Effects of whale watching activities on the behavior of Risso's dolphin at the Azores

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Abstract

Behavioral response of Risso's dolphin (*Grampus griseus*) to whale-watching activities was studied by comparison of activity rates between the high and low season of whale watching. We had the exceptional opportunity to study Risso's dolphin behavior from land, enabling observations of both disturbed and undisturbed groups. Whale watching activities were divided in a low season and a high season of activities, based on the intensity of vessel presence. Daily whale watching activities were characterized by a bimodal distribution, with low abundance between 1 and 2 PM. Risso's dolphin daily pattern of resting behavior was strongly influenced by high intensity whale watching activities, but the natural resting pattern was maintained when whale-watching operators are present in low numbers. At high intensity of whale watching activities, Risso's dolphins did not react by decreasing their overall time spent resting, but shifted their daily, double peaked pattern of resting behavior towards a single-peaked pattern, with highest resting rates during periods of lowest vessel abundance. The difference from the usual pattern implies that the dolphins have to adopt an alternative and possibly less favorable pattern when whale watching activities are high. Their reaction is most likely primarily induced by vessel noise, implying that the impact of whale watching could be reduced by regulating both vessel abundance and vessel speed in the area.

Keywords:

Risso's dolphin, *Grampus griseus,* whale-watching, Azores, behavioral budget, North Atlantic Ocean, behavioral shift, resting behavior

Introduction

World-wide whale-watching tourism has grown exponentially over the last few decades, attracting more than nine million people per year and leading to a strong rise in the exposure of cetaceans to boat traffic and interactions with humans (Miller 1993; Hoyt 2001). Although marine ecotourism can strongly benefit the conservation of marine habitat and its inhabitants through the increase of public awareness (Duffus and Deardon 1990), whale-watching activities can also be highly disturbing for cetaceans. Studies on a range of cetacean species have shown vessel-avoidance responses ranging from an increase in dive intervals (Janik and Thompson 1996; Nowacek and Wells 2001; Williams *et al*. 2002) to shifts in behavior (Lusseau 2003a, b), change in vocalizations (review: Richardson *et al*. 1995), change of foraging habitat selection (Baker and Herman 1989; Allen and Read 2000; Forest 2001) and even a shift in habitat (Kruse 1991). A basic cause of disturbance by vessel presence is thought to be noise pollution, decreasing cetacean communication, hearing and orientation capacity (Van Parijs and Corkeron 2001; Erbe 2002). Other impacts are the obstruction of travel paths and the disturbance of important behavioral types, such as resting and foraging (Blane and Jaakson 1994; Constantine 2001, 2004; Lusseau 2003b). The long-term biological significance of these impacts still remains poorly understood, but a strong consensus exists that intrusive, repetitive or persistent disturbance clearly forms a conservation threat (Kruse 1991; Janik and Thompson 1996; Bejder et al. 1999; Hastie et al. 2003).

The Azorean waters constitute a highly diverse ecosystem in the Central North-Atlantic Ocean (Morton *et al.* 1998). Due to upwelling, in combination with run-off from the islands and the influence of the Gulf Stream and the North-Atlantic Current, the area constitutes a food-rich area in the oligotrophic Central North-Atlantic Ocean (Angel 1989; Johnson and Stevens 2000). Twenty-four species of resident and migrating cetaceans are observed in in-shore waters, forming a true hotspot of marine biodiversity (Nowak 1999). The high cetacean diversity has led whale-watching activities to become one of the most important tourist attractions for the archipelago (MARE 2002). At present, fifteen tour operators offer daily trips from seven islands of the Azores, the islands of Pico and Faial being the centre of activity. Local regulations (1999), aiming to regulate these whale watching activities, are little enforced.

Risso's dolphin (*Grampus griseus;* Cuvier, 1812) is a pelagic species feeding mainly on deep-water cephalopods (Tomilin 1957; Pauly *et al.* 1998) and inhabiting offshore regions (350 - >1000 m), as well as waters at the continental shelf edge and places where the continental shelf is narrow (Ross 1984; Baumgartner 1997; Davis *et al.* 1998; Airoldi *et al*. 2000). Mature individuals show a range of coloration patterns, from brown, slightly scarred to almost totally white (Leatherwood *et al*. 1982). This is probably caused by a scarcity or loss of pigment, inhibiting repigmentation of scar tissue. Individual Risso's dolphins can be identified by the scarification patterns of their dorsal fins (McCann 1974; Lockyer and Morris 1990). Despite its world-wide presence in tropical and temperate waters (Aguayo 1975; Nowak 1999), behavioral patterns and social organization of *Grampus griseus* are still largely unknown (Atkinson *et al*. 1996; Airoldi *et al*. 2000).

