Mother and calf humpback whale responses to vessels around the Abrolhos Archipelago, Bahia, Brazil

MARIA E. MORETE[*+], TATIANA L. BISI[*+] AND SERGIO ROSSO[+]

Contact e-mail: miamorete@terra.com.br

ABSTRACT

As the humpback whale population spreads along the Brazilian coast, whalewatching activities are becoming more frequent especially along the coast of the state of Bahia. In order to evaluate the appropriateness of the Brazilian legislation that regulates vessel approaches to cetaceans, the behaviour of humpback whale mothers and calves was studied around the Abrolhos Archipelago, an area with a high concentration of tourism vessels. Mother and calf groups were observed by means of continuous sampling and tracked along with vessels using a theodolite. Three whale-vessel categories of distances were analysed: closer than 100m (category 1); between 100-300m (category 2); and further than 300m (category 3). Rates of behavioural events and time spent in particular behavioural states of mothers and calves were compared separately in the three categories to observations of randomly selected mother and calf groups not involved in an interaction with a vessel (category 0). A total effort of 39hr was analysed including observations in each of the four categories. The results showed that differences in humpback whale mother and calf behaviour occurred mostly in the presence of vessels within distances of 100-300m. Mothers increased linearity and mean speed of movement, decreased blow intervals and time spent resting. Calves exhibited less rolling, fluke-ups and others active behavioural events, as well as diminished resting time. During interaction with vessels, the frequency of potentially important behaviours, both for mothers and calves, reduced, probably as a response to the approaching whalewatching vessels. Repeated short-term behavioural disturbances might lead to cumulative effects that may result in risks for species conservation. It is recommended that the Brazilian legislation should include a 300m-radius restrictive zone around mother and calf groups or include a 300m caution zone, where boats should reduce speed and avoid sudden changes in engine status and direction. The environmental education work with local communities along the coast must be continued and constant.

KEYWORDS: HUMPBACK WHALE; WHALEWATCHING; SHORT-TERM CHANGE; SHORE-BASED; BRAZIL; REGULATIONS; BEHAVIOUR; SOUTHERN HEMISPHERE; ENERGETICS

INTRODUCTION

For many years, Abrolhos Bank was considered the only known breeding and calving ground for humpback whales (*Megaptera novaeangliae*) in the western South Atlantic, however there is evidence that the population that winters off the Brazilian coast has increased in recent years (Freitas *et al*., 2004) and humpback whales are now being encountered along the entire coast (Andriolo *et al*., 2006; Martins, 2004; Pizzorno *et al*., 1998; Zerbini *et al*., 2004). Nevertheless, the area surrounding the Abrolhos Archipelago is still considered unique because of the high concentration of whale groups with calves (Martins *et al*., 2001; Morete *et al*., 2007; Morete *et al*., 2003b).

Accompanying this increased occurrence of humpback whales along the Brazilian coast are whalewatching activities which are becoming more frequent, not only around the Abrolhos Archipelago, but in other sites along the coast of Bahia (Cipolotti *et al*., 2005). Whalewatching is a particularly lucrative industry in many parts of the world and is often seen as an economic alternative to whaling (e.g. Hoyt, 1995). However, several studies worldwide suggest that whalewatching can cause short and long-term adverse reactions by humpback whales, perhaps affecting them at the population level. Short-term reactions include changes in respiration, diving and swimming patterns, and/or exhibitions of particular behaviours (breaching, head slap). These changes may be correlated with vessel numbers, proximity, speed and direction changes and depend on the composition of the group of whales present (Baker *et al*., 1983; Baker *et al*., 1982; Bauer, 1986). Longer-term reactions such as cow-calf pairs becoming less frequent close to shore with increasing numbers of recreational boats have been suggested by Glockner-Ferrari and Ferrari (1985; 1990) and Salden (1988). However, the number of whales in Hawaiian waters seems to be increasing despite continuous exposure to human activities (Bauer *et al*., 1993). Similarly, humpback whales still use the waters off Cape Cod, Massachusetts, USA as an annual feeding ground, despite exposure to many kinds of vessels (Clapham *et al*., 1993). Watkins (1986) noted that humpback whales off Massachusetts have gradually changed their reactions towards whalewatching boats, suggesting a positive habituation. However, a long-term study (by Bejder *et al*., 2006a) on Indo-pacific bottlenose dolphins (*Tursiops* sp.) suggested that although one could think of dolphin moderate short-term behavioural responses towards whalewatching vessels as a process of habituation, it might be a process of displacement of those individuals more sensitive to dolphin-watching tourism, resulting in a decline in relative abundance (Bejder *et al*., 2006b). Gill *et al*. (2001) proposed that the decision of whether or not to move away from disturbed areas is determined by other factors such as the quality of the site being occupied, so animals with no suitable habitat nearby may be forced to remain despite disturbance, regardless of whether or not this will affect their survival or reproductive success.

