Aquatic Mammals 2002, **28.3,** 267–274

Short-term reactions of sperm whales (*Physeter macrocephalus*) to whale-watching vessels in the Azores

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Abstract

There is a great lack of information on the effects of boat operations on sperm whales (*Physeter macrocephalus*), which is the target species of the recent whale-watching industry in the Archipelago of the Azores. During the 1998 Azorean whale-watching season, between 4 June and 23 September, observations were carried-out from land-based lookouts and at sea from whale-watching boats to quantify short-term reactions of sperm whales to the presence and manoeuvres of boats. Results from land-based observations did not indicate changes in the behaviour of sperm whales, either due to the presence of boats or when exposed to inappropriate boat manoeuvres (as designated by proposed Azorean legislation). From boat-based observations, change in the whale's speed and the presence of aerial displays were significantly more frequent when facing inappropriate boat manoeuvres. The presence of swimmers also led to a higher frequency of aerial displays by whales. In the presence of boats, mature females and immature individuals significantly increased their individual mean blow interval when accompanied by calves. Although some indications of disturbance were detected, we found no clear pattern of short-term reactions of sperm whales to whale-watching boats. It is strongly recommended that the activity is continuously monitored to assess its long-term effects, which generally remain unclear.

Key words: boat-based observations, land-based observations, *Physeter macrocephalus*, behaviour, whale-watching, short-term reactions, Azores, sperm whale.

Introduction

Cetaceans always have aroused human emotions and scientific interest. With the current increase in environmental awareness the whale-watching tourism industry is growing worldwide. This activity was recognized by the International Whaling Commission as '... contributing largely to the economy, education and to the furthering of scientific knowledge of a number of countries ...' (IWC, 1993). It is necessary that this activity is monitored, to guarantee a sustainable use of cetaceans as a resource.

In the Azores Archipelago, whale-watching has been occupying an increasingly important role at a socio-economical level. The activity is growing rapidly, having registered 100 clients in 1992, the first year of operation, to approximately 7000 in 1998. In the waters around the Azorean archipelago, located in the Northeast Atlantic (see Fig. 1), 22 confirmed cetacean species have been recorded (Reiner, 1990; Reiner *et al*., 1993; Steiner, 1995). The archipelago has a volcanic origin, which results in the lack of a continental shelf. These reasons make the Azores a privileged place for watching oceanic cetacean species close to the shore (Santos *et al*., 1995).

The sperm whale (*Physeter macrocephalus*) is the main target species of the Azorean whale-watching activity. The area south of Pico Island is one of the most important places for this activity, in the same way that formerly it was one of the most prosperous Azorean sperm whaling grounds. The whale-watching season starts in late April and lasts until September, when appropriate climatic conditions can be found. The whale-watching fleets operate mainly with small inflatable boats powered with out-board engines and depend on directions given, by VHF radio, from land-based observers, who locate the animals.

The sperm whale is the largest of the odontocete cetaceans, displaying a high degree of sexual dimorphism. It spends about 75% of its time foraging, in which it performs a series of long and deep dives (sometimes for about 40 min reaching 1000 m)

