Avoidance of whale watching boats by humpback whales in their main breeding ground in New Caledonia.

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ABSTRACT

In recent years, whale and dolphin watching activities have developed rapidly in the South Pacific Island region. In particular, the presence of humpback whales during winter months attracts thousands of tourists every year. New Caledonia is one of the leading countries for humpback whale-watching in this region, with the industry focusing on the whale's main reproductive area in the southern lagoon of the island, recently listed as a World Heritage site. The growth of whale-watching activities in New Caledonia has remained uncontrolled since its start in 1995 and, until 2008 no measures had been implemented for the management of this industry. With concerns regarding the sustainability of these activities, a study was conducted between 2005 and 2007 in order to assess the effect of boats on the behaviour of a small endangered population of humpback whales overwintering in New Caledonia. All observations were made from a land-based research station, from which humpback whales were tracked in the presence and in the absence of boats using a theodolite. A multiple linear regression analysis showed that whales significantly increased their dive time from 2.7 (±2.4) to 3.1mins (±1.9), and decreased the linearity of their path when boats were present within 1000m of the animals. The effect on linearity also proved to increase with the number of boats. The combined use of vertical and horizontal avoidance strategies, commonly used by many species to avoid predators, suggests that the presence of boats represents a major disturbance for humpback whales. Due to the high site fidelity of the New Caledonian humpback whale population, such impact has the potential to be cumulative over the years. This short-term behavioural impact is also likely to induce higher energetic costs and could have longer term implications for humpback whales breeding in New Caledonia.

INTRODUCTION

For many decades, humpback whales in the South Pacific were amongst the numerous species of great whales to be hunted during commercial whaling operations, leading to the depletion of many stocks (Clapham and Baker, 2001). Today, these populations show little sign of recovery and their conservation status has therefore been recently updated from vulnerable to endangered (IUCN, 2008). In recent years, humpback whales have become living resources and observing these whales in their natural habitat has arisen as a valuable economic alternative to whaling (Hoyt, 2001; Economists At Large, 2008).

Following the worldwide trend, the whale and dolphin watching industry is demonstrating a remarkable growth of 45% per annum since 1992 in the South Pacific Island region (Economists At Large, 2008). In particular, humpback whales, migrating every winter from Antarctica to their tropical breeding grounds, attract thousands of tourists, and represent an important part of this development (Orams, 1999; Schaffar and Garrigue, 2007; Economists At Large, 2008). In 2005, a total of six countries and 49 tour operators offered humpback whale-watching trips to over 15,000 participants, generating a total economic value of US$3.6 million (Schaffar and Garrigue, 2007). In order to ensure the sustainable development of this industry and the conservation of cetacean species, management measures regulating approaches to whales and dolphins are essential (IWC, 2000) and have been implemented on several whale watch sites around the world (Carlson, 2004).

New Caledonia is considered as one of the leading humpback whale-watch destination in the South Pacific island region (Schaffar and Garrigue, 2007; Economists At Large, 2008). Commercial humpback whale-watching activities focus on the Southern Lagoon of the island, an area identified as the main breeding ground for this population (Garrigue *et al.*, 2001), and listed as a World Heritage site in 2008. These activities started in 1995 and have grown at an average annual rate of 46% since then (Schaffar *et al.*, 2007). In 2005, 18 operators conducted 238 whale watch cruises, for approximately 3,109 participants (Schaffar and Garrigue, 2006). Many recreational boats also participate to this activity. Management of the whale-watching industry has been greatly lacking in New Caledonia, with no specific measures undertaken for 13 years.

The growth of humpback whale-watching activities in New Caledonia and the long-lasting absence of management measures raise the question of the potential impact these activities may have on the animals being watched. The presence of boats around cetaceans is known to induce behavioural changes in many of the species exposed to these activities (e.g. Baker and Herman, 1989; Corkeron, 1995; Sousa-Lima *et al.*, 2002; Williams *et al.*, 2002; Scheidat *et al.*, 2004; Stockin *et al.*, 2008), and may represent a threat to some populations (e.g. Bejder *et al.*, 2006). Humpback whales wintering in New Caledonian waters could be particularly vulnerable to this unregulated tourism industry as it remains one of the smallest population across the South Pacific Island region with only 472 individuals (Baker *et al.*, 2006). Moreover, strong site fidelity (Garrigue *et al.*, 2002), combined with demographic and reproductive isolation (Garrigue *et al.*, 2004), added to the endangered status of the species, suggests that any threats on their breeding ground may put this population at risk. A study was therefore initiated in 2005 to assess the effects of commercial and recreational whale-watching boats on the behaviour of humpback whales.