Scheidat *et al*. (2004) suggested that mother-calf humpback whale pairs may be especially vulnerable to whalewatching disturbance since some potential avoidance responses (for example, increased swim speed and longer dives) may be beyond the physiological limits of the calf and because calves may have less opportunity to nurse if the mother is forced to increase her speed or change her

[*] *Instituto Baleia Jubarte. Rua Barão do Rio Branco, 26, Caravelas, Bahia, 45900-000, Brazil.*
[+] *Departamento de Ecologia –Instituto de Biociências. Universidade de São Paulo. Rua do Matão, 321, São Paulo, São Paulo, 055088-900, Brazil.*
300m before arriving at the group and not leaving the group after interaction.

behaviour from resting to swimming. Lien (2001) suggested that mother and calf groups are especially vulnerable to human presence, and so they should receive more strict protection under regulations.

Baker and Herman (1989) reported that most behavioural changes of humpback whales on the Alaskan feeding ground were caused by vessels within 400m of a group. However, behaviour could be affected by vessels up to 4km distant. Watkins (1986) shows that whales can have negative reactions (i.e. changes from activity to inactivity, usually suspending vocal activity, startle responses including sharply turning away or diving quickly, persistent movement away from the sources of stimuli) when within 100m of sound sources (sudden and loud sounds such as engine start up, ships' close approaches, propeller cavitation during reverse or sharp turns). Most whalewatching guidelines and/or legislation worldwide suggests a 300m radius from a whale group as a caution area, from which the speed of the vessel should be decreased and the closest approach of a vessel towards a whale group is normally 100m. The Brazilian legislation (117/1996) concerning whalewatching activities states that boats cannot go closer than within 100m of a whale group, but does not consider any caution zone before this minimum distance. Stimulated by this legislation, the objective of this study was to evaluate the responses of mother and calf groups to vessels in three distances categories, based on 100m and 300m limits. Three vessel-whale distance categories were analysed: vessel present further than 300m; vessel within 100 to 300m; and vessels closer than 100m.

The behaviour of humpback whale mothers and calves was studied around the Abrolhos Archipelago, an area of high concentration of tourist vessels, in order to evaluate whether it is necessary to improve Brazilian legislation.

MATERIALS AND METHODS

The Abrolhos Bank (16°40'S to 19°30'S, 37°25'W to 39°45'W) is an extension of the continental shelf on the east coast of Brazil. It is characterised by water that is both warm (winter average temperature =24°C) and shallow (average depth ≈20m), as well as by an extensive coral reef system. These features are typically associated with breeding grounds for humpback whales in other locations around the world (e.g. Clapham, 1996; Whitehead, 1981; Whitehead and Moore, 1982). The land-based observation station (17°57'44''S, 38°42'22''W) was located 37.8m above highest sea level, on the top of the western portion of the Santa Barbara Island, in the Abrolhos Archipelago. The height of the land-station was measured using a 'total station' (a device which may produce an error of 3cm in the height being measured at a distance of 10km). The measurements were made from Siriba and Redonda Islands (both less than 500m from the land station) so this error was unlikely to be problematic. The study area encompassed a radius of 9.3km around the land-station (Fig.1), however to reduce measurement error of the whale's position, intrinsic in theodolite tracking approach (see Würsig *et al*., 1991), only those whale and boat interactions that occurred within 3.5km radius of the land-station were considered for this study. At 3.5km from the land-station, a 10cm error in the instrument's height-above-sea-level would produce an error of 10m in the whale or boat position, a 50cm error in instrument's height could produce an error of 48m. Unfortunately, the measurement of swell height is very difficult from the land-station, and it has been assumed that some uncertainties may have been introduced in the whale position due to swell. Limiting observations to good weather and sea-state conditions minimised these errors. In addition, the maximum error of measured distance between interacting whales is much less than the error of range from the distant land-station, making the errors in relative position much smaller (Tyack, 1981).