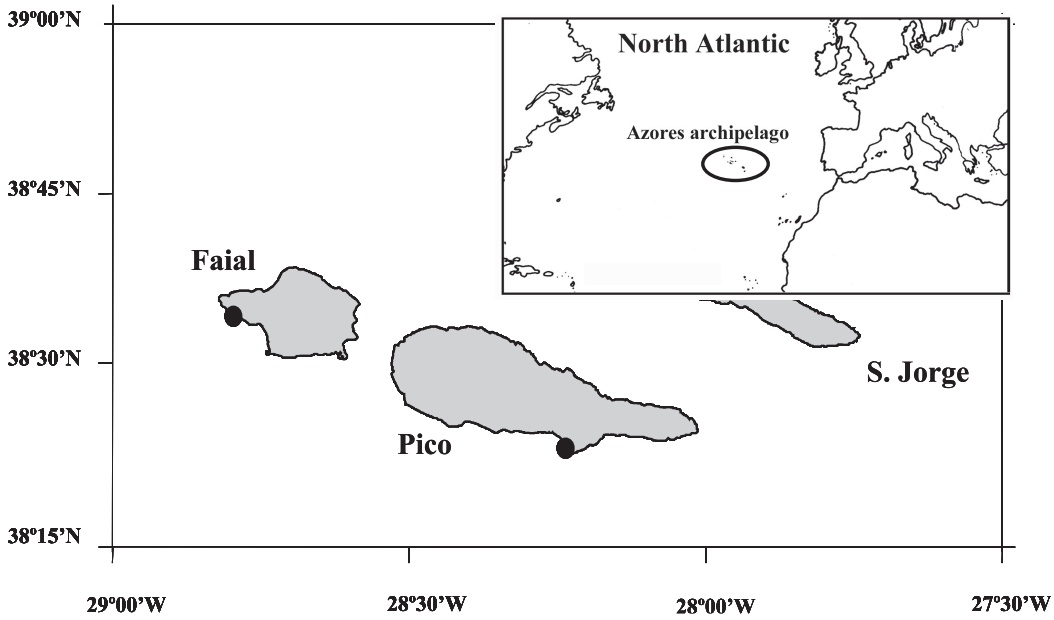

Figure 1. Map with three of the nine islands of the Azores Archipelago showing the location of the two land-based lookouts.

searching for prey (mostly cephalopods). These dives are interspersed with recovery periods of about 10 min at the surface (Best, 1979; Clarke *et al*., 1980; Papastavrou *et al*., 1989). When socializing or resting, the whales stay at or near the surface for longer periods, almost immobile or interacting with each other. Mature females typically form groups with calves and immature individuals and inhabit temperate to tropical waters. Mature males are solitary and frequent colder waters, occasionally visiting females in warmer waters to breed (Best, 1979; Whitehead *et al*., 1991). The Azores Archipelago is frequented by female groups more often than by mature males (Gordon & Steiner, 1992).

There is a great lack of information on the effects of boat operations on sperm whales. We found three studies on this topic, all conducted onboard; two have been carried-out by McGibbon (1991) and Gordon *et al.* (1992) in New Zealand, and another by Eberhardt (1993) in Norway. All had as targets male sperm whale populations. However, all are still only available as unpublished reports. The Gordon *et al.* (1992) study, which differentiates between resident and transient whales in the area, described high variability in behaviour among individuals. Obvious reactions were noticed when the whales were exposed to careless boat handling. The study was carried-out onboard and therefore, could not rule-out the effects of the observation vessel on the behaviour of the whales. No references were found on land-based remote observations of sperm whales.

The tourism activity is at an initial phase of development in the Azorean Archipelago and there is an increased need for scientific knowledge on the interactions between whale-watching and cetacean communities. This study was carried-out during the formulation of the first regional management plans, which included a code of conduct for the whale-watchers in the vicinity of cetaceans. By then, the operators were aware of this ethical code of conduct, which in part had been suggested by them. This code of conduct was integrated in the Azorean legislation that came into force in March 1999. The aim of this study is to present a preliminary description of short-term (immediate) reactions of sperm whales due to the presence of whale-watching boats, in the light of the codes of conduct proposed for legislation. It also discusses the two methods of observation used (direct and remote) and their utility for this topic.

Materials and Methods

Data collection

Land-based observations were carried-out from two old whaling lookouts, one located in the south of the Island of Pico ('Vigia da Queimada', at a 75 m height) and the other southwest of the Island of Faial ('Vigia dos Capelinhos', at a 110 m height) from 4 June to 23 September 1998, whenever

visibility and sea conditions allowed, between 07:30 and 21:00h (Fig. 1). Searching and tracking of whales was made using 15x80 Steiner binoculars with a compass mounted on tripods, performed by two observers simultaneously. One of the observers was an experienced lookout that worked in a whaling company searching for sperm whales for 36 years. Whenever a whale or group was sighted, information was annotated on data sheets and the search proceeded. Only sperm whale sightings made up to 10 nmi offshore were investigated (maximum range for reliable observations).

Opportunistic boat-based observations were carried-out between 3 July and 15 September 1998. One researcher joined whale-watching trips whenever possible and registered data on a tape recorder.