METHODS

Data collection

All observations were made from Cap Ndoua, a lookout point located 189m above sea level and overlooking the area where the majority of interactions between boats and humpback whales occur within the Southern Lagoon (Figure 1).

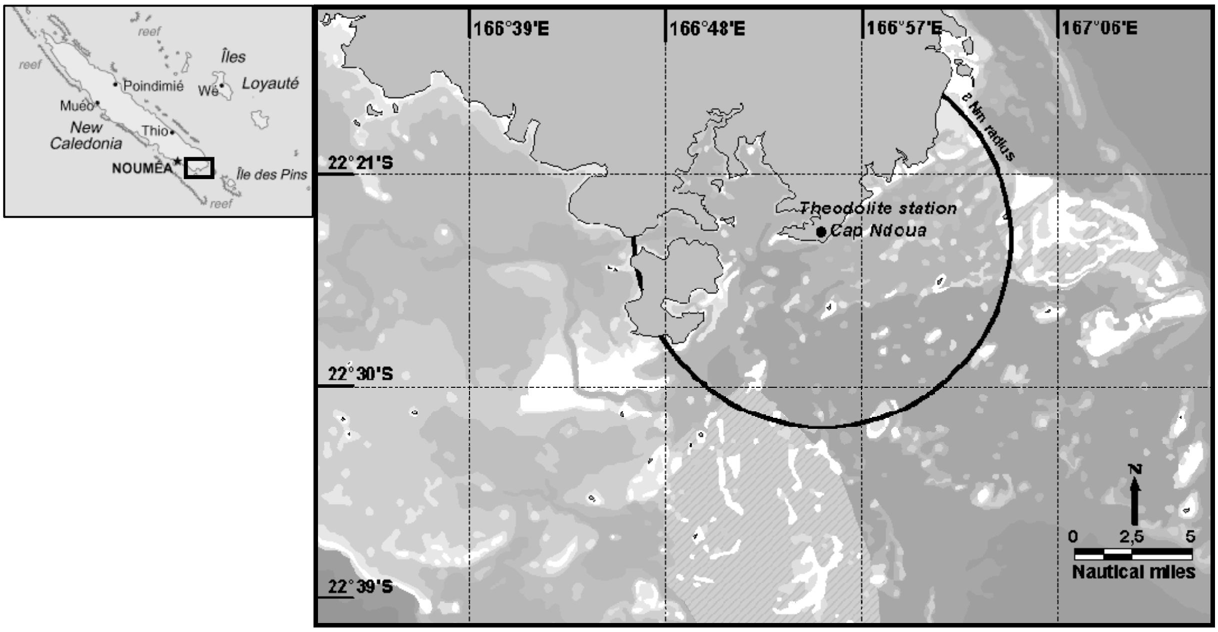

Figure 1. Observation site and study area within an 8 nautical mile radius.

Observations were conducted by a team of three researchers and took place from early morning (around 7am) to mid-afternoon (around 3pm) over the main period of presence of humpback whales in the southern lagoon of New Caledonia (mid-July to mid-September). Observations were restricted to days with no rain and a wind speed less than 15 knots.

A Sokkia Set 5 theodolite was used to monitor the movement and behaviour of humpback whales in the absence and in the presence of boats. The theodolite was connected to a laptop computer running the tracking program

Cyclopes (Kniest and Paton, 2001). This program automatically transformed the vertical and horizontal coordinates from the theodolite readings into GPS points, and was used to record other behavioural and fix data, which were verbally relayed by the theodolite operator to the computer operator. In order to minimise inter-observer variability, the same person (AS) operated the theodolite for all days of this study.

Comparison of data collected from the land-based station and from boat-based surveys on the same group of whales showed that they could reliably be tracked up to eight nautical miles from the lookout point on clear days and with a wind speed less than five knots. The maximum distance at which humpback whales were tracked was therefore set at eight nautical miles but varied with weather conditions and wind speed.

Due to the small numbers of humpback whales within the New Caledonian population (estimated at 472 CV = 0.18, Baker et al., 2006), the sighting rate within the study area remains relatively low with an average of only 1.8 groups per day. Moreover, group composition on breeding grounds is highly unstable. These characteristics reduce the likelihood of re sampling the same group multiple times per day (pseudoreplication) and the choice of which group to track. When more than one group was within sight of the land-based station, the group closest to shore was tracked. This choice was made to increase the probability of observing the group with boats afterwards.