Field observations

Every morning, weather permitting, a one-hour scan was conducted. After the scan, a group of humpback whales would be chosen (normally one of the closer groups) for continuous sampling behavioural observations (Mann, 1999), which involved collection of behavioural data (events and states, see Altman (1974)) on a whale or group of whales containing a maximum of two adults and one calf, as recommend by Altmann (1974) for obtaining reliable data. Sampling continued until the group either moved out of the study area or until sighting conditions reduced observation quality (rain or Beaufort Sea state >4 and glare). Observations of mother-calf groups approached by vessels were collected opportunistically (i.e. when the group under observation was approached by a tourist vessel, or in some instances when our research vessel was in the vicinity and was contacted by radio to approach the group). These data were collected from 1998 to 2003, during the months of July to November, using a *Sokkia* DT5 30-power digital theodolite and *Tasco* 7×50 binoculars. The position of an object relative to the land-based observation station was obtained by measuring the angles of depression (or vertical deviation) and angles of horizontal deviation to the object. This method allows one to follow the movements of whales and boats in detail (Tyack, 1981).

The land-based station team consisted of three people: the theodolite operator, who was the principal observer; the binoculars observer; and the computer operator. The theodolite observer communicated all whale behaviour to the computer operator, who entered the data in real-time on a *Macintosh* Powerbook computer running the time-synchronised data-collection program *Aardvark* (Mills, 1996), designed for land-based cetacean studies (Frankel and Clark, 1998; Frankel *et al*., 1995). The theodolite operator also gave vocal commands for the computer operator to record the theodolite readings (position) of the target whale (or vessel) when this was possible. The theodolite operator also recorded positions of the vessel as often as possible without compromising the whale observations and took a mean of one whale position for each 1.5min of observation. The binoculars observer served as a 'back-up' since binoculars have a broader range of view than the theodolite. This observer alerted the principal observer of the approach of vessels, other whale groups in the vicinity and would check if the principal observer (theodolite operator) had missed any behavioural events.

Tide variations were entered into *Aardvark* hourly for correction of the eyepiece height of the theodolite above the surface of the water. *Aardvark* statistical outputs were used to estimate the mean whale speed and direction for each distance category.

Definitions

A calf was defined as an animal in close proximity to an adult whale, estimated to be less than 50% of the length of the accompanying animal (Chittleborough, 1965) and presumably born during the current season. A whale was considered to be a mother when it had a calf by its side. The variables used for behavioural events and states are listed and described in Table 1.

