morete *et al.*, 2008), behavioural state (Stockin *et al.*, 2008a; Arcangeli & Crosti, 2009; Montero-Cordero & Lobo, 2010; Meissner *et al.*, 2015), group cohesiveness (Bejder *et al.*, 2006a; Steckenreuter *et al.*, 2012), surface active behaviours (Morete *et al.*, 2008; Noren *et al.*, 2009; Cammareri & Vermeulen, 2010) and vocalization rate (Markowitz *et al.*, 2011; Pirota *et al.*, 2012; Papale *et al.*, 2015). How and whether these acute behavioural effects are associated with a long-term impact is difficult to establish although it has been suggested that they may lead to a decrease in energy uptake at the individual level. Potentially, this could lead to a decrease in fitness and ultimately changes in population levels (Williams *et al.*, 2006; Lusseau *et al.*, 2009; Parsons, 2012; Christiansen *et al.*, 2015).

The Azores Archipelago is established as a destination for nature tourism with whale watching being one of the primary activities (32.4%) practiced (Queiroz *et al.*, 2014). Whale watching in the Azores began in the early 1990s with one operator on Pico Island and 468 tourists in 1993 (Silva, 2015; Bentz *et al.*, 2015). In 2013, ~59,000 tourists engaged in whale watching and swim-with-dolphin tours (Bentz *et al.*, 2015). The wide variety of species that can be observed in Azorean waters has contributed to this growth. Overall, 28 species have been recorded in the region (Silva *et al.*, 2014).

Corresponding author:

A. Cecchetti

Email: arianna.cecchetti@uac.pt

Some are encountered only occasionally while on migration (Visser *et al.*, 2011a; Silva *et al.*, 2013, 2014), while others are known to occur year-round. However, information on distribution, residency and behavioural patterns of cetaceans in the Azores remains limited (e.g. Hartman *et al.*, 2008; Silva *et al.*, 2014; Hartman *et al.*, 2015).

Short-beaked common dolphins (*Delphinus delphis*, hereafter referred to as common dolphins) are the most frequently observed species in the archipelago. They occur year-round in the waters off all islands (Silva *et al.*, 2003, 2014), and are an important focus for commercial tour activities. However, although frequently encountered, baseline information including local population size, distribution and degree of site fidelity are not known. Occasionally, common dolphins are observed in mixed-species foraging associations, mostly with Atlantic spotted (*Stenella frontalis*) and striped dolphins (*Stenella coeruleoalba*) (Clua & Grosvalet, 2001; Quérouil *et al.*, 2008). Calves are observed year-round (unpublished data, MONICET database), though assumed to peak in spring-summer, as reported in other temperate common dolphin populations (Westgate & Read, 2007; Stockin *et al.*, 2008b). Similar to other small delphinids, *Delphinus* often form large aggregations and occasionally exhibit conspicuous behaviours above water (Ferguson *et al.*, 2006), which aids their detection from land. Furthermore, common dolphins also tend to approach moving boats (Neumann & Orams, 2006), increasing the probability of the same groups experiencing repeated encounters, thus increasing the risk of cumulative impacts (Parsons, 2012; Meissner *et al.*, 2015).

Behavioural effects associated with tourism activities have been best studied in New Zealand. For example, in the Hauraki Gulf, common dolphins were shown to reduce the time spent foraging and resting (Stockin *et al.*, 2008a) when engaged with tour boats. Once disrupted, dolphins also took significantly longer to resume foraging. Similarly, in the Bay of Plenty, dolphins reduced the proportion of time spent foraging (Meissner *et al.*, 2015). A tendency to increase travelling in the presence of boats was further reported for common dolphins in Mercury Bay, although the overall activity budget was not affected. Dolphin group size also had

an effect on response, with smaller groups being more likely to show boat avoidance (Neumann & Orams, 2006). To date in the Azores, only two studies have addressed the effects of the whale watching activities on local cetacean populations (Magalhães *et al.*, 2002; Visser *et al.*, 2011b). Magalhães *et al.* (2002) identified changes in speed and increased aerial displays in sperm whales (*Physeter macrocephalus*) off Pico and Faial Islands when the code of conduct was violated by tour operators. Risso's dolphins (*Grampus griseus*) off Pico spent less of the day resting during the season with highest traffic and rested and socialized less when more than five boats were present (Visser *et al.*, 2011b).

Knowledge of the behaviour and ecology of local populations becomes more important with increasing pressure from tourism on living resources. For this reason, the present study aims to provide first insights on the effects of whale watching on the behaviour of common dolphins off the southern coast of São Miguel, the largest and most developed island in the archipelago. Specifically, the probability that dolphins would change their current behavioural activity in the presence of tour boats was investigated using stochastic Markov chains. In addition, compliance with local whale watching regulations, specifically approach manoeuvres, speed, number of boats and encounter duration was assessed.

MATERIALS AND METHODS

Study area

The study site was located off the southern coast of São Miguel, Azores, delimited by an observation angle of 150° and a radius of ~ 9 km from a lookout point at Ponta Garça, at a height 93 m above sea level. This area covered $\sim 6\%$ of the total sea space used by the six companies operating from two harbours, Ponta Delgada and Vila Franca do Campo (Figure 1). Tour operators conduct daily whale watching and swim-with-dolphins activities throughout the year, with the main season occurring between April and October. Scuba diving and recreational private boats also use the

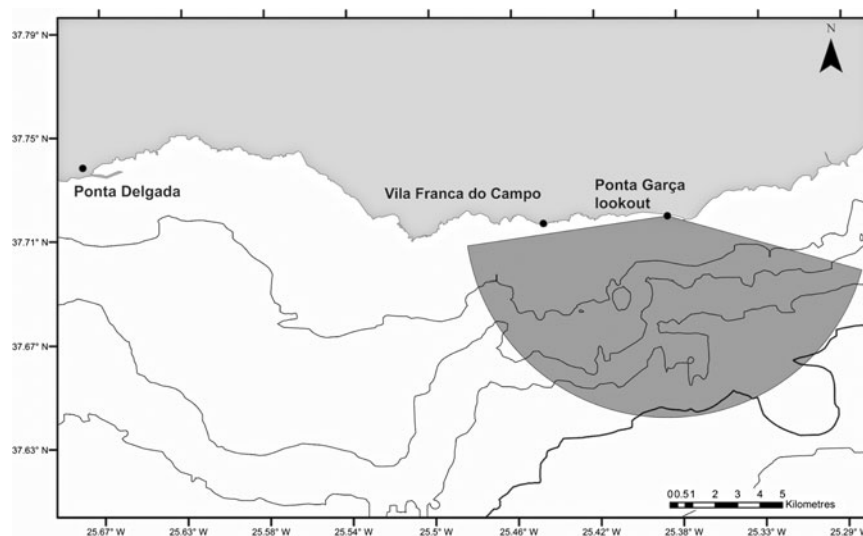


Fig. 1. Study area showing the location of the observation point in Ponta Garça ($37^\circ 42' 50.76''$ N $25^\circ 22' 23.16''$ W) on the south coast of São Miguel Island and the observation site.

area, but tend to stay closer to shore where common dolphins are less frequent.