For Risso's dolphin, the Azorean waters form a breeding, foraging and nursing area. The species is present year-round and is observed daily resting, socializing and foraging. Locally, the species is called '*moleiro'* (miller), referring to the white coloration pattern of adult Risso's dolphins. In contrast to most other areas, in the Azores, Risso's dolphin is usually found in inshore waters, between 0.5-6 km from the coast (Hartman, unpublished observations). Risso's dolphins are relatively shy cetaceans and do not readily approach boats (Tinker 1988). During the summer months, the species is under daily pressure of largely unregulated whale-watching activities, entailing long-lasting close approaches by vessels for swim-with-dolphins tourism, and posing a high disturbance potential.

Due to the presence of Risso's dolphins in Azorean inshore waters, we had the unique opportunity to study the behavior of Risso's dolphin from land. Observations from land are seldom used in the study of cetacean behavior, due to the restricted sightings of animals and limited observation of their behavior (Mann 1999). In the Azores, due to the steep submarine slopes and absence of a continental shelf, cetaceans are commonly sighted very near the coast. This creates the exceptional opportunity to study cetacean presence, abundance and behavior from land. Land observations have the strong advantage that observers do not have an impact on the animals studied, enabling comparisons of behavior in an undisturbed environment, with behavior in the presence of vessels.

To determine the impact of whale-watching activities at the Azores on the behavior of Risso's dolphin, we assessed its' patterns of behavior between periods of high and low intensity from whale-watching activities. Here, we provide the first report on the impact of whale watching on Risso's dolphin, showing that their daily patterns of resting behavior are significantly influenced by the presence of larger numbers of whale-watching vessels.

Methods

Field observations

From May 1st – October 28th, 2004, daily binocular-aided observations (25x80 *Steiner Observer*; from sunrise to dawn) were conducted from a permanent land-based observation platform at 38 m above sea-level, located in Santa Cruz das Ribeiras on the south coast of Pico, Azores (38°24′ N, 28°11′ W; research area (Risso's dolphin): 200 km^2; sighting radius Risso's dolphin: 14.8 km) (Figure 1). Observation day-time was divided over 4 fixed periods of at least 2.5 hours. During suitable weather conditions, a minimum of one observation was conducted per period, extended with 1-4 randomly-timed observations, resulting in an even distribution of land observations over the day. Observations were composed of two parts: 1) Survey of the research area, recording size, composition and behavioral state of all groups of Risso's dolphins, the number of whale-watching vessels and their group of focus. Surveys had a maximum duration of 30 minutes, to avoid double-counts of cetacean groups and to maintain equal sampling conditions. Groups were followed for a maximum of 5 minutes (point sampling; Mann 1999), and 2) Focal group follows of Risso's dolphins, recording group size and -composition, behavioral state (several behavioral parameters, data not shown in this paper), time span of vessel presence and vessel conduct (continuous; Mann 1999). The relatively small average group-size of Risso's dolphin (8.6) largely rules out the vulnerability to sampling bias of focal group sampling (Bejder and Samuels 2003). Groups were defined as congregations of individuals who interact socially and/or show coordinated activity in their behavior (Mann 1999; Whitehead 2003), with a maximum inter-animal distance of 50 m. Focal groups were followed for a minimum of 15 minutes, unless the group was lost from sight or weather- or sea state conditions deteriorated. Behavioral state was determined by recording the predominant group activity as one of four mutually exclusive behavioral states, viz. resting, traveling, socializing and foraging (Altmann 1974; Shane 1990). Mating was recorded as socializing behavior, as the distinction between mating and socializing behavior could not always be determined with certainty from land. Focal groups were chosen, based (1) on their distance from shore, (2) presence of whale watching vessels and (3) behavior. Observations of groups >8 km offshore were excluded from focal follows as the distance resulted in decreased reliability of observations of behavior and group size (distance determined from the relative position between shore-line and horizon). Preference was given to groups with whale watching vessel(s) present. It was attempted to sample all behavioral types equally over the research period, resulting in a preference for the behavioral type which was sampled least at the moment of observation. At the presence of >2 groups in the research area, observations were conducted by two observers simultaneously. Whale-watch vessel presence was continuously recorded by the timing of vessels entering and leaving the research area. Sea state (Beaufort Sea state, Bft), wind direction, wind speed (Bft), % cloud coverage and sighting conditions were continuously monitored.

Most whale-watching companies operating in the research area organize two trips per day, departing from the harbor of Lajes do Pico (7 km from research area). Other whale-watching operators observed in the research area are based on the west side of the island, in Madalena (approx. 42.5 km from research area) or in Horta on the neighboring island of Faial, (approx. 50 km from research area). Trips usually last 3-4 hours, starting at 9:30 or 10 AM and at 2 or 2:30 PM. Several whale-watching vessels regularly stayed on the water during the entire day. During the summer months, tours often ran until after 6 PM.