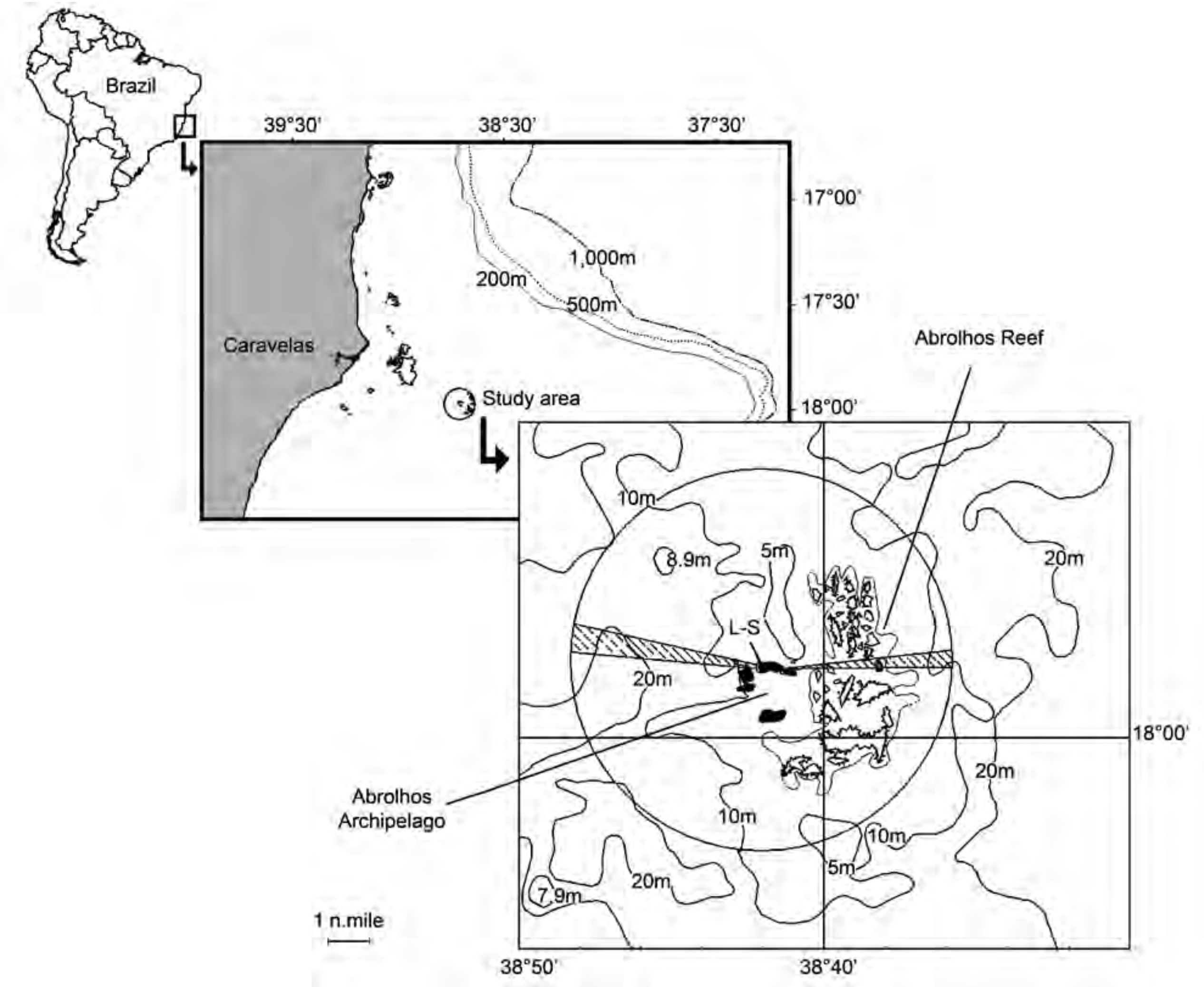

Fig. 1. The study area encompasses 9.3km (5 n.miles) radius excluding the two blind areas (to east and west) from the land-based observation station (L-S) at Santa Barbara Island in the Abrolhos Archipelago, east coast of Brazil.

Analyses

In order to evaluate the behaviour of mothers and calves in the presence of the vessel, three distances categories were created: (1) the presence of the vessel closer than 100m (category 1); (2) between 100-300m (category 2); and (3) further away than 300m[1] (category 3). Some whale groups were approached and re-approached by whalewatching or research vessels within the same continuous sampling period (e.g. a boat entered a 300m radius of a whale, spent some time with the group, left, then re-approached). In such cases, only one period of sampling in each distance category was considered for the analyses. In other words, for each continuous sampling, only one set of data from each distance category was included. Due to the opportunistic nature of this study, not all observations contained the three distance categories. Some observations commenced when the boats were already closer than 300m and fewer observations were carried out in category 1. This would be expected because in Brazilian waters, tourism boats theoretically cannot approach a whale closer than 100m (ordinance 117/1996) and in fact, all observations made in category 1 were of research vessels. This ordinance stipulates that tourism boats cannot stay longer than 30min watching a group, resulting in short periods of observations in categories 1 and 2. These shorter interactions (less than 10min in each category) were excluded from the analyses in order to reduce bias. Fifteen continuous samplings of mother and calf groups that were not approached by vessels were chosen randomly to serve as a control. This set of data was entered into the analysis as category 0.