For both methods, if a group was seen to split, or joined-up with another group during a track, only one of them was considered for details and registered as a new sighting (Best *et al*., 1995). If no boat was in the vicinity of the whales, the new group to be followed was randomly chosen. If a boat was present, the group closer to the boat was followed.

For all sightings (from lookouts) and encounters (at sea), information on group size, individual relative sizes, and group type was registered. One observer registered the observations continuously. Behavioural variables recorded for whales were heading, speed, spatial arrangement (from lookouts), swimming pattern (recorded as constant or erratic, from at sea observations), diving pattern (fluke-up or not), aerial displays (e.g., spy hop, breaching, lob-tailing), and activity (behavioural state, such as feeding or socializing/resting; see IFAW, 1996).

Subsequently, behavioural analysis was based on the presence/absence of changes in behavioural variables (Martin & Bateson, 1993). Changes in sperm whales behaviour were considered to occur whenever one of the following was observed: change in heading exceeded 30°, abrupt change in swim speed, altered spatial arrangement in any way, erratic swimming pattern, or a deep dive not preceded by a fluke-up (adapted from IFAW, 1996).

For land-based observations, groups, were considered as a unit for statistical treatment (i.e., if a change was detected in one individual it was considered to occur in the group). For boat-based observations, the observer would do a continuous scan-sample of all individuals in a group. Individuals were treated as statistical units, either when isolated or belonging to a same group.

Whale size was categorized in three classes: small (*ca*. <6 m), medium (*ca*. 7 to 12 m), and large (*ca*. >13 m), with the first corresponding to calves, the second to mature females and immature individuals, and the third to mature males (Best, 1968, 1969). In this study, three group types were designated according to their known social structure: small and medium-sized whales formed mixed groups, the large-sized whales constituted male groups (usually lone individuals), and all sizes together formed mixed groups with visiting males.

For each observation, the presence or absence of boats was noted. Boats were considered to be 'present' when the distance to the closest whale was *ca*. <500 m. Number of boats, boat type, boat manoeuvres (such as distance, speed, and angle), and the number of swimmers (if present) were registered. Two periods were distinguished during boat-based data collection: approach to cetaceans and manoeuvres during the period of encounter. These were classified as 'correct' or 'inappropriate' in the light of the codes of conduct described in the first Azorean legislation proposal. The proposed policy stated that: the approach should be within an angle of 60° from behind with a constant speed at a maximum of 4 kts. During the encounter, the boat should be positioned in an angle of 60° from behind, keeping a minimum distance of 100 m from the nearest whale (if feeding or socializing). The swim speed of the whales should never be exceeded. The encounters should not exceed 30 min and only two boats were allowed within a distance of 400 m. No swimming with whales should be allowed.

Ventilation patterns

Ventilations were recorded with a chronometer to measure the interval (in sec) between consecutive blows. This only happened whenever the observer could guarantee that only one individual was being measured. Individual mean blow intervals (MBI) and standard errors (SE) were calculated by averaging the measured intervals. Only the last 20 blow intervals before fluking-up were considered for statistical procedures. Blow intervals >50 s were excluded from the analysis; these typically represent shallow dives during a surface sequence (Gordon & Steiner, 1992). The ventilation pattern of small whales was not analysed, due to the low sample size, since priority was given to medium-sized whales. Differences between ventilation data collected from both methods of observation were investigated.

Statistical procedures

Because the hypothesis of normality and homogeneity of variance of the behavioural data collected was rejected, non-parametric statistics were used for analysis. Moreover, independence of events could not be assured. The Fisher Exact Test was used in the analysis of discrete data (presence or absence of changes in behaviour) in small samples and when dealing with boat manoeuvres (correct or inappropriate) (Martin & Bateson, 1993).