Local legislation to regulate the whale-watching activities at the Azores was implemented in 1999. This includes guidelines on approach limits, maximum duration of presence at one pod, angle of approach and the maximum number of vessels allowed per group. Also, more strict regulations apply to groups with calves. In June 2005, signs displaying these regulations were placed at all harbors with bases of whale-watching operators. Unfortunately, enforcing of this legislation is only very limited and violations are regularly observed in the research area. These violations include speeding in the close vicinity of groups, surpassing approach limits (especially in the presence of two or more vessels), cutting of dolphin travel paths and enclosing dolphin pods. Most violations are observed during activities for swim-with-dolphins tourism. The Azores are one of the few places where it is still allowed to swim with five species of wild dolphins, including Risso's dolphin, bottlenose dolphin (*Tursiops truncatus*), common dolphin (*Delphinus delphis*), striped dolphin (*Stenella coeruleoalba*) and Atlantic spotted dolphin (*Stenella frontalis*). Whale-watching vessels are guided by an observer from land, enabling whale-watching vessels to travel to whale or dolphin pods at high speed, directed by the observer. Whale or dolphin pods or that have been missed by the observer or are not of interest at that time (primary interest is in observations of sperm whales (*Physeter macrocephalus*)), are regularly passed at high speed and close distance.

Data analysis

Observations at Beaufort Sea state >3 or limited visibility and focal follows <15 minutes were excluded from analysis. Total and monthly abundance of Risso's dolphin in the research area was determined by the daily average abundance per observation (survey data). Group-size was determined from the average size of focal groups. The behavioral budget of Risso's dolphin was determined by the proportion of time spent per behavioral state, averaged per time-unit (time behavioral state/total time focal follow). The behavioral budget was also determined on a daily scale, at 1-hour intervals over the day. Here, the budget was determined by the average proportion of time spent per behavioral state per 1-hour interval. The behavioral budget was not calculated per group, as this would have resulted in relatively small sample sizes per time-interval. The intensity of whale-watching activities was determined by analysis of vessel abundance on a daily and a seasonal scale. Seasonal patterns of whale-watching vessel abundance were determined by calculating daily total vessel abundance. Vessels were denoted 'present' between arrival and departure and counted once at every new arrival (including presence of research vessel: 4% of total vessel observations). Daily patterns of vessel abundance were determined at 1 hour-intervals over the day, by calculating average vessel abundance per time interval. Whale-watching intensity was calculated for the total period, including days of bad weather and rough sea state conditions (Bft>4), not suitable for whale-watching activities. Behavioral response to the presence of whale-watching vessels was analyzed by comparison of the behavioral budget and daily patterns of behavior of Risso's dolphin between periods of low and high whale-watching intensity (data from focal follows).

Statistical analysis of the influence of whale watching activities on activity rates was performed by the definition of a tobit model, a censored regression model estimation and maximum likelihood procedure. Due to the censored data for activity rate (at 0 and 1) we could not use least-squares techniques, such as OLS, since these would lead to inconsistent parameter estimates. Therefore, in order to get consistent estimates, a tobit model was used. Activity rate is a censored variable, as the observed value (0= no resting; 1=resting) does not always provide the complete scope of information, which is likely to differ between focal groups. Reaction thresholds of cetacean groups are dependant on several factors, including received noise level, behavior prior to exposure, the age and sex of individuals, past experience and habituation (Erbe 2002). Therefore, the magnitude of a change in the environment, triggering a 'start' or 'end' of resting behavior may differ between focal groups, while the same value for activity rate is recorded (1 or 0). In our model, we assumed that the disturbance terms were drawn from a normal distribution with expectation 0 and variance 1, using robust covariance estimates. We optimized the function using a numerical method (quadratic hill climbing) and used a general-to-specific approach in all analyses (Verbeek 2000). General-to-specific modeling approach is a statistical method, which primarily estimates the full model, using all potential explanatory variables. Consecutively, variables are removed from the model in order of least significance, re-estimating the level of significance of the remaining variables after each removal. A significance level of $p<0.05$ was used for all analyses.

To determine whether the observed patterns of behavior were a natural, seasonal pattern or were influenced by whale-watching vessel presence, we tested for the causality between resting rate, vessel abundance, time of day (1-hour intervals) and time of year (month, low season, high season). We tested for causality, assuming that the model was correctly specified and that no other parameters existed that would explain (a large part of) the variation in behavior. Both time-variables (time of day, time of year) were included to control for natural, seasonal changes in behavioral patterns. The parameters which were not included in the model, as well as unobserved effects, were assumed to be correlated to the time-variables, thereby correcting for their absence. In the second run of the model, we replaced the variable vessel abundance for squared vessel abundance, in order to determine the effect of adding an extra vessel.

Results

Abundance of Risso's dolphin

Risso's dolphins were sighted daily in the research area (97% of 176 observation days) and during 75% of the observations (448 focal follows; 311 h observations of focal groups). Risso's dolphin abundance did not show significant changes over the study period (Kruskal-Wallis test, N= 331, k=4, p=0.93). On average 2 groups (median group abundance: 2; range: 0-9), corresponding to 13.7 animals (median group size: 10.5; range: 0-90), were present in the study area. Average group size was 8.6 ± 1.7 animals. The discrepancy between group size determined from Risso's dolphin abundance (6.9) and average group size of focal groups (8.6) either results from underestimation of the number of individuals during surveys, compared to focal follows, of 1-2 animals per group, or shows a bias towards observations of larger groups during focal follows. Small groups of 1-3 animals are more easily excluded from analysis, as they have a relatively high chance to be lost from sight within 15 minutes.