The variables analysed for the mothers and calves are listed in Table 1. For the calves, blow rate was not taken into consideration because of the potential error of counts due to the small size of the blow which easily could be missed by the observer if the calf was 'behind' the mother (in relation to the theodolite observer), or if glare or wind were strong. Three mutually exclusive and cumulative inclusive behavioural states were considered for the mothers (swimming, tail-up and resting) and for calves (swimming, resting and milling). Calves do not perform tail-up behaviour (Morete *et al*., 2003a). Behavioural states were checked every time the whale surfaced. As positions of the mothers were obtained the variable linearity was used as an indirect measure of their milling. For behavioural states, the proportion of time the whale spent in each state was calculated.

Data from the three distance categories for mother and calf behaviours (separately) were compared to data from category 0, using a non-parametric Mann-Whitney test for two independent samples. All statistical analyses were run in the software *STATISTICA* 6.0 (Statsoft Inc, 2001).

[1] 300m before arriving at the group and not leaving the group after interaction.

Table 1

Variables including behavioural events and states to evaluate the behaviour of mothers and calves in the presence of a vessel in three distance categories and in the absence of the vessel.

Variables	Definitions
Linearity*	Calculated by dividing the distance between the first and last position of the whale by the cumulative distance covered between all recorded positions.
Mean speed*	Total distance covered divided by total time of observation.
Blow interval*	Elapse time between blows.
Blow*	Exhalation above the surface of the water.
No blow*	Surfacing with no evidence of exhalation.
Fluke up	Submerging, lifting the flukes so that the ventral side of the fluke can be exposed.
Active	Including breaches, pectoral fin slap, tail and peduncle slap, tail slashes, tail breach and head slap.
Rolling**	Including exposition of pectoral fins, movement showing the ventral part of the body, exposition of half of the fluke and belly-up.
Lap**	The calf goes on top of the mother's rostrum while the mother is resting, and almost its whole body can be observed out of the water.
Head exposition**	When the calf moves its head above the surface at an angle less than 60°.
Spyhop**	Lifting the head vertically above the surface of the water (90° angle).
Tail-up*	Behavioural state: maintaining fluke above the water for some period – see Morete *et al.* (2003a).
Swimming	Behavioural state: movement in a fixed direction (for calves) and/or in varying direction (for mothers) when the whale shows the dorsal part of the body intermittently, sometimes interspersed by diving.
Resting	Behavioural state: floating motionless, lying at the surface exposing the dorsal part of the body.
Milling**	Behavioural state: as swimming, however varying direction, within a small area – for a calf also when it swims circling the mother.

*Variables calculated just for mothers. **Variables calculated just for calves.

RESULTS

Due to the opportunistic nature of data collection, a balanced design was impossible to achieve. Excluding other humpback whale groups categories, groups observed further than 3.5km from the land station, periods of the sampling where boats re-approached the same group and observations of known individual whales that were already part of the dataset, 23 mother-calf groups observations were analysed, summing 17.2h of continuous observations of whales in the presence of vessels. Among these, 1.6hr (n=6; mean=0.26hr; SE=0.025) in category 1; 4.26hr (n=14; mean=0.3hr; SE=0.028) in category 2 and 11.33hr (n=14; mean=0.81h; SE=0.144) in category 3. A total of 22.1hr (n=15; mean=1.47hr; SE=0.198) of observations of mother and calf groups was used as control for the analyses (category 0). In all 23 whale-vessel interactions never more than one boat was present. Mean values for the rates of occurrence of behavioural events and states for mother and calf are listed in Table 2.

Mothers

The comparison of all variables for mothers, between category 0 and category 3 revealed no significant difference. Mothers' mean speed in the presence of vessels within 100m (3.98km hr^{-1}) was significantly faster when compared to the control (1.99km hr^{-1}). Between categories 0 and 2 there were statistically significant differences in linearity, mean speed, blow interval and resting state (Table 3). When compared to the absence of boats, mothers tended to move in a more straightforward manner and faster when vessels were between 100 to 300m away (category 2). Additionally, mothers' blow intervals were smaller in the presence of vessels (100-300m), leading to an increase blow rate that was not statistically different from when boats were absent. The proportion of time spent in the resting behavioural state reduced by 54%, from 27.02% (category 0-control) to 12.49% when vessels were present between 100-300m (category 2).