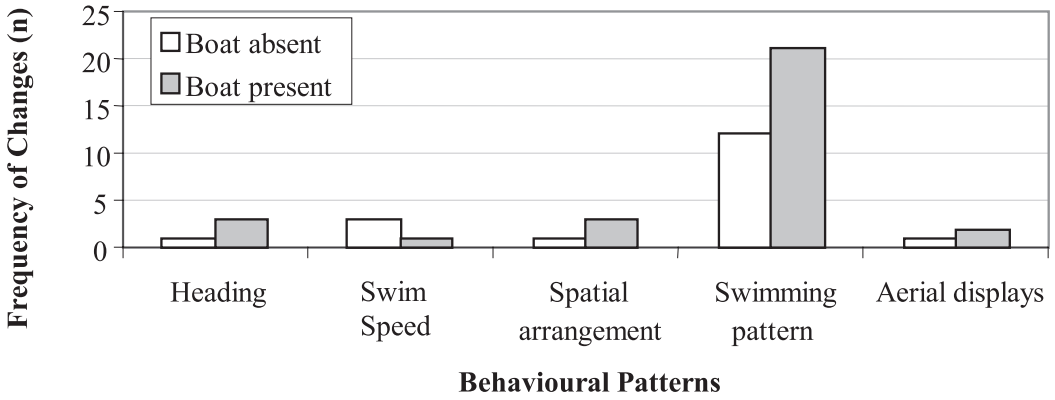

Figure 2. Frequency of changes of the behavioral patterns of sperm whales in the presence and absence of boats (total n=64). Results from land-based observations.

For land-based observations, presence of changes in behaviour and the ventilation patterns were compared in the presence and absence of boats. For both methods of observation, and when boats were present, changes in behaviour were compared between correct and inappropriate boat manoeuvres. Although the hypothesis of normality (Kolmogorov-Smirnov Test) was accepted for ventilation data, there was no homogeneity of variance in the sample (Levene's Test). Moreover, the non-assurance of independence of events and a small sample size in some cases makes the use of non-parametric statistics more appropriate. Mann-Whitney *U* Test was used to investigate differences in ventilation patterns.

The level of significance used in this study for rejection of all null hypotheses was $P \leq 0.05$. Statistical procedures followed Zar (1996) and data were analysed using the software *Statistica for Windows*© version 5.5 (StatSoft, Inc., 1999).

Results

Land-based observations

An overall observation effort of 187.5 h was conducted on 39 different days, of which 84.5% was south of Pico Island. A total of 216 sightings were recorded, comprehending nine different cetacean species. Sperm whales were sighted 69 times, of which 64 were up to 10 nmi offshore and are considered here for statistical procedures. A total of 49 sperm whale sightings comprehended isolated individuals and the remaining 15 comprised groups. The groups averaged 3.1 ($\pm$ 0.3 SE) whales per group, with a maximum of five. Of the group types observed, 34 (53%) were mixed groups, 16 (25%) were males, and 14 (22%) remained undetermined. No mixed groups with visiting males were recorded. Calves were registered on 14 occasions, always included in mixed groups. For 43 (67%) of the sightings, sperm whales were reported in feeding activities and for 3 (5%) in socializing/resting. In the remaining 18 (28%) occasions, activity type was not possible to determine.

Whale-watching boats were present in 39 (61%) of the 64 sperm whale sightings. No change in apparent activity, such as feeding and socializing/resting was ever registered, despite the presence of whale-watching boats. Change of heading, spatial arrangement, diving pattern, and frequency of aerial displays was greater in the presence of boats. Changes in swim speed occurred more often in the absence of boats. However, none of these differences were statistically significant (Fisher Exact Test, n=64; heading: $P=0.489$, speed: $P=0.161$, spatial arrangement: $P=0.489$, swimming pattern: $P=0.311$, aerial displays: $P=0.664$, Fig. 2).

Boats entirely respected the regulations proposed in 18 (46%) of the encounters. Approach was inappropriate on 10 (26%) occasions, and manoeuvres during encounters were inappropriate on 18 (46%) occasions. The angle was the most violated rule observed during approaches (9%, n=6). Violating angle and distance simultaneously were the most frequently observed inappropriate manoeuvres during encounters (12.5%, n=8). There were no significant effects of inappropriate boat handling manoeuvres on any of the behavioural patterns analysed (Table 1).

Boat-based observations

In 25 days of fieldwork, 106.8 h was spent at sea. A total of 107 encounters involved nine different cetacean species; 40 were sperm whales and investigated herein. During these encounters, a total of 80 individuals was observed, 18 of which were isolated. Mean group size of the 22 groups observed was 3.1 ($\pm$ 0.3 SE), with a maximum of seven individuals.