Whale-watching intensity

Whale-watching vessels were present during 29% of total observation time (489 vessel records; 225 h presence during land observations). The season of whale watching started relatively late, with one observation of vessel presence in May (2 vessels) and daily activities starting mid-June. Vessel abundance strongly fluctuated over the research period, with significant differences between months (Figure 2, Table 1). The highest abundance was recorded during the months July and August, showing an average daily vessel presence of 6.0, versus 1.0 vessel in the other months (Multiple comparisons; Dunn test; p<0.001). Increasing whale-watching activity resulted in a marked increase of the pressure on Risso's dolphin groups, from 6% of focal groups followed in June to 14% in August. Vessel presence between 9 AM and 6 PM increased from 10% in June to 60% in August, resulting in long periods of continuous vessel noise. Based on these data, the research period was divided in a period of high intensity (high season: July and August) and low intensity (low season: May, June, September and October) of whale-watching activities. Next to the seasonal variation, the intensity of whale watching activities showed a bimodal distribution during the day, resulting from the timing of whale watching trips (see section *Field observations*). Two peaks of high activity, around 11

AM and 3 PM are alternated by a period of less activity from 1-2 PM (Figure 3). The pattern of daily vessel abundance, divided between the low season and the high season, again shows the strong difference in whale-watching intensity between these two periods.

Behavioral patterns and the impact of whale-watching activities

The behavioral budget of Risso's dolphin showed a high rate of traveling behavior followed by a relatively high proportion of time spent socializing and resting. Overall activity rates did not show significant differences between the high and low season of whale-watching activities (Table 2), or between observations in the presence and absence of whale watching vessels.

Further analysis of the behavioral budget of Risso's dolphin showed a significant impact of high intensity whale-watching activities on the daily patterns of resting behavior. Risso's dolphin resting rate, accounting for 28% of total time budget, fluctuated over the day. Comparisons of the pattern of resting behavior between the high and the low season of whale watching revealed a clear shift in the timing of resting of Risso's dolphin groups (Figure 4). This shift was only observed for resting behavior, no significant differences were found between activity patterns of socializing, foraging and traveling behavior between the two periods.

The low-intensity months of May, June, September and October were characterized by a double-peaked resting pattern, with highest resting rates from 10-12 AM and from 2-4 PM, showing strong similarity with the daily pattern of whale-watching vessel abundance in July and August. During the high-intensity months, this double-peaked (natural) pattern of resting during the morning and afternoon shifted to a single peak between 1-2 PM, when whale-watching activity was lowest (Figures 3 and 4). During the high season, the 10-12 AM peak of resting activity, observed during the low season, is absent, while the timing of the 2-4 PM peak is shifted backwards, towards the timing of low intensity whale watching activities.

This does not rule out the possibility of natural changes in resting patterns between months. To analyze whether the change in resting pattern was related to vessel abundance or is a seasonal pattern, we tested for the causality between resting rate and vessel abundance, time of year (different months) and time of day (1-hour intervals), performing a general-to-specific approach (Table 3). In this model, only vessel abundance during the high season showed a significant relation with resting rate ($p=0.007$; Table 3a). None of the time-variables, time of year and time of day, showed a significant relation with resting rate. Therefore, the observed changes did not merely result from seasonally changing patterns of resting behavior. High season vessel abundance did not influence activity rates for socializing and resting behavior, but did demonstrate a positive effect on traveling behavior ($c=0.115$; $p=0.002$) (Table 3a).

Since the influence of vessels was only significant during the high season when the number of vessels was high, this implied that the effect of adding an extra vessel increased at increasing vessel abundance. It could be possible that Risso's dolphin uses non-continuous decision variables, changing its behavior when a certain threshold level of vessels is surpassed. Also, an increasing marginal effect might be due to increased competition among the vessels in the area. This was investigated by including the square of vessel abundance in the model (Table 3b), replaced for the seasonal impact of vessel abundance. In this model, the quadratic function of the number of vessels showed a significant negative relation with resting rate ($c=-0.016$; $p=0.0055$), meaning that the impact of adding an extra vessel increases with vessel abundance in the research area.