Field data collection

Data were collected from a land-based station using Steiner 15 × 80 binoculars mounted on a rotating platform. A team of two trained observers undertook dedicated watches between 0800 and 1700 h from July to September 2013 and April to October 2014. Surveys were conducted in ≤3 Beaufort, in good visibility (>10 km) and in the absence of precipitation or fog using focal group follows to sample the predominant group activity (Altmann, 1974; Mann 1999). Common dolphins, like many other small delphinids, tend to form large fluid groups making it impossible to track individuals (Neumann 2001; Stockin *et al.*, 2009). However, the substantial elevation did provide a good vantage point from which to observe the extent of even large focal groups (Martinez, 2010). The subject for the first focal follow of each day was the dolphin group first observed during scan sampling. This a priori rule limited bias due to group size or behaviour. Subsequent encounters were selected based on direction and distance from the original group, to minimize the probability of pseudo-replication.

Based on preliminary behavioural observations, four behavioural categories were identified: foraging, travelling, high surface activity and low surface activity. Behavioural definitions applied were a simplified version of the states described by Neumann (2001) and Stockin *et al.* (2009) (Table 1). Low surface activity included both resting and milling behaviours previously described by Neumann (2001) and Stockin *et al.* (2009), while high surface activity included individuals engaged in behavioural events such as breaching, porpoising and head slapping, which are previously described indicators of social behaviour. These pooled categories were

Table 1. Definition of behavioural categories considered in the present study adapted from Neumann (2001) and Stockin *et al.* (2009).

Activity category	Definition
Foraging	Individuals involved in any effort to pursue, capture and/or consume prey, as defined by observation of fish chasing (<i>herding</i>), coordinated directional movements and prolonged dives. Cohesiveness of the group and heading vary often during foraging/feeding activity. When actual feeding occurs close to the surface it may involve aerial activity and associated seabirds
Travelling	Individuals engaged in persistent, directional movements making noticeable headways along a specific compass heading
High surface activity	High frequency of active surface behaviour (excluding foraging and travelling) which may include breaching, leaping, chasing or body surface contact and involves at least two individuals (mother-calf excluded)
Low surface activity	Slow movement and absence of active surface behaviour. May include slow circling movements and absence of forward propulsion (motionless). Close distance range between individuals and regular surfacing patterns are observed. Recurrent re-direction headings can be observed

used because it was difficult to reliably identify and discriminate between the previously described states at a distance. All behavioural observations of dolphins were performed by the same observer (AC) to avoid inter-individual variability.

The behaviour of a group being followed was allocated to one of the four categories every 2 min. Behaviour was based upon the activity in which >50% of the group was engaged (Stockin *et al.*, 2009). Data were recorded until the focal group was lost from sight or the reliability of data was compromised due to distance or ambiguity of view. Any sampling unit in which either the behaviour or proportion of group engaged was considered ambiguous was omitted from analysis.

Boat manoeuvres during encounters were recorded to allow compliance with the requirements of local whale watching guidelines (Decreto Legislativo Regional 9/99/A, 10/2003/A) to be assessed. For each encounter, the angle of boat approach was classified into three categories (parallel and behind, parallel and ahead and transversal), and the speed of the boat was noted as idle, equal to that of the dolphins or exceeding that of the dolphins.

Data were recorded using the Epicollect+ (version 1.5, <http://www.epicollect.net/>) Android App. When not recording data, the second observer assisted with searching for dolphin groups in order to reduce observer fatigue. Additional search support was given by the whale watch lookout operating from the same station. This further reduced the probability of resampling the same group.

The duration of the encounter was based on the number of 2 min intervals the boats were present and interacting with the dolphins group. An interaction was defined as boats slowing down and stopping within the vicinity of, or moving amongst dolphins.

Guidelines for swim-with-dolphin activities do not include type approach and maximum encounter duration. Whale watching companies were aware at the time of observation that a study to assess effects of dolphin tourism was in progress.

Data analysis

Control and interaction intervals were identified in each focal group follow based on the presence or absence of tour boats interacting with the group of dolphins (either observing or placing swimmers in the water). Boats other than tour vessels were occasionally present in the area but did not specifically target or interact with dolphins, and thus are not considered here.

A Markov chain analysis, which allows for the dependence of an event with preceding ones to be assessed, was used (Guttorp, 1995). A first-order Markov chain analysis, where a category is only dependent on the immediately preceding one, was applied to derive transition probabilities between mutually exclusive behavioural categories and used to develop two-way contingency tables as described in Lusseau (2003). Hence, within each focal follow if no tour boat interaction occurred between two samples, the transition between the two categories was tallied in the control table. If an interaction occurred, it was tallied in the interaction table. In instances where it was difficult to decide whether a transition was to be considered within a control or interaction sequence, e.g. arrival and departure of a boat (Lusseau, 2003), a conservative approach was followed (Meissner *et al.*, 2015). Hence, to avoid ambiguity, transitions occurring between a sample

after an interaction and the following sample were removed (Lusseau, 2003; Stockin *et al.*, 2008a; Meissner *et al.*, 2015).

Transition probabilities for control and interaction chains were calculated by:

$$p_{ij} = \frac{a_{ij}}{\sum_{j=1}^n a_{ij}} \cdot a_{ij}, \sum_{j=1}^n p_{ij} = 1$$

where i is the preceding behavioural category and j is the succeeding behavioural category (ranging from 1 to 4, total number of categories observed and included in the analysis), a_{ij} is the number of transitions observed from category i to category 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 transition between control and interaction (Fleiss *et al.*, 2003).

Following Lusseau (2003), the activity budget in control and interaction scenarios was derived from the left eigenvector of the dominant eigenvalue of the transition matrices using the Excel add-in PopTools (version 3.0.3, CSIRO, www.cse.csiro.au/poptools). A two-tailed Z-test for proportion was used to compare control and interaction activity budgets and 95% CI were calculated. The time to return to a preceding activity after a change occurred was calculated for both control and interaction scenarios and for each activity category (Stockin *et al.*, 2008a; Meissner *et al.*, 2015):

$$E(T_j) = \frac{1}{\pi_j}$$

where $E(T_j)$ is the number of transitions, which when multiplied by the time unit (2 min interval in the present study) gives the time taken by the dolphins to return to the initial activity j , and π_j is the steady-state probability of each activity in the chain. The average bout length for each category in control and interaction scenarios was approximated, following Lusseau (2003), from the mean of the geometric distribution of p_{ii} (Guttorp, 1995):

$$t_{ii} = \frac{1}{1 - p_{ii}}$$

where p_{ii} is the probability to stay within the same behavioural category i . A Mann–Whitney test was subsequently applied to compare average bout lengths for both scenarios. The cumulative activity budget, i.e. the time dolphins could potentially be exposed within the season was derived following Lusseau (2003); Christiansen *et al.* (2010) and Meissner *et al.* (2015) using the following formula:

$$\text{Cumulative budget} = (I \times \text{interaction budget}) + (C \times \text{control budget})$$

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 equals 0 when there is no interaction with tour boats, and the cumulative budget corresponds to the control budget. If interaction with tour boats was continuous, I equals 1 and the cumulative budget corresponds to the interaction budget.