Table 1. Fisher Exact Tests statistical significance of the effect of boat manoeuvring (during approach and encounter) and of the presence of swimmers on several sperm whales behavioural parameters analysed. Results from land-based and sea-based observations.

		Approach		Encounter		Swimmers	
Method	Behaviour	n	P	n	P	n	P
Land	Heading	37	0.376	38	0.541	—	—
	Speed	37	0.730	38	0.526	—	—
	Spatial arrangement	6	0.500	5	0.700	—	—
	Diving pattern	33	0.257	36	0.470	—	—
	Aerial displays	37	0.780	38	0.730	—	—
Sea	Heading	69	0.546	63	0.185	69	0.150
	Speed	80	0.187	74	0.000*	80	0.066
	Swimming pattern	76	0.596	48	0.610	76	0.174
	Diving pattern	51	0.114	48	0.519	51	0.530
	Aerial displays	80	0.187	74	0.000*	80	0.000*

* Significant difference at $P \leq 0.05$.

On four occasions, all size categories were observed together, with mature males visiting mixed groups. The remaining three records of large whales comprised lone individuals. The presence of calves was registered on 12 occasions. Feeding was the main activity observed (55%, n=22), while socializing/resting was reported in 6 (15%) of the observations, and on 12 (30%) occasions the activity was not classified.

Only a single whale-watching boat (with the observer onboard) was present on 75% of occasions (n=40), with a mean of 1.6 ($\pm$0.1 SE) boats per encounter, and a maximum of six. In 16 (40%) of the encounters, boats entirely respected the regulations proposed. The angle was the most commonly disrespected rule of approach (6 of 9, 67%). Simultaneously, inappropriate manoeuvres were the mostly observed during encounters (5 of 17, 29%). When swimmers were put into the water the boat would position ahead of the whale and drop the swimmers in their path. In the nine occasions observed, swimmers were equipped with snorkeling gear. Of these, five were with a single swimmer and a maximum of four swimmers was seen once.

No change in feeding or socializing/resting was ever observed. The behaviour of the 80 individuals observed was analysed. For each test performed, when n<80 the behaviour was undetermined in the remaining occasions. It was verified that changes in swim speed and the presence of aerial displays were significantly more frequent when exposed to inappropriate boat manoeuvres (changes in speed: correct manoeuvres n=3, inappropriate manoeuvres n=19) (Fisher Exact Test: n=74, P=0.00) (presence of aerial displays: correct manoeuvres n=2, inappropriate manoeuvres n=20) (Fisher Exact Test: n=74, P=0.00). The frequency of aerial displays was significantly higher when swimmers were in the water (frequency of aerial displays: absence of swimmers n=9, presence of swimmers n=13) (Fisher Exact Test: n=80, P=0.00). No statistically significant changes were detected in any of the other parameters analysed, such as heading, swimming pattern, or diving pattern due to the effect of boat manoeuvring or the presence of swimmers (see Table 1).

Ventilation patterns

A total of 34 sperm whales ventilation cycles was considered here. No differences were found in the medium-sized whale's MBI without calves and in the presence of boats between land-based (MBI=13.6 s, $\pm$0.7 SE, n=7) and boat-based observations (MBI=14.0 s, $\pm$1.3 SE, n=7). Subsequently, ventilation data were pooled from both methods when boats were present and compared with the 'control' sample when boats were absent (observed from the lookouts only).

No statistically significant differences were found in MBI between medium-sized whales (13.9 s, $\pm$2.8 SE, n=28) and large whales (18.7 s, $\pm$3.3 SE, n=6).

The presence of calves did not cause a significant effect on the MBI of medium-sized whales (accompanied by calves: MBI=15.9 s, $\pm$1.6 SE, n=4; not accompanied by calves: MBI=13.5 s, $\pm$0.5 SE, n=24). No significant differences were found between the MBI of medium-sized whales when boats were present (MBI=14.4 s, $\pm$0.7 SE, n=17) or absent (MBI=13.0 s, $\pm$0.8 SE, n=11). However, when boats were present, medium-sized whales showed a significantly higher MBI when accompanied by calves (with calves MBI=17.3 s,

± 1.2 SE, n=14; without calves MBI=13.8 s, ± 0.7 SE, n=3) ($U_{14,3}$=5.000, *P<0.05)*.