The coefficients (c) in table 3 cannot simply be interpreted as the marginal effect of an extra whale-watching vessel, as would be possible for regular OLS models. Due to the properties of the tobit model, the variable both influences the resting rate and the probability of observing either resting or no resting. For example, the coefficient for the impact of squared vessel abundance ($c = -0.016$), can only be interpreted as a negative impact of this variable, but not as the negative effect per whale watching vessel. Marginal effects in this model, however, can be calculated by multiplication of the coefficient by the proportion of observations of which the activity rate is between 0 and 1 (Verbeek 2000). This proportion was 0.3 for the data set used in analysis. We can now approximate the effect of adding an extra vessel. At a vessel presence of 2, resting rate will decline with $0.3*-0.016*(2)^2= -0.019$, compared observations in the absence of vessels. At a vessel presence of 5 and 10 vessels, the resting rate is estimated to decline with 0.0-0.12 and 0.0-0.48 respectively. Theoretically, in the presence of 5 vessels, a decrease in resting rate of 0-12% will be observed, compared to observations in the absence of vessels.

In contrast to resting, the activity rates of socializing and foraging were not influenced by vessel abundance, but showed a relation to both time variables. Socializing rates were significantly higher in July ($c=0.483$; $p<0.001$) and from 8-10 AM and 4-9 PM ($c=0.474$-1.229; $p<0.001$-0.038), compared to the other time intervals, and showed no relation to (squared) vessel abundance. Foraging rates were significantly lower between 9 AM and 2 PM ($c= -0.0746$ - -10.904; $p<0.001$-0.040) and highest during the months July-October ($c=0.653$-1.189; $p=0.007$-0.048). Traveling rates showed a relation both to time and to (squared) vessel abundance. Rates were lowest in June ($c= -0.369$; $p=0.034$) and from 5-6 PM ($c=-0.658$; $p=0.010$). Traveling rates demonstrated a positive relation to squared vessel abundance ($c=0.014$; $p=0.014$), indicating that increasing vessel abundance resulted in an increase in traveling behavior. In combination with the decline in resting behavior and the positive relation to vessel abundance (Table 3a), this implies that increased vessel abundance induces a behavioral shift from resting to traveling behavior.

Discussion

Our results show a significant impact of whale-watching tourism on the patterns of resting behavior of Risso's dolphin, induced by high vessel abundance.

Pattern of whale-watching intensity

Whale-watching intensity in the research area showed strong monthly and daily fluctuations, dividing the research period in a low season and a high season of whale-watching tourism. The high season months, July and August, were characterized by a significant increase in average daily vessel abundance (6.0 vs. 1.0), time span of vessel presence (60% vs. 10% of daytime) and proportion of focal groups followed by whale-watching vessels (14% vs. 6%) compared to the low season months (May, June, September and October). As most operators organize two trips per day, the daily pattern of whale-watching vessel intensity showed a bimodal distribution of vessel abundance. Abundance was highest from 10 AM- 1 PM and from 3-6 PM, strongly declining between 1-2 PM.

Behavioral budget

The behavioral budget of Risso's dolphin showed a high proportion of traveling behavior (40%), complemented by 28% resting behavior, 23% socializing behavior and 9% foraging behavior. The rate of foraging behavior seems relatively low, but is most likely underestimated due to sampling during day-light hours. Foraging behavior is less intense from 9 AM to 2 PM, demonstrating non-uniform distribution of foraging behavior over the day, taking place in the early morning and afternoon. As for pilot whales (*Globicephala* sp.), which also have a diet of deep-sea squid (Shane 1995), Risso's dolphins might spend a considerable amount of foraging time during the night when their prey migrates upwards in the water column. Also, foraging Risso's dolphins have a scattered distribution, are usually observed solitary at the surface and spend a great amount of their time under water, limiting the chance and duration of recording this behavioral type during land observations (Hartman, unpublished results). Night-time foraging might also explain the relatively high resting rate observed in the research area, compared to other cetaceans (Moberg 2000; Nowacek and Wells 2001; Constantine 2003; Lusseau 2003a). The rate of socializing behavior is highest in July, indicating increased intensity of the mating season during this month.

Impact of whale-watching activities

The overall activity rates of Risso's dolphin were not influenced by the presence of whale-watching vessels or between the high and low season of whale watching activities. Instead, during periods of high intensity of whale watching activity, profound changes occurred in the daily timing of resting behavior. During the low intensity months, the daily resting behavior of Risso's dolphin was characterized by a double-peaked pattern, showing strong similarity to the daily pattern of whale-watching in the high intensity months of July and August. During these high intensity months, the pattern was shifted towards a single peak, between 1 and 2 PM, hence, at minimum abundance of whale-watching vessels: resting now takes place during the low intensity hours.

The observed shift in resting patterns is not a seasonal behavioral pattern of Risso's dolphin. Resting rate only showed a significant relation to vessel abundance during the high season and had no relation to seasonal and daily time variables. In addition, as resting rate is not influenced by vessel abundance during the low season, the influence of vessel presence first emerges when average vessel abundance is high (average 2-3 vessels present per 1-hour time interval). This is strongly supported by the fact that the effect of adding an extra vessel increases significantly with vessel abundance in the research area. Theoretically, at a vessel abundance of five vessels present, resting rates will decrease with 12%, compared to 1.9% with two vessels present. Apparently, the impact of whale-watching activities on the resting behavior of Risso's dolphin is strongly related to vessel abundance: Risso's dolphins maintain their natural resting pattern when whale-watching operators are present in low numbers, but shift their resting behavior towards periods of low vessel activity when intensity (and presumably noise) surpasses a certain threshold. During the high intensity hours, resting behavior is shifted to the much more costly traveling behavior, which demonstrated an opposite, positive correlation to vessel abundance. Foraging and socializing rates showed no relation to vessel abundance, indicating that these behavioral types are either less sensitive to vessel noise, or, in the case of foraging, mostly take place outside high-intensity hours of whale watching.