A two-tailed Z-test for proportion was used to compare cumulative and control budget for each behavioural category. The difference between the Z-test P -values of control and cumulative budgets were used to explore the effects of cumulative budget based on the intensity of tour boat traffic.

RESULTS

Field effort

Data were collected during 83 days, corresponding to a total effort of 599 h, of which 157 were spent engaged in group focal follows. A total of 3357 control and 419 interaction transitions were recorded during 154 and 25 follow sequences, respectively. Control sequences lasted on average 46 min (median = 36 min, SD = 17.12, range = 14–215 min), while interaction sequences averaged 34 min (median = 32 min, SD = 33.9, range = 14–78 min). Of the 25 interaction sequences, 11 involved whale watching only, seven only swimming with dolphin activities and a further seven sequences included both activities. The maximum number of tour boats observed during interaction sequences was three (4% of transitions, $N = 419$), while most of the interaction sequences involved only one boat (79% of transitions, $N = 419$).

Effects of boat interactions

Transition probabilities were highest between the same behavioural category for both control and interaction scenarios (Figure 2). The category transitions which were significantly affected by the presence of tour boats (Figure 3) were: foraging to high surface activity ($Z = 5.15$, $P < 0.001$) and travelling to high surface activity ($Z = 2.14$, $P = 0.032$), which increased from 0.3 to 4.8% and from 7 to 12%, respectively, while travelling to foraging decreased from 4.9 to 0.7% ($Z = 2.26$, $P = 0.023$) when boats were interacting with the dolphins.

The proportion of time spent in high surface activity and foraging differed significantly between control and interaction sequences (Figure 4), with dolphins engaging more in high surface activity (39% vs 17%, $Z = 6.822$, $P < 0.001$) and less in foraging (12.4% vs 38%, $Z = 3.78$, $P < 0.001$) when boats were present. In the presence of tour boats, low surface activity and travelling decreased (9.6% to 8.6%) and increased (35% to 39%), respectively.

Time taken to return to the preceding activity differed during interaction with tour boats. Dolphins engaged in foraging and low surface activity before an interaction, took longer to return to their initial activity, 10.8 and 2.2 min more, respectively. While engaged in high surface activity, dolphins took less time (6.5 min difference) to return to their initial activity after interacting with tour boats (Table 2).

The average length of bouts of consistent behaviour varied significantly between control and interaction sequences (Table 3). Bout length increased 13% for groups in high surface activity ($V = 1658.5$, $P < 0.0001$), while it decreased 15% for foraging ($V = 2994.5$, $P < 0.0001$) and low surface activity groups ($V = 1420$, $P < 0.0001$), and by 3.1% for travelling dolphins ($V = 4945.5$, $P < 0.0001$).

The cumulative interaction time analysis (Figure 5) shows that high surface activity and foraging by common dolphins could be affected when 44% and 48% of the time, respectively,

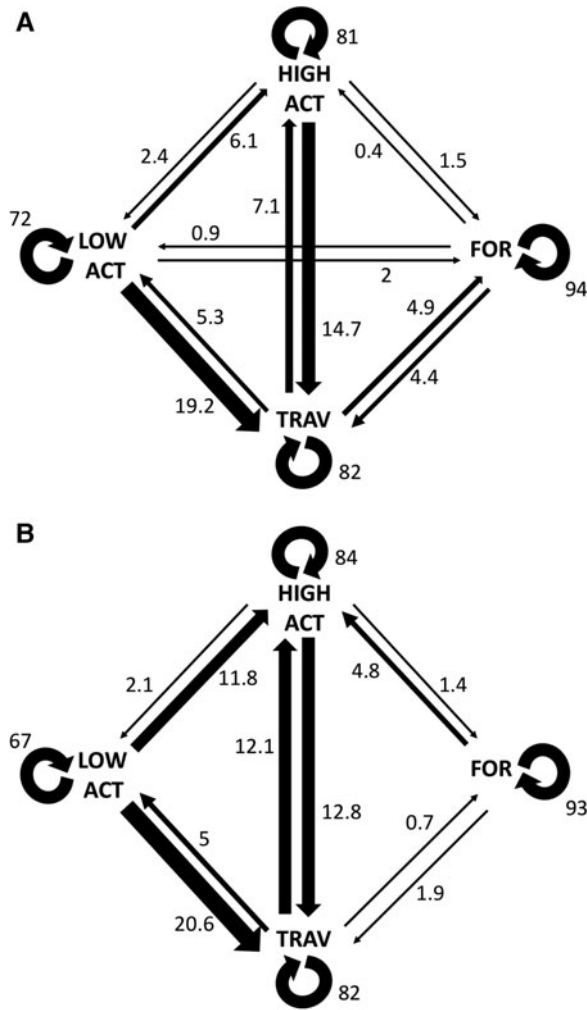


Fig. 2. Transition probabilities calculated for both control (a) and interaction (b) scenarios. Thicker arrows indicate transitions. Values shown are percentages.

is spent interacting with tour boats. In the present study, dolphin groups were observed spending only 10.5% of their time interacting with tour boats.

Compliance with whale watching guidelines

Whale watching tour boats demonstrated compliance by approaching and manoeuvring around dolphins on 90.4% (N = 197) of encounters. However, during 9.6% (N = 197) of cases, boats approached the group either transversally, parallel and ahead or moved into the middle of the pod, or moved too quickly nearby the dolphins. Duration of encounters ranged between 2 and 53 min (mean = 22.67; SD = 14.97; median = 19), exceeding the 30 min permitted time limit in 27% (N = 18) of cases.

DISCUSSION

Transition probability analysis revealed that interactions with tour boats affected the behaviour of common dolphins off São Miguel, Azores. In the presence of tour boats, common dolphins spent less time foraging and more time in high surface activity. Furthermore, the time required to resume foraging after a tour boat interaction was higher.