Calves

The comparison of all variables for calves between category 0 and category 3 resulted in no significant difference; however a significant difference was found between categories 0 and 1 and between 0 and 2 (Table 3). In the presence of boats within a radius of 300m of the calf (both categories 1 and 2), the number of rolling events decreased. When boats were between 100 and 300m away they exhibited less active events, less fluke-ups and reduced the time spent resting. When boats were closer than 100m, calves decreased the amount of time spent milling. Although the lap event was not significantly different between categories 0 and 1, it is important to note that it did not occur while boats were within 100m of the group (Table 2).

DISCUSSION

Land-based research platforms for studying cetacean behaviour, especially when the objective is to evaluate whale responses to human activities, have been used worldwide (Bauer, 1986; Frankel and Clark, 1998; Frankel *et al*., 1995; Heckel *et al*., 2001; Scheidat *et al*., 2004; Williams *et al*., 2002) because they offer the advantage of being non-intrusive, when compared to research vessels that can influence the measured response.

Many studies have shown that the responses of humpback whales to whalewatching vessels can occur at distances further than the 300m (the distance stipulated for this research). Bauer (1986) shows that several behaviours appear to be affected by the presence of a vessel within 500m and/or between 500 to 1,000m; Baker and Herman (1989) observed that humpback whale behaviour on the Alaskan feeding grounds could be affected by vessels up to 4km away, but most changes were caused by vessels within 400m.

Motivated by whalewatching guidelines and legislation around the world and especially by the Brazilian legislation, which stipulates 100m as the minimum distance of a whalewatching vessel to a group of whales, this study focussed on the presence of vessels further away than 300m, between 300 – 100m and within 100m.

Corkeron (1995) found significant differences in some humpback whale behaviours when exposed to boats within 300m. The results presented here mainly show differences in humpback whale mother and calf behaviour in the presence of vessels within a distance of 300 to 100m, when compared to the control situation (category 0: continuous sampling

Table 2

Mean values and standard deviation (SD) of rates of occurrence of behavioural events, proportion of time in behavioural states of humpback whale mothers and calves in the absence of vessels (Cat 0) and in the presence of vessels in three categories of distance: category 1 (Cat 1), category 2 (Cat 2) and category 3 (Cat 3).

	Cat 0 (no vessel)		Cat 1 (0-100m)		Cat 2 (100-300m)		Cat 3 (+300m)	
	N = 15		*N* = 6		*N* = 14		*N* = 14	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Mothers								
Linearity	0.66	0.23	0.79	0.20	0.83	0.17	0.63	0.26
Means speed (km hr^{-1})	1.99	1.65	3.98	2.71	4.18	2.83	2.38	1.39
Blow interval (min)	1.70	0.68	1.54	0.31	1.21	0.63	1.47	0.67
Blow hr^{-1}	38.59	11.85	30.82	10.94	49.84	21.63	42.11	13.77
No blow hr^{-1}	7.24	5.17	14.13	21.21	13.69	13.21	8.28	9.47
Fluke up hr^{-1}	0.53	0.87	0	0	9.05	15.88	1.30	1.99
Active hr^{-1}	0.89	1.52	0.71	1.74	0.95	1.95	0.30	0.54
Tail-up duration (min)	7.25	0.38	4.58	1.84	8.16	3.92	7.00	3.42
%tail-up	8.15	21.5	25.9	31.4	17.4	23.9	19.6	26.92
%swimming	64.83	35.60	57.45	49.38	70.13	35.43	47.42	36.40
%resting	27.02	27.77	16.67	22.21	12.49	21.29	32.94	30.67
Calf								
Fluke up hr^{-1}	1.06	2.10	0.71	1.74	0.00	0.00	0.53	1.21
Rolling hr^{-1}	7.72	13.44	0.71	1.74	3.65	12.54	9.15	13.47
Active hr^{-1}	8.15	19.10	4.27	10.45	0.15	0.55	4.16	8.19
Lap hr^{-1}	0.76	1.44	0.00	0.00	0.68	1.80	1.08	1.86
Head exposition hr^{-1}	1.45	3.43	0.71	1.74	0.76	2.24	2.17	4.83
Spyhop hr^{-1}	0.09	0.20	0.00	0.00	0.00	0.00	0.54	1.41
%swimming	53.04	36.43	54.40	50.87	70.13	35.44	42.39	35.46
%resting	15.20	19.56	40.33	45.46	5.50	14.07	18.41	18.34
%milling	31.76	32.81	5.26	12.89	24.37	28.64	39.20	27.70