No statistically significant differences were found between the MBI of large-sized individuals when boats were present (MBI=20.5 sec, ± 4.9 SE, n=4) or absent (MBI=15.1 sec, ± 0.8 SE, n=2).

Discussion

Methods

Much of the behaviour of sperm whales is veiled to observers above the water surface, especially when whales are foraging. In addition, the long range of most land-based observations means that, it is most likely that individuals are not seen when they are just below the surface. Moreover, the number of calves can be underestimated (Whitehead, 1996). Despite this, land-based observations give a better understanding of group behaviour than boat-based observations. The most striking advantage of land-based observations, which has not been reported before for sperm whales, is that it allows the collection of information on the undisturbed behaviour of whales. It also makes possible the collection of information before, during, and after boat encounters. In addition, it does not introduce new potential sources of disturbance to the whales. Conversely, the proximity of boat-based observations allows the collection of more detailed information on individuals, particularly calves. Furthermore, it provides the chance of making photo-identification and acoustic studies. Opportunistic observations onboard whale-watching vessels that are near whales anyway should be made. The disadvantages of this method are that it provides information on the behaviour of potentially disturbed whales and it is difficult to evaluate the level of disturbance imposed by the presence of the boat itself.

For the purposes outlined here, we suggest that the use of remote observations is most valuable, since it allows the comparison of the natural behaviour of an animal with behaviour under different sources of possible disturbance. The use of a theodolite allied with innovative geomatic techniques, would allow the improvement of the accuracy in the geographic positioning and distance assessment.

Behaviour

Feeding was the most common activity observed in sperm whales, as verified by Gordon & Steiner (1992), in this area. In fact, the mean group size observed in this study (3.1 individuals) was within the values reported by Whitehead & Arnbom (1987) for foraging sperm whales, seen at the surface in small sets of one to four individuals. The predominance of feeding over other activities, and the frequency of observed calves, suggests that this area is an important feeding ground for female sperm whales and their offspring. Mutual caring for calves by females against predators and cooperation in the location and capturing of food are the two main factors for the evolution of gregariousness of the species (Best, 1979).

Changes in the activity apparently performed by sperm whales, such as feeding or socializing/resting, due to the presence of boats were not detected in this study.

From the analysis of land-based observations, we found no significant evidence of disruption in sperm whales behavioural patterns due to the simple presence of boats, although there seemed to be a tendency towards disturbance (Fig. 2). A land-based study of killer whales (*Orcinus orca*) identified an increase in swim speed (but not change in course) as a common response to the presence of boats (Kruse, 1991). Regarding boat manoeuvring, results from land-based observations did not point towards significant differences in behavioural changes when exposed to correct and inappropriate boat manoeuvres, despite the high rate of inappropriate boat handling observed. However, from boat-based observations we detected significantly higher changes in speed and in the frequency of aerial displays of individuals when exposed to inappropriate boat manoeuvres. Gordon *et al*. (1992), in a boat-based study in New Zealand, found that in 10% of boat encounters, sperm whales were disturbed when facing careless boat handlers that did not respect the local guidelines about minimum distance and approach. Whale reactions included no fluking-up before diving, abrupt heading changes, and higher frequency of aerial displays. In our study, the percentage of inappropriate boat manoeuvring verified by both methods of observation used was similar. Differences in the results found between the two methods could be due to a higher sensitivity of *in situ* observations, through the detection of smaller changes in behaviour, but at the cost of introducing a possibly new source of disturbance.

The presence of swimmers in the water led to a significant increase in the aerial displays performed by sperm whales, but it did not affect any of the other behavioural parameters analysed. However, these observations were based on a small sample size (n=13). In a study in New Zealand, Bejder *et al*. (1999) did not detect significant changes in the behaviour of Hector dolphins (*Cephalorhynchus hectori*) due to the presence of swimmers. These authors suggested that this evidence could be answered by the easy avoidance of swimmers by dolphins and concluded that dolphins avoided more pronouncedly the presence of boats than the swimmers themselves, which does not apply in the case of sperm whales. It is also possible that swimmers

were not seen as a threat by sperm whales. A larger sample size of observations would allow clearer conclusions.