Feeding is a biologically significant activity so any disruption may reduce energy intake and pose risk to the wellbeing and potential survival of individuals which could in turn lead to consequences at population level (Christiansen *et al.*, 2011, 2013). The reduction of time allocated to foraging observed in this study could result in a reduction in feeding rate. Oceanic delphinids are reported to feed mostly at dusk and during the early hours of the morning (Neumann, 2001; Ringelstein *et al.*, 2006; Pusineri *et al.*, 2007, 2008), i.e. when whale watching activities do not occur. If the same diurnal pattern of foraging occurred in the Azores then it might be argued that disruption of foraging during

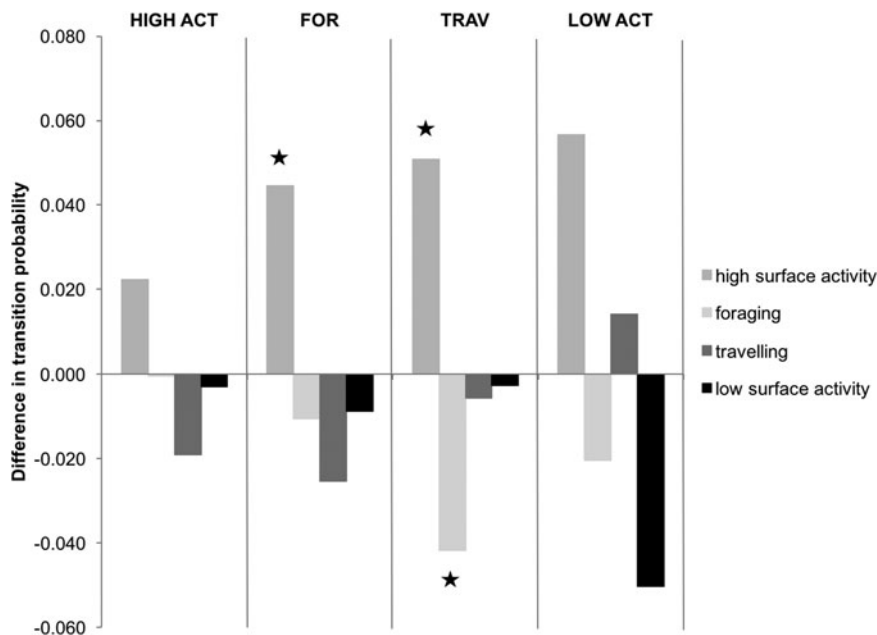


Fig. 3. Effect of boat interactions on activity transitions, based on differences in transition probabilities. The graph is divided into four parts delimited by vertical lines each representing a different preceding behavioural activity. Bars indicate succeeding behavioural activities. Those marked by ★ are significantly different. Negative values indicate that the transition probability of the control chain is higher to that of the interaction chain.

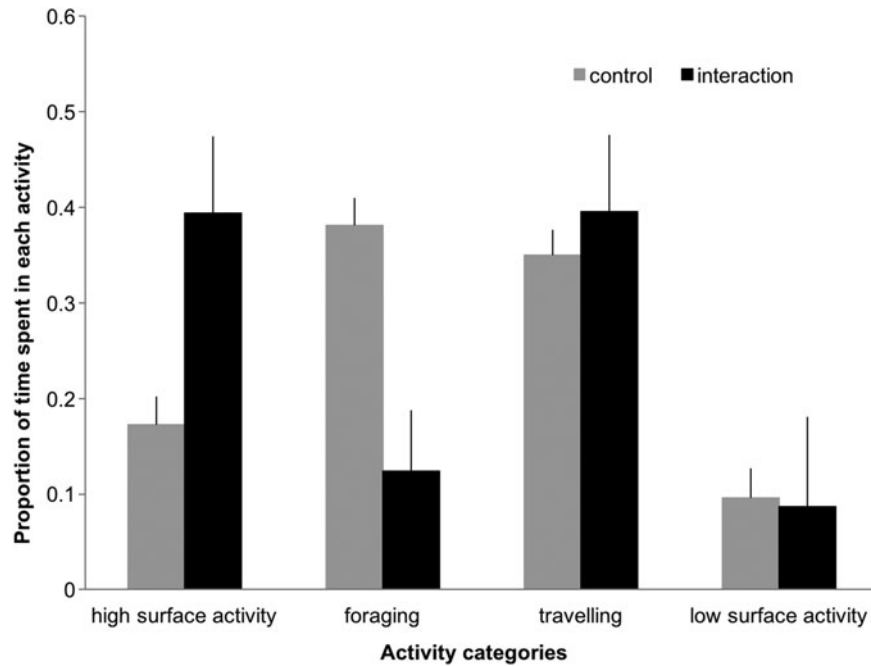


Fig. 4. Proportion of time (min) dolphins spent in each activity during control and interaction scenarios. Error bars represent 95% confidence intervals.

daylight hours might have a minor consequence on the total daily food input. However, within this study, foraging frequently occurred associated with diving Cory's shearwaters (*Calonectris diomedea borealis*) indicating that actual feeding during daylight hours did indeed occur. Moreover, whale watch operators anecdotally report the observation of bait balls during such encounters with foraging dolphins. Therefore, although the extent to which common dolphins off São Miguel feed at night remains unknown, foraging bouts during daylight hours do appear profitable. Significant amounts of daytime foraging has certainly been reported in *Delphinus* observed within the Hauraki Gulf, New Zealand (Stockin *et al.*, 2009). A decrease in feeding activity is a particular concern for common dolphins given their need to cover high metabolic costs resulting from their small size and active swimming habits (Spitz *et al.*, 2010). Further, food availability in oceanic habitats is typically patchily distributed, creating a need for considerable movements in order to find resources (Benoit-Bird & Au, 2003). Common dolphins, like other small delphinids, are reported to use cooperative foraging techniques, for example to gather bait-balls (Gallo Reynoso, 1991; Neumann & Orams, 2003; Benoit-Bird & Au, 2009; Vaughn *et al.*, 2010). Such complex and cooperative behaviour is likely to be particularly vulnerable to disruption.

Table 2. Probabilities of staying in a particular behavioural category (π_j), relative average number of time units $E(T_j)$ taken to return to an activity after boat approached and time needed to return to that activity. Control/interaction values are reported.

Activity category	π_j	$E(T_j)$	Resumed activity
High surface activity	0.172/0.393	5.80/2.53	11.60/5.07
Foraging	0.381/0.124	2.62/8.04	5.24/16.08
Travelling	0.350/0.395	2.85/2.52	5.70/5.05
Low surface activity	0.095/0.086	10.40/11.50	20.87/23.08

Other studies have indicated that tour boats may affect foraging in a number of cetacean species (Williams *et al.*, 2006; Dans *et al.*, 2012; Steckenreuter *et al.*, 2012), a finding reflected in Senigaglia *et al.* (2016), which revealed decreased foraging as one of the most consistent responses to whale watching vessels. For instance, foraging common dolphins in New Zealand responded to commercial tourism boats by reducing time spent in this activity and by delaying their feeding bouts (Stockin *et al.*, 2008a; Meissner *et al.*, 2015). The main concern for the population in the Hauraki Gulf was linked to its elevated site fidelity, potentially leading to higher long-term effects (Stockin *et al.*, 2008a; Hupman, 2016) compared with a neighbouring site in the Bay of Plenty (Meissner *et al.*, 2015). In the Azores, common dolphins are observed year-round, although no information is available about their site fidelity or breeding cycles. Concern, in this case, would be associated with the frequent presence of calves during summer months, when the peak of the tourism activities occurs. Common dolphins were also observed increasing high surface activity in the presence of the tour boats, in particular increasing the transitions from foraging to high surface activity and from travelling to high surface activity. The high surface activity category probably included socializing, a state which is biologically important in ensuring better cooperation during group foraging, as a means of defence strategy and for

Table 3. Average bout length, t_{ii} (min) for each behavioural category in both control and interaction scenarios.