Table 3

Values of Mann-Whitney test (U) and respective p value of rates of occurrence of behavioural events, proportion of time in behavioural states of humpback whale mothers and calves in the absence of vessels (Cat 0) and in the presence of vessels in three categories of distances: category 1 (Cat 1), category 2 (Cat 2) and category 3 (Cat 3). P significant at level 0.05. Significant differences appear in **bold**.

	Cat 0/Cat 1		Cat 0/Cat 2		Cat 0/Cat 3	
	U	*P*	U	*P*	U	*P*
Mother						
Linearity	30	0.242	55	**0.029**	99	0.793
Mean speed (km hr^{-1})	20	**0.051**	57	**0.036**	84	0.359
Blow interval (min)	43	0.876	50	**0.016**	78	0.238
Blow hr^{-1}	25	0.119	76	0.206	92	0.57
No blow hr^{-1}	32	0.31	82	0.315	91	0.54
Fluke up hr^{-1}	27	0.078	84	0.305	97.5	0.707
Active hr^{-1}	36.5	0.43	92.5	0.506	88	0.381
Tail-up duration (min)	0	0.083	4	0.505	5	0.738
%tail-up	29.5	0.106	78	0.134	76	0.108
%swimming	44	0.937	84	0.354	73	0.161
%resting	31	0.272	59	**0.04**	87.5	0.444
Calf						
Fluke up hr^{-1}	31.5	0.24	49	**0.001**	76.5	0.15
Rolling hr^{-1}	16.5	**0.02**	41	**0.002**	104	0.96
Active hr^{-1}	29	0.18	47	**0.002**	94	0.61
Lap hr^{-1}	27	0.08	82	0.2	102.5	0.9
Head exposition hr^{-1}	33	0.29	75	0.11	95	0.62
Spyhop hr^{-1}	36	0.25	84	0.08	100	0.76
%swimming	43.5	0.91	75.5	0.19	86.5	0.42
%resting	37.5	0.55	62.5	**0.049**	81	0.29
%milling	16.5	**0.02**	85.5	0.38	82	0.31

with no whale-vessel interaction). Mother and calf groups increased their mean speed and presented more direct displacement and the mothers decreased their blow intervals. The increase of speed in the presence of boats has been observed in other humpback whale studies (Au and Green, 2001; Bauer, 1986; Scheidat *et al*., 2004). Bauer (1986) and Baker *et al*. (1982) found that the closer the vessel, the smaller the mean blow interval and Baker (1988) stated that within 400m whales responded to close proximity of vessels by decreasing their blow intervals, as was observed for the mothers in category 2 of this study. Additionally, it was observed that mothers and calves reduced their time spent resting. Additionally, calves significantly reduced their activities above the surface (i.e. fluke-up, rolling and other active behavioural events).

The results presented here point to significant changes in humpback whale mother-calf pairs behaviour in the presence of vessels and they can be thought of as negative effects. Due to the high energetic cost of lactation (e.g. Lockyer, 1981) and the virtual absence of feeding during the winter season, mothers should theoretically spend more time in the resting state as an energy saving measure. Conversely, calves could benefit from vigorous activity in the form of play (Bisi, 2006; Thomas and Taber, 1984) since exhibiting active behavioural events leads to the development of motor skills and coordination. While mothers rested, calves were frequently observed circling them (milling) and rolling interspersed by dives, which could be related to nursing activity (Bisi, 2006). With the approach of a vessel, these behaviours (resting and presumably suckling), reduced. Normally after a captain had spotted a whale group for the first time and until the final approach, the boat changed speed and direction several times repeatedly to keep following the whale group as close as 100m. Watkins (1986) discussed that whales respond negatively to sudden and loud sounds from nearby sources, such as from an engine starting or propeller cavitation during reverse or sharp turns. However, he noted that the sounds of an engine that had been running at a particular rate for some time generally did not cause a reaction (Watkins, 1986). In fact, although whalewatching vessels usually maintain the 100m minimum distance stipulated by the Brazilian legislation, they do frequently change engine status while the group is underwater and thus generate the sounds discussed by Watkins (1986).