The fact that in this study immediate disturbances were not clearly detected does not imply a lack of responses. Further research to increase sample size and observation time is advisable, to assess the effects of whale-watching activities at the population level.

Ventilation patterns

The ventilation results in this study cannot be directly compared to others of the same species (or different species) since they employ a different statistical treatment. Herein, the individual MBI is the unit compared among individuals, instead of a set of blows per individual classes. Individual MBI prevents the statistical error known by pseudoreplication, which happens when treatments are not replicated (though samples may be) or replicates are not statistically independent (Hulbert, 1984). Moreover, known studies of sperm whale ventilation were conducted onboard vessels that could not discard the effect of their own presence in the blowing behaviour of the whales.

Blow intervals change significantly with order during a surfacing sequence, the last blows being higher and more likely to be seen than the first ones, which occur immediately after surfacing (Gordon & Steiner, 1992). For this reason, only the last twenty blows of a set before fluke-up per individual were investigated.

The fact that no statistically significant differences between the MBI of medium-sized and large whales were found, could be due to the very low sample size of large males (n=6). Gordon & Steiner (1992) studied ventilation and dive patterns of sperm whales and found a higher MBI for mature males (15.9 s) (after excluding blow intervals >50 s, which accounted for much of the variance) than for females (12.4 s).

Some authors suggested that blow rates could be useful in characterizing different behavioural states and, therefore, to assess the effects of disturbance on whales (Würsig *et al.*, 1986). However, others (*e.g.*, Watkins, 1986; Watkins *et al.*, 1984) argued that the use of these parameters as a feasible indicator of whales' reactions is questionable due to the natural and frequent changes in cetacean behaviour and blow frequency. The results presented here point toward longer blow intervals as a response of both mature females and immature individuals in the presence of calves and boats, although these were not significant. Moreover, it also indicated that this class of individuals, when boats were in the vicinity, showed a significantly higher MBI if accompanied by calves. Previous studies showed that females seem to show alloparental care, by reducing their dive synchrony when calves are present, and thus likely increase calf protection while permitting greater foraging freedom for mothers (Whitehead, 1996). It is then possible that the occurrence of calves by itself already interferes in adults diving physiology. In addition, the presence of whale-watching boats could amplify existing disturbances with biological significance. Conversely, boats did not seem to affect the ventilation pattern of mature males, although the small sample size did not allow clear conclusions.

Because no clear evidence of disturbance to the sperm whale population occurred due to the exposure to whale-watching boats, it did not seem necessary to suggest modifications to the actual Azorean legislation, which was enforced later in March 1999, or to prevent the growth of the whale-watching industry in the region. However, reinforcement is highly recommended facing the percentage of inappropriate boat handling observed. It is necessary to keep in mind that this work is a preliminary approach to this issue and to take in account that short-term studies might not detect long-term factors that could lead to significant biological and ecological consequences. Some of them include population distribution and negative effects on reproductive rate. In the Azores, the sperm whale possibly uses the area to mate and bear calves (Evans, 1987) and the potential disturbance to sperm whale reproduction (mating and/or calve survival) is of further concern, given the currently accepted population parameters for the species. The IWC (1982) suggested a maximum potential rate of increase of less than 1% per year for sperm whales. Future studies should focus on the carrying capacity of cetacean populations in this area and on the validation of rules proposed by legislation. The activity should be continuously monitored to assure constant revision of management plans and therefore, guarantee a sustainable use of cetaceans in the area.

Acknowledgments

We acknowledge the enterprises Espaço Talassa, Norberto Diver and Aquaçores for their support in the field. Mr. João 'Vigia' Gonçalves and Mr. Sidónio Gonçalves (from Espaço Talassa) gave invaluable support in the lookouts. We are very grateful for the valuable input of Pedro Afonso in behavioural issues. This work was partly funded by the Azorean Regional Tourism Directorate and by the EU LIFE Project 'Integrated Management of Coastal and Marine Areas in the Azores' (B4–3200/98/509). We thank Carlos Guerra, President of the Institute for Nature Conservation (Portugal) for allowing Mónica A. Silva to participate in this study. A revision by Mark Bolton, Peter Wirtz and

two anonymous reviewers greatly improved this manuscript.

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