Ecological significance

A decrease in resting behavior has been one of the most frequently observed responses of animals to human disturbance (Constantine 2001; Henry and Hammil 2001; Hooker et al. 2001; Lusseau 2003a). Resting is a fundamentally important behavioral state, since a reduction in resting rates results in a reduction of energy reserves and can affect reproductive and foraging success. Lusseau (2003b) showed that resting and socializing behavior are sensitive to boat interactions and emphasized the value of the protection of areas of significant importance to dolphins when resting or socializing. Although no decrease in resting rate was observed, high intensity whale-watching activities strongly influenced the patterns of resting behavior of Risso's dolphin. Changes in the patterns of resting behavior have also been found for Spinner dolphins (*Stenella longirostris*). A population exposed to swimmers showed delayed (earlier departure times) and compressed (shorter periods of resting) resting patterns during periods when large numbers of swimmers were present in the area, indicating a potential adverse impact of the presence of swimmers on dolphin resting patterns (Danil *et al.* 2005). Changes in behavior are directly related to the energy budget of individuals and populations and can provide information on the biological significance of an impact (Bejder and Samuels 2003). Short-term responses of behavior are typically used as a measurable, quantifiable variables to evaluate long-term costs (Mann 1999). For Risso's dolphin, the alteration of their natural resting pattern, shifting from resting to traveling behavior, implies that the dolphins have to adapt to an alternative and potentially less favorable situation, especially as their undisturbed resting behavior shows a clear pattern. Adaptation to a potentially less favorable situation can be directly translated into less efficient time management of the dolphins and consequently into a long-term negative impact on the population.

Whale-watching intensity

It can be argued that, with an average vessel presence of 6 boats during the high season, whale-watching pressure at the Azores is relatively low, compared to several other regions with whale-watching activities. However, this study was conducted in a relatively small research area (200 km^2), covering only a part of the operating area of Azorean whale-watching activities. In such a small area, a daily abundance of 6 vessels and maximum presence of 18 vessels is high, especially considering the level and continuous nature of noise pollution. Current plans for whale watching tourism include a doubling of the number of licenses for whale watching vessels. Also, due to the limited regulation of the activities, vessels are not bound to speed limits and are often observed cruising at high speed in the research area, strongly increasing noise production per whale-watching vessel (Erbe 2002). Moreover, at the Azores, whale-watching operators also use land observations from look-out posts to locate the cetaceans, thereby reducing cetacean opportunity and choice to avoid vessels. This poses an extra potential cause of disturbance, especially during swim-with-dolphins tourism (entailing close approaches of dolphin groups).

Vessel noise

Risso's dolphins react to the presence of vessels even when they are not in the direct vicinity of a group. Their response is initiated by high vessel abundance in the research area. This suggests that the impact of vessel presence is related to vessel noise (Schevill 1968, Erbe 2002). Since under-water boat noise can be distinguished from far greater distances than would be possible based on solely visual perception (Erbe 2002), dolphins are likely to react primarily to the presence of vessels based on acoustic, rather than visual cues. Erbe (2002) calculated that boat noise is audible for killer whales from a distance of over 16 km. High noise levels have been suggested as possible cause of the lack of recovery of the Southern community of resident killer whales (*Orcinus orca*) in British Columbia, in combination with chemical pollution and reduction of prey availability in the waters (Erbe 2002). Personal observations in our research area showed that audible levels of noise could be registered with a hydrophone more than ten minutes before a vessel came into view. The level of noise received by dolphin pods is related to vessel abundance, vessel speed, distance from the vessel(s) and type of engine. Noise strongly increases with vessel speed (Erbe 2002) and large, powerful engines are noisier than small engine types (Young and Miller 1960).

Therefore, we would like to stress the importance of the implementation and control of management measures to regulate whale watching activities at the Azores before these will be expanded. In the current situation, with limited vessel abundance and limited control, we find profound impacts on dolphin behavior. Our results show that whale-watching pressure –and its negative impacts- could be significantly reduced by limitation of the number of whale-watching vessels in an area and the use of silent engines, such as outboard water jet engines. Moreover, vessel noise can be strongly reduced by reducing vessel speed. Erbe (2002) proposed a maximum cruising speed of 10km/h within a few hundred meters of cetaceans and a minimum vessel distance of 50 m (killer whales), to avoid hearing damage and change in behavior. Also, pressure could be reduced by the implementation of fixed intervals of limited vessel presence during 'resting hours'.