Activity category	t_{ii}	
	Control	Interaction
High surface activity	5.39	6.13
Foraging	17.6	14.8
Travelling	5.76	5.58
Low surface activity	3.66	3.09

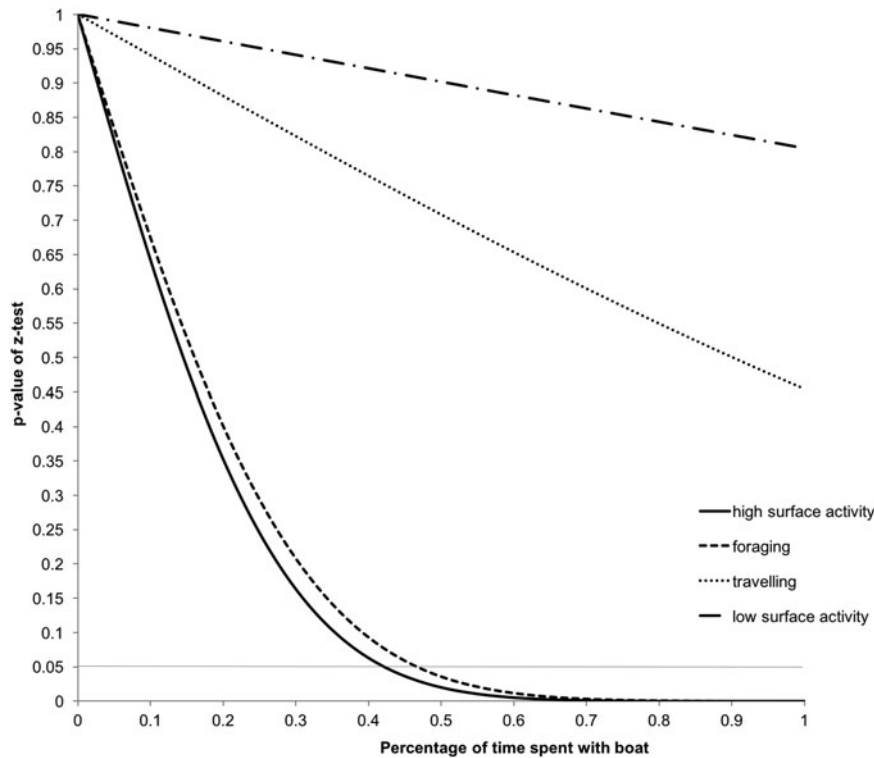


Fig. 5. Effect of tour boat traffic intensity on common dolphin activity budget. Z-test P -values of the difference between cumulative and control budgets. The dotted horizontal line indicates the level of significance set at $P < 0.05$.

enhancing reproductive success (Silk, 2007; Schülke *et al.*, 2010). The limitation in being able to distinguish among such functions makes the results problematic to interpret, especially given the likelihood that high surface activity in the presence of boats *vs* control scenarios could have been different. Dolphins engaged in high surface activity are often performing aerial behaviours, possibly functioning as a means of communication. During interaction with the tour boats, dolphins could have increased their surface activity to improve communication as a response to disorientation and noise perturbation (Lusseau, 2006; Noren *et al.*, 2009). From a metabolic perspective, two possible inferences could be derived from these findings. Either tourism activities are not affecting energetics and thus dolphins can still engage in costly behaviours or alternatively, dolphins not only reduce energy intake as a consequence of foraging disruption, but also increase their energy costs by engaging more in high surface activity behaviours.

With respect to the former point, it is notable that short-term responses to disturbance do not necessarily match stress levels as these may be delayed in their expression (Holmes *et al.*, 2005). This would challenge the interpretation of immediate reactions deemed either as 'negative' or 'positive'. For instance, the approach behaviour of dolphins towards oncoming vessels gives an impression of lack of disturbance and is usually understood as a positive response. However, dolphins engaged in a particular activity may stop in order to bow-ride, reducing the time used for the initial activity. Similarly, an evidently negative reaction could lack biological significance in the long term (Blumstein & Fernández-Juricic, 2010). Although category of activity states used in the present study were pooled to minimize bias, results presented here still require cautious interpretation.

Effects of cetacean tourism are likely to be cumulative rather than acute (Bejder *et al.*, 1999). In the present study, the cumulative effects on dolphins engaged in foraging and high surface activity were predicted to occur above 48% and 44% of tour boat exposure, respectively. Common dolphins within the study area were observed spending only ~10% of their daytime interacting with tour boats. This is lower than other exposed populations (e.g. 28.9% in Hauraki Gulf, New Zealand, Stockin *et al.*, 2008a; 21% Bay of Plenty, New Zealand, Meissner *et al.*, 2015), which could potentially allow for recovery between interactions (Christiansen & Lusseau, 2014). However, the area surveyed is only a small portion of the coast of São Miguel used by tour boats, suggesting dolphin exposure reported here is underestimated, at least during April–October when operations are mostly prolific. Unfortunately, the lack of data assessing population size and site fidelity of common dolphins in the Azores prevents clarity on the potential for cumulative effects.

Tour operators rarely violated the approach guidelines or the observation time limits. Typically, only one boat at a time approached dolphins, although on occasion as many as three vessels were recorded in proximity of a dolphin group, three being the maximum limit set by the guidelines. When a breach of the guidelines did occur, no change in dolphin behavioural category was recorded. The small sample size relative to interaction sequences of the present study emphasizes the need for further monitoring, covering a larger area. Bentz *et al.* (2015), for instance, working from a much larger dataset, reported that in over 20% of cetacean encounters, the limit of three boats was exceeded. Future studies could also specifically address other proxies such as direction patterns and breathing rates (Hastie *et al.*, 2003; Lusseau,

2006), allowing a more comprehensive insight to the full effects of dolphin tourism in this region.

We cannot know whether the behavioural changes revealed by this study have any biological significance, especially given (i) the relatively small sample size of interaction data and (ii) the small proportion of time dolphins were exposed to tourism in this study. Indeed, establishing that whale watching has biologically significant impacts has rarely been achieved, and only in very well studied locally resident populations (e.g. Bejder *et al.*, 2006b; Tyne *et al.*, 2017). Given this, it is appropriate to apply caution in the interpretation of findings presented here, especially since the overall effect on the population remains unknown, and may not as has been observed in other species, be necessarily an indicator that current levels of tourism are not sustainable (Filby *et al.*, in press). Nonetheless, the development of effective guidelines should be considered crucial. Future research should focus on the development of best practice boat approaches to reduce disturbance reported in this study. Until the effects reported here are proven as having no demonstrable biological impact on the broader population, we recommend the precautionary principle, and no further licencing for dolphin tourism be issued in this region.