It could thus be expected that mother and calf groups would react most strongly to vessels closer than 100m. However, except for the percentage of time spent milling and the rate of occurrence of rolling by calves, (significantly lower when compared to the control condition) and the increase in swimming speed for mothers, no other alterations were statistically significant. The absence of the occurrence of lap behaviour (calf on top of mothers rostrum) by calves while in the presence of vessels within 100m is a cause for concern and it is thought that the low number of samples in category 1 may have compromised the significance level of the results presented here. The lack of a significant difference in this instance may have been due to a type II statistical error, but in all six cases of vessels present within 100m of a mother and calf the boats were research vessels. Although these approached closer than whalewatching vessels, avoiding abrupt changes in direction and speed, or even keeping the engine in idle most of the time, would have considerably reduced or eliminated noise (Au and Green, 2001).

Whale responses to vessels approaching but still further than 300m, were not different from the behaviour of control whale groups (category 0). Assuming that vessels navigate at a mean speed of 15km hr^{-1}, it would take about 4min to travel 1km, so the duration of time whales were exposed to the vessel in this study was much shorter when compared to the whole period of observation. The mean time of continuous sampling in category 3 was 0.81hr, diluting any behavioural changes that might occur further away than 300m, as found in some other studies (Baker and Herman, 1989; Bauer, 1986; Green and Green, 1990). Nevertheless we believe that at least visually it is not possible to attribute a given reaction from a humpback whale to the presence of a boat that is not nearby, because others factors unrelated to the vessel not under the view/control of the observers may influence that whale group.

Short-term reactions to whalewatching vessels are well documented in the literature and once again were observed here. However, the ultimate question of what may be the long term effects of whalewatching activity is still unanswered. Normal behaviours by mothers and calves were altered in the presence of vessels and that may interfere with how the whales deal with their energetic demands. Repeated short-term behavioural changes such as these may lead to cumulative effects that might prevent animals from carrying out normal life processes. If disruption occurs to a particular segment, or to a significant number of individuals within a population, it follows that conservation of the population may be at risk (Lien, 2001). Whalewatching is spreading along the coast of Brazil (Cipolotti *et al*., 2005), in regions inside and outside protected areas. Although there is no information on the extent to which the total population in the area is affected, it is known that these interactions occur in a great part of its distribution and certainly not all the people conducting this activity have knowledge and/or are conscious of the national regulations.

Whether the short-term behavioural changes described here are accompanied by a long term avoidance of the Abrolhos Archipelago region as a breeding site has not been determined. Abundance estimates in the area suggest that the population is increasing (Andriolo *et al*., 2006; Freitas *et al*., 2004). Indices of abundance around the land-station have shown that sightings of adult whales per scan increased, especially from 2002-04 based on a seven-year study from 1998 to 2004 (Morete *et al*., In press). Gill *et al*. (2001) proposed that the decision of whether or not to move away from disturbed areas is actually determined by other factors such as the quality of the site being occupied, so animals with no suitable habitat nearby may be forced to remain despite disturbance. In addition, for long-lived, slow-breeding species, the long-term effects of reduced resting behaviour on fitness, individual reproductive success and hence population size, would take a long time to detect (e.g. Thompson *et al*., 2000; Wilson *et al*., 1999) and cannot be observed until they have actually occurred (Tyack *et al*., 2004). The acceptable limit of the observed short-term reactions (i.e. decrease of resting, increase of swimming speed, decrease of suckling) that would not trigger long-term effects, as suggested by Lusseau (2003) must now be investigated.

At a practical level, from a precautionary perspective we recommend that Brazilian legislation should be amended to create a 300m radius restrictive zone around mother and calf groups or at least should contain an item about a 300m caution zone, where boats should reduce speed, avoid sudden changes in direction and speed (i.e. reduce noise level) and approach and leave whales cautiously and slowly. In any event, Brazilian whalewatching legislation must be respected by whalewatching vessels and for this to occur, extensive environmental education work with local communities along the coast must be continued. Training of boat captains and effective reinforcement of the guidelines should be done by the appropriate Brazilian authorities.

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