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Tables:

Table 1. Mean, maximum and median daily vessel abundance per month. Low season: May, June, September and October; High season: July and August.

Month	Mean	Maximum	Median
May	0.1	2	0.0
June	1.1	5	0.0
July	4.8	17	4.0
August	7.3	18	6.0
September	2.5	10	1.5
October	0.2	2	0.0
Total	2.7	18	0.0
Low season	1.0	10	0.0
High season	6.0	18	5.5

Table 2. Behavioral budget of Risso's dolphin. Rates are defined as the proportion of time spent per behavioral type. Low season: mean value May, June, September and October; High season: mean value July-August. The activity rate for socializing comprises both socializing and mating behavior (mating 30-50%).

	Activity rate	Low season	High season
Resting	0.28	0.31	0.25
Foraging	0.09	0.09	0.09
Socialising	0.23	0.22	0.24
Traveling	0.40	0.38	0.42

Table 3. The impact of whale watching activities on the activity rates of Risso's dolphin. Statistical results from the censored normal regression model, using a general-to-specific approach. Only results for variables with p< 0.05 are shown. Significant results for time variables are not shown (outlined in text). N=446 observations. ***a****. Causality between resting rate, vessel abundance in the high and low season, time of day and time of year.* ***b.*** *Causality between resting rate, squared vessel abundance, time of day and time of year.* n.s.*: not significant.*

Resting		Coefficient	Std. Error	z-Statistic	Probability (p)
a	Constant	0.007	0.095	0.078	0.938
	Vessel abundance high season	-0.094	0.035	-2.697	0.007
	Vessel abundance low season				n.s.
b	Constant	-0.058	0.068	-0.845	0.398
	Squared vessel abundance	-0.016	0.006	-2.778	0.006
Traveling					
a	Constant	0.098	0.101	0.976	0.329
	Vessel abundance high season	0.115	0.037	3.091	0.002
	Vessel abundance low season				n.s.
b	Constant	0.337	0.079	4.269	0.000
	Squared vessel abundance	0.014	0.005	2.465	0.014
Foraging					
a	Vessel abundance high season				n.s.
	Vessel abundance low season				n.s.
b	Constant	-1.678	0.361	-4.645	0.000
	Squared vessel abundance				n.s.
Socialising					
a	Vessel abundance high season				n.s.
	Vessel abundance low season				n.s.
b	Constant	-0.861	0.134	-6.410	0.000
	Squared vessel abundance				n.s.

Figures:

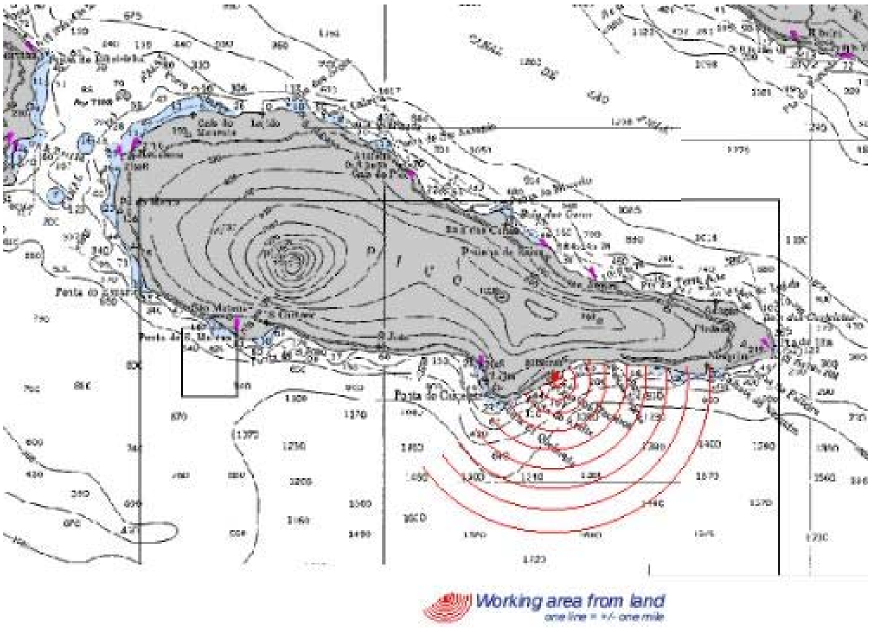

Figure 1. Research area from land, Santa Cruz das Ribeiras, Pico. Curved lines indicate the sighting range from the research platform during good sighting conditions (approx. 15 km zone; 8 nautical miles).