ACKNOWLEDGEMENTS

We would like to thank all the volunteers involved in data collection as well as Terra Azul whale watching company for extra support during data collection. The authors also acknowledge two anonymous reviewers whose comments improved earlier versions of this manuscript. The map of the study area was produced by Marc Fernandez.

FINANCIAL SUPPORT

This research was partially supported by the European Regional Development Fund (ERDF) through the COMPETE – Operational Competitiveness Programme and national funds through FCT – Foundation for Science and Technology, under the project PEst-C/MAR/LA0015/2013, by the Strategic Funding UID/Multi/04423/2013 through national funds provided by FCT – Foundation for Science and Technology and European Regional Development Fund (ERDF), in the framework of the programme PT2020 and by cE3c funding (Ref:UID/BIA/003329/2013). It was also partly supported by CIRN (Centro de Investigação de Recursos Naturais, University of the Azores), and CIIMAR (Interdisciplinary Centre of Marine and Environmental Research, Porto, Portugal). A. Cecchetti was supported by the Regional Fund for Science scholarship M.3.1.2/F/036/2011.

REFERENCES

- Altmann J. (1974) Observational study of behaviour: sampling methods. *Behaviour* 49, 227–267.
- Arcangeli A. and Crosti R. (2009) The short-term impact of dolphin-watching on the behaviour of bottlenose dolphins (*Tursiops truncatus*) in western Australia. *Journal of Marine Animals and their Ecology* 2, 3–9.
- Bejder L., Dawson S.M. and Harraway J.A. (1999) Responses by Hector's dolphins to boats and swimmers in porpoise Bay, New Zealand. *Marine Mammal Science* 15, 738–750.
- Bejder L., Samuels A., Whitehead H. and Gales N. (2006a) Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. *Animal Behaviour* 72, 1149–1158.
- Bejder L., Samuels A., Whitehead H., Gales N., Mann J., Connor R., Heithaus M., Watson-Capps J., Flaherty C. and Krützen M. (2006b) Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology* 20, 1791–1799.
- Benoit-Bird K.J. and Au W.W.L. (2003) Prey dynamics affect foraging by a pelagic predator (*Stenella longirostris*) over a range of spatial and temporal scales. *Behavioural Ecology and Sociobiology* 53, 364–373.
- Benoit-Bird K. and Au W.W.L. (2009) Cooperative prey herding by the pelagic dolphin *Stenella longirostris*. *Journal of Acoustical Society of America* 125, 125–137.
- Bentz J., Rodrigues A., Dearden P., Calado H. and Lopes F. (2015) Crowding in marine environments: divers and whale watchers in the Azores. *Ocean and Coastal Management* 109, 77–85.
- Blumstein D.T. and Fernández-Juricic E. (2010) *A primer of conservation behavior*. Sunderland, MA: Sinauer Associates.
- Cammarrerri A. and Vermeulen E. (2010) Behavioural response of southern right whales (*Eubalaena australis*) to anthropogenic approaches in Bahía San Antonio, Rio Negro Argentina. *Report for the International Whaling Commission*, Document SC/62/www1, 7 pp.
- Christiansen F., Bertulli C.G., Rasmussen M. and Lusseau D. (2015) Estimating cumulative exposure of wildlife to non-lethal disturbance using spatially explicit capture-recapture models. *Journal of Wildlife Management* 79, 311–324.
- Christiansen F. and Lusseau D. (2014) Understanding the ecological effects of whale-watching on cetaceans. In Higham J., Bejder L. and Williams R. (eds) *Whale-watching: sustainable tourism and ecological management*. New York, NY: Cambridge University Press, pp. 177–192.
- Christiansen F., Lusseau D., Stensland E. and Berggren P. (2010) Effects of tourist boats on the behaviour of Indo-Pacific bottlenose dolphins off the south coast of Zanzibar. *Endangered Species Research* 11, 91–99.
- Christiansen F., Rasmussen M. and Lusseau D. (2011) Whalewatching boats disrupt the foraging activities of minke whales in Faxaflói Bay. *Report for International Whaling Commission*, Document SC/63/WW2, 13 pp.
- Christiansen F., Rasmussen M. and Lusseau D. (2013) Whalewatching boats disrupt feeding activities of minke whales on a feeding ground. *Marine Ecology Progress Series* 478, 239–251.
- Cisneros-Montemayor A.M., Sumaila U.R. and Kaschner K.P.D. (2010) The global potential for whale watching. *Marine Policy* 34, 1273–1278.
- Clua E. and Grosvalet F. (2001) Mixed-species feeding aggregation of dolphins, large tunas and seabirds in the Azores. *Aquatic Living Resources* 14, 11–18.
- Courbis S. and Timmel G. (2009) Effects of vessels and swimmers on behavior of Hawaiian spinner dolphins (*Stenella longirostris*) in Kealake'akua, Honaunau and Kanuhako bays, Hawai'i. *Marine Mammal Science* 25, 430–440.
- Dans S.L., Degradi M., Pedraza S.N. and Crespo E.A. (2012) Effects of tour boats on dolphin activity examined with sensitivity analysis of Markov chains. *Conservation Biology* 26, 708–716.
- Decreto Legislativo Regional (1999) http://www.riac.azores.gov.pt/NR/rdonlyres/C7F4EFB4-5B3B-4A92-8B3C-8FCB78F7E045/596272/DLR_9_1999_A.pdf.