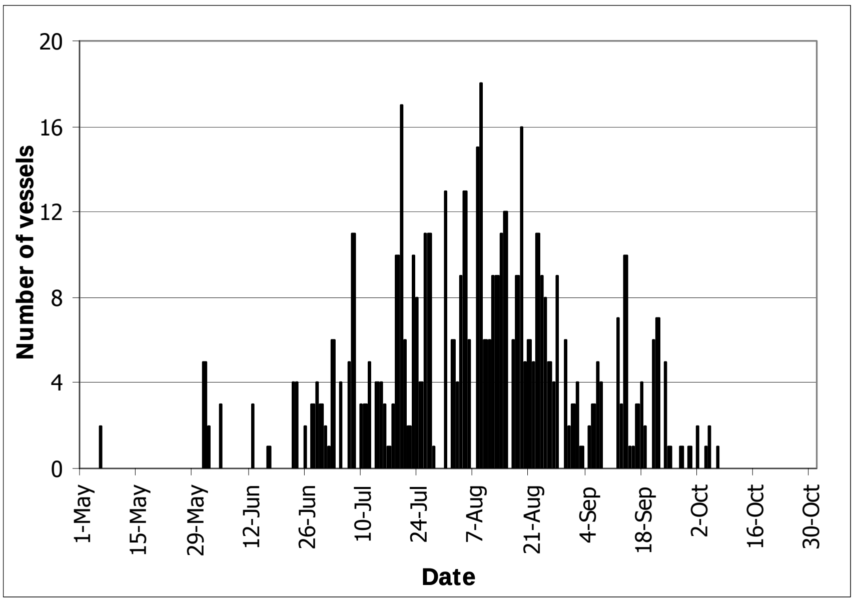

Figure 2. Whale-watching vessel abundance in the research area, May-October 2004.

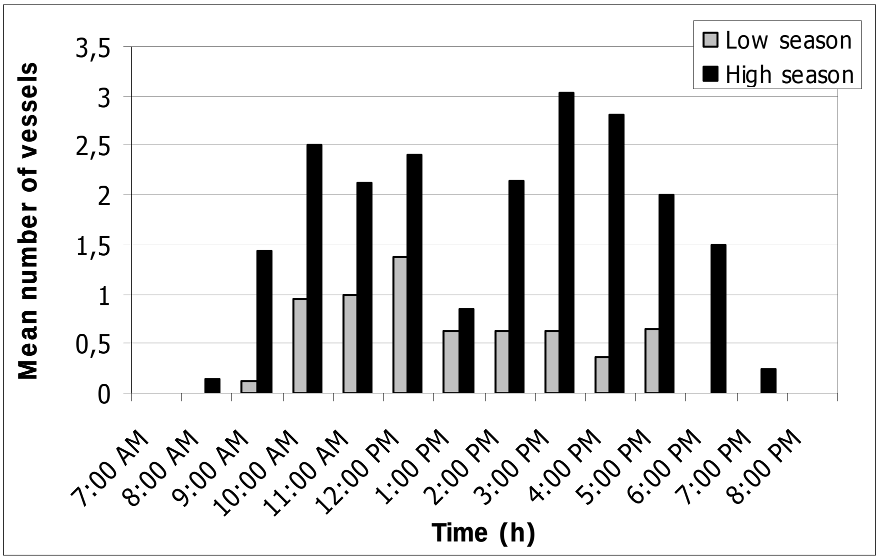

Figure 3. Whale watching vessel abundance at 1-hour intervals during the low season (gray bars) and the high season (black bars).

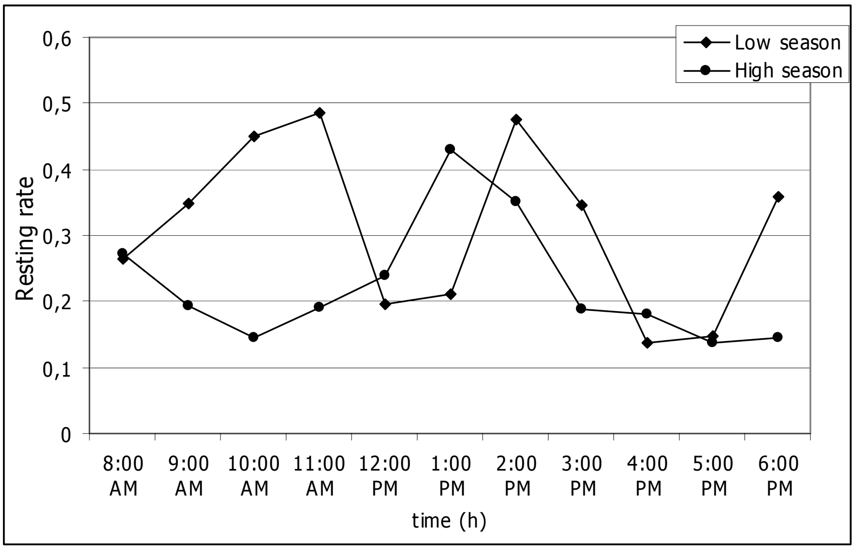

Figure 4. Risso's dolphin resting rate during the day at 1-hour intervals. Values state the proportion of time spent resting per 1-hour interval per day. The pattern shifts between periods of low (May, June, September, October) and high (July, August) intensity of whale- watching activities.