- Decreto Legislativo Regional** (2003) http://www.azores.gov.pt/NR/rdonlyres/CA328D23-D2E5-46F3-B382-B8A8970BoFAE/o/PropostaAlteracaoDLROTC_CMA_IV.pdf.
- Ferguson M.C., Barlow J., Fiedler P., Reilly S.B. and Gerrodette T.** (2006) Spatial models of delphinid (Family Delphinidae) encounter rate and group size in the eastern tropical Pacific Ocean. *Ecological Modelling* 193, 645–662.
- Filby N.E., Christiansen F., Stockin K.A. and Scarpaci C.** (in press) Effects of swim-with-dolphin tourism on the behaviour of a threatened species: the Burren dolphin (*Tursiops australis*). *Endangered Species Research*.
- Fleiss J.L., Levin B. and Paik M.C.** (2003) *Statistical methods for rates and proportions*. New York, NY: Wiley.
- Gallo Reynoso J.P.** (1991) Group behaviour of common dolphins (*Delphinus delphis*) during prey capture. *Anales del Instituto Biológico de la Universidad Nacional Autónoma del México* 62, 253–262.
- Guttorp P.** (1995) *Stochastic modelling of scientific data*. London: Chapman & Hall.
- Hartman K., Visser F. and Hendriks A.J.E.** (2008) Social structure of Risso's dolphins (*Grampus griseus*) at the Azores: a stratified community based on highly associated social units. *Canadian Journal of Zoology* 86, 294–306.
- Hartman K.L., Fernandez M., Wittich A. and Azevedo J.M.N.** (2015) Sex differences in residency patterns of Risso's dolphins (*Grampus griseus*) in the Azores: causes and management implications. *Marine Mammal Science* 31, 1153–1167.
- Hastie G.D., Wilson B., Tuft L.H. and Thompson P.M.** (2003) Bottlenose dolphins increase breathing synchrony in response to boat traffic. *Marine Mammal Science* 19, 74–84.
- Holmes N., Giese M. and Krikwoken L.K.** (2005) Testing the minimum approach distance guidelines for incubating Royal penguins *Eudyptes schlegeli*. *Biological Conservation* 126, 339–350.
- Hoyt E.** (2001) Whale watching 2001: worldwide tourism numbers, expenditures and expanding socioeconomic benefits. *Report from the International Fund for Animal Welfare*, 165 pp.
- Hupman K.** (2016) *Photo-identification and its application to gregarious delphinids: common dolphins (Delphinus sp.) in the Hauraki Gulf, New Zealand*. PhD thesis, Massey University, New Zealand.
- Jacob M.H. and Harms M.** (2014) Influence of interpretation on conservation intentions of whale tourists. *Tourism Management* 42, 123–131.
- Johnson G. and McInnis C.** (2014) An effective education programme is no fluke. In Higham J., Bejder L. and Williams R. (eds) *Whale-watching: sustainable tourism and ecological management*. New York, NY: Cambridge University Press, pp. 128–145.
- Lusseau D.** (2003) Effects of tour boats on the behaviour of bottlenose dolphins: using Markov chains to model anthropogenic impacts. *Conservation Biology* 17, 1785–1793.
- Lusseau D.** (2006) The short-term behavioural reactions of bottlenose dolphins to interactions with boats in Doubtful Sound, New Zealand. *Marine Mammal Science* 22, 802–818.
- Lusseau D., Bain D.E., Williams R. and Smith J.C.** (2009) Vessel traffic disrupts the foraging behavior of southern resident killer whales *Orcinus orca*. *Endangered Species Research* 6, 211–221.
- Lusseau D. and Bejder L.** (2007) The long-term consequences of short-term responses to disturbance experiences from whalewatching impact assessment. *International Journal of Comparative Psychology* 20, 228–236.
- Magalhães S., Prieto R., Silva M.A., Gonçalves J., Afonso-Dias M. and Santos R.S.** (2002) Short-term reactions of sperm whales (*Physeter macrocephalus*) to whale watching vessels in the Azores. *Aquatic Mammals* 28, 267–274.
- Mann J.** (1999) Behavioural sampling methods for cetaceans: a review and critique. *Marine Mammal Science* 15, 102–122.
- Markowitz T.M., Richter C.F. and Gordon J.** (2011) Effects of tourism on the behaviour of sperm whales inhabiting the Kaikoura Canyon. *Kaikoura Sperm Whales and Tourism Research Project Report*, PACE-NZRP, 123 pp.
- Martinez E.** (2010) *Responses of South Island Hector's dolphins (Cephalorhynchus hectori hectori) to vessel activity (including tourism operations) in Akaroa Harbour, Banks Peninsula, New Zealand*. PhD thesis, Massey University, New Zealand.
- May-Collado L.J., Barragan-Barrera D.C., Quinones-Lebron S.G. and Aquino-Reynoso W.** (2012) Dolphin watching boats impact on habitat use and communication of bottlenose dolphins of Bocas del Toro, Panama during 2004, 2006–2010. *Report for the International Whaling Commission*, Document SC/64/WW2, 8 pp.
- Meissner A., Christiansen F., Martinez E., Pawley M., Orams M. and Stockin K.A.** (2015) Behavioural effects of tourism on oceanic common dolphins, *Delphinus* sp., in New Zealand: the effects of Markov analysis variations and current tour operator compliance with regulations. *PLoS ONE* 10, e0116962. doi: 10.1371/journal.pone.0116962.
- Montero-Cordero A. and Lobo J.** (2010) Effect of tourist vessels on the behaviour of the pantropical spotted dolphin, *Stenella attenuata*, in Drake Bay and Caño Island, Costa Rica. *Journal of Cetacean Research and Management* 11, 285–291.
- Morete M.E., Bisi T.L. and Rosso S.** (2008) Mother and calf humpback whale responses to vessels around the Abrolhos Archipelago, Bahia, Brazil. *Journal of Cetacean Research Management* 9, 241–248.
- Neumann D.** (2001) The activity budget of free ranging common dolphins (*Delphinus delphis*) in the northwestern Bay of Plenty, New Zealand. *Aquatic Mammals* 27, 121–136.
- Neumann D.R. and Orams M.** (2003) Feeding behaviours of short-beaked common dolphins, *Delphinus delphis*, in New Zealand. *Aquatic Mammals* 29, 137–149.
- Neumann D.R. and Orams M.** (2006) Impacts of ecotourism on short-beaked common dolphins (*Delphinus delphis*) in Mercury Bay, New Zealand. *Aquatic Mammals* 32, 1–9.
- Ng S.L. and Leung S.** (2003) Behavioral response of Indo-Pacific humpback dolphin (*Sousa chinensis*) to vessel traffic. *Marine Environmental Research* 56, 555–567.
- Noren D.P., Johnson A.H., Rehder D. and Larson A.** (2009) Close approaches by vessels elicit surface active behaviors by southern resident killer whales. *Endangered Species Research* 8, 179–192.
- Papale E., Gamba M., Perez-Gil M., Martin M.V. and Giacoma C.** (2015) Dolphins adjust species-specific frequency parameters to compensate for increasing background noise. *PLoS ONE* 10, e0121711, doi: 10.1371/journal.pone.0121711.
- Parsons E.C.M.** (2012) Review article: the negative impacts of whale watching. *Journal of Marine Biology* 2012, Article ID 807294. doi: 10.1155/2012/807294.
- Pirotta E., Milor R., Quick N., Moretti D., Di Marzio N., Tyack P.L., Boyd I. and Hastie G.** (2012) Vessel noise affects beaked whale behavior: results of a dedicated acoustic response study. *PLoS ONE* 7, e42535, doi: 10.1371/journal.pone.0042535.
- Pusineri C., Chancollon O., Ringelstein J. and Ridoux V.** (2008) Feeding niche segregation among the Northeast Atlantic community of oceanic top predators. *Marine Ecology Progress Series* 361, 21–34.

- Pusineri C., Magnin V., Meynier L., Spitz J., Hassani S. and Ridoux V.** (2007) Food and feeding ecology of the common dolphin (*Delphinus delphis*) in the Oceanic Northeast Atlantic and comparison with its diet in neritic areas. *Marine Mammal Science* 23, 30–47.
- Queiroz R.E., Guerrero J. and Ventura M.A.** (2014) Demand of the tourists visiting protected areas in small oceanic islands: the Azores case-study (Portugal). *Environment, Development and Sustainability* 16, 1119–1135.
- Quérouil S., Silva M.A., Cascão I., Magalhães S., Seabra M.I., Machete M.A. and Santos R.S.** (2008) Why do dolphins form mixed-species associations in the Azores? *Ethology* 114, 1183–1194.
- Ringelstein J., Pusineri C., Hassani S., Meynier L., Nicolas R. and Ridoux V.** (2006) Food and feeding ecology of the striped dolphin, *Stenella coeruleoalba*, in the oceanic waters of the north-east Atlantic. *Journal of the Marine Biological Association of the United Kingdom* 86, 909–918.
- Schülke O., Bhagavatula J., Vigilant L. and Ostner J.** (2010) Social bonds enhance reproductive success in male macaques. *Current Biology* 20, 2207–2210.
- Senigaglia V., Christiansen F., Bejder L., Gendron D., Lundquist D., Noren D.P., Schaffar A., Smith J.C., Williams R., Martinez E., Stockin K.A. and Lusseau D.** (2016) Meta-analyses of whale watching impact studies: comparisons of cetaceans responses to disturbance. *Marine Ecology Progress Series* 542, 251–263.
- Silk J.B.** (2007) The adaptive value of sociality in mammalian groups. *Philosophical Transactions of the Royal Society B* 362, 539–559.
- Silva L.** (2015) How ecotourism works at the community-level: the case of whale-watching in the Azores. *Current Issues in Tourism* 18, 196–211. doi: 10.1080/13683500.2013.786027.
- Silva M.A., Prieto R., Cascão I., Seabra M.I., Machete M., Baumgartner M. and Santos R.** (2014) Spatial and temporal distribution of cetaceans in the mid-Atlantic waters around the Azores. *Marine Biology Research* 10, 123–137.
- Silva M.A., Prieto R., Jonsen I., Baumgartner M. and Santos R.** (2013) North Atlantic blue and fin whales suspend their spring migration to forage in middle latitudes: building up energy reserves for the journey? *PLoS ONE* 8, e76507, doi: 10.1371/journal.pone.0076507.
- Silva M.A., Prieto R., Magalhães S., Cabecinhas R., Cruz A., Gonçalves J.M. and Santos R.** (2003) Occurrence and distribution of cetaceans in the waters around the Azores (Portugal) summer and autumn 1999–2000. *Aquatic Mammals* 29, 77–83.
- Spitz J., Mourocq E., Leauté J.-P., Quérouil J.-C. and Ridoux V.** (2010) Prey selection by the common dolphins: fulfilling high energy requirements with high quality food. *Journal of Experimental Marine Biology and Ecology* 390, 73–77.
- Stamation K.A., Croft D.B., Shaughnessy P.D., Waples K. and Briggs S.V.** (2010) Behavioral responses of humpback whales (*Megaptera novaeangliae*) to whale-watching vessels on the southeastern coast of Australia. *Marine Mammal Science* 26, 98–122.
- Steckenreuter A., Möller L. and Harcourt R.** (2012) How does Australia's largest dolphin-watching industry affect the behaviour of a small and resident population of Indo-Pacific bottlenose dolphins? *Journal of Environmental Management* 97, 14–21.
- Stensland E. and Berggren P.** (2007) Behavioural changes in female Indo-Pacific bottlenose dolphins in response to boat-based tourism. *Marine Ecology Progress Series* 332, 225–234.
- Stockin K.A., Binedell V., Wiseman N., Brunton D.H. and Orams M.B.** (2009) Behavior of free-ranging common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand. *Marine Mammal Science* 25, 283–301.
- Stockin K.A., Lusseau D., Binedell V., Wiseman N. and Orams M.** (2008a) Tourism affects the behavioural budget of the common dolphin (*Delphinus* sp.) in the Hauraki Gulf, New Zealand. *Marine Ecology Progress Series* 355, 287–295.
- Stockin K.A., Pierce G.J., Binedell V., Wiseman N. and Orams M.** (2008b) Factors affecting the occurrence and demographics of common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand. *Aquatic Mammals* 34, 200–211.
- Timmel G., Courbis S., Sargeant-Green H. and Markowitz H.** (2008) Effects of human traffic on the movement patterns of Hawaiian spinner dolphins (*Stenella longirostris*) in Kealakekua Bay, Hawaii. *Aquatic Mammals* 38, 402–411.
- Tyne J.A., Johnston D.W., Christiansen F. and Bejder L.** (2017) Temporally and spatially partitioned behaviours of spinner dolphins: implication for resilience to human disturbance. *Royal Society of Open Science* 4, 160626, <http://dx.doi.org/10.1098/rsos.160626>.
- Vaughn R., Würsig B. and Packard J.** (2010) Dolphin prey herding: prey ball mobility relative to dolphin group and prey ball sizes, multispecies associates, and feeding duration. *Marine Mammal Science* 26, 213–225.
- Visser F., Hartman K., Pierce G.J., Valavanis V.D. and Huisman J.** (2011a) Timing of migratory baleen whales at the Azores in relation to the North Atlantic spring bloom. *Marine Ecology Progress Series* 440, 267–279.
- Visser F., Hartman K., Rood E.J.J., Hendriks A.J.E., Zult D.B., Wolff W.J., Huisman J. and Pierce G.J.** (2011b) Risso's dolphins alter daily resting pattern in response to whale watching at the Azores. *Marine Mammal Science* 27, 366–381.
- Westgate A.J. and Read A.J.** (2007) Reproduction in short-beaked common dolphins (*Delphinus delphis*) from the western North Atlantic. *Marine Biology* 150, 1011–1024.
- Williams R., Bain D.E., Smith J.C. and Lusseau D.** (2009) Effects of vessels on behaviour patterns of individual southern resident killer whales *Orcinus orca*. *Endangered Species Research* 6, 199–209.
- Williams R., Lusseau D. and Hammond P.S.** (2006) Estimating relative energetic costs of human disturbance to killer whales (*Orcinus orca*). *Biological Conservation* 133, 301–311.
- Williams R., Trites A.W. and Bain D.E.** (2002) Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats: opportunistic observations and experimental approaches. *Journal of Zoology* 256, 255–270.
- and
- Wilson C. and Tisdell C.** (2002) Conservation and economic benefits of wildlife-based marine tourism: sea turtles and whales as case studies. *Economics, Ecology and the Environment Report*, 19 pp.

Correspondence should be addressed to:

A. Cecchetti
Biology Department, cE3c – Centre for Ecology,
Evolution and Environmental Changes/Azorean
Biodiversity Group, University of the Azores,
9501-801 Ponta Delgada, Azores, Portugal
email: arianna.cecchetti@uac.pt