Groups of whales were tracked for a minimum of 20 minutes combined with at least five surfacing bouts, during which the whales' position was fixed with the theodolite once every minute. The fix was taken on the first whale to come to the surface after that time elapsed. A group of whales was considered as one or more whales within 100m of each other, generally moving in the same direction in a coordinated manner (Whitehead, 1983; Mobley and Herman, 1985). Group type was recorded at the start of each tracking session. Four categories of group type were used: singleton, pair, groups of three adults or more, and groups containing a mother-calf pair. A calf was defined as an animal in close proximity to another whale, visually estimated to be less than 50% of the length of the accompanying animal. All surface behaviours of the whales, such as blows, breaches, and tail slaps, were continuously recorded. Between each recording of the whales' position, the position of all boats within a 1000m radius of the whales was also recorded. Each boat was individually identified and it was noted whether it was a commercial whale-watching boat or a recreational boat. An observer would keep track of the whales' behaviour while the theodolite operator was fixing the position of boats. Another track was started when conditions changed: if boats arrived within 1000m of the whales, if all boats left the whales, if group composition changed (i.e. affiliation of disaffiliation of individuals).

Data preparation

Groups of whales tracked at a distance over 8 nautical miles from the land-based station were excluded from the data set.

The distance of each boat to the group and the number of boats present within 1000m of the whales were calculated for each whale position fixed with the theodolite. Based on these data, the maximum number of boats present and the minimum approach distance were obtained for each tracking session.

The whales' dive time was calculated by averaging the maximum time between surfacing events obtained for each leg of a tracking session. The mean swim speed of the animals was obtained by averaging the speed given by *Cyclopes* for each whale position fixed with the theodolite throughout a tracking session. Two measures of path predictability were calculated for each track: the linearity and the re-orientation rate (Williams *et al.*, 2002). The linearity refers to the straight-line distance between the first and the last fix of a tracking session divided by the cumulative surface distance really covered by the animals. It ranges from 0 (circular path) to 1 (straight line). The re-orientation rate is obtained by adding the angles of adjacent whale fixes and dividing this sum by the duration of the tracking session.

Histograms were generated for these different behavioural variables in order to assess normality for statistical analysis and whether transformation of the data was needed. Swim speed was the only variable to be normally distributed. Linearity was transformed using arc-sinus while re-orientation and dive time were log-transformed.

Statistical analysis

A multiple linear regression analysis was conducted on tracks with and without boats within 1000 meters of whales. Groups of whales observed both before the arrival of boats and while boats were present were also considered as tracks with and without boats in this analysis. Tracks conducted after the departure of boats were excluded from this analysis as they cannot be considered as tracks without boats due to their previous presence. The effect of group type, the presence of boats, the maximum number of boats present and the minimum distance of approach on the whales dive time, speed, linearity and re-orientation rate were tested.

Parametric tests were used to assess changes in the behaviour of whales observed both with and without boats. T-test with known variances at the 95% level of confidence (i.e. $\alpha = 0.05$) were used to compare mean dive time, speed, linearity and re-orientation rate for each group of whales before boats arrived and while boats were present. These behavioural variables were also compared for each group while boats were present and after boats had left.

RESULTS

Research effort and sample size

Data were collected over three field seasons from 2005 to 2007 (Table 1). An average of 48.6 days was spent on the field each season, which represents an average of 290.96 hours of observation annually.

Year	Dates	Number of days of observation	Number of hours of observations
2005	14 July - 4 September	42	235.85
2006	18 July - 17 September	51	329.03
2007	12 July - 19 September	53	308.00
TOTAL		**146**	**872.88**

Table 1. Research effort.

A total of 389 groups of humpback whales were sighted from the land-based research station and 175 groups were tracked using the theodolite. For the multiple linear regression analysis, 184 tracking sessions (83 with boats and 101 without boats) collected on 154 groups were used (Table 2). T-tests were conducted on 41 groups observed both with and without boats.

Year	Number of groups	Groups tracked with boats	Groups tracked without boats	Groups tracked before and during interactions	Groups tracked during and after interactions	Groups tracked before, during and after interactions
2005	33	16	11	5	0	1
2006	59	13	30	10	6	0
2007	62	13	30	12	5	2
Total	**154**	**42**	**71**	**27**	**11**	**3**

Table 2. Number of humpback whale groups tracked.

Each group of whales was tracked for an average of one hour and seven minutes (±0.8 hrs, range = 20 mins to 5.1 hrs, n = 154). The average number of whale fixes recorded was 14.8 per tracking session. The majority of groups tracked were singletons (41%, n = 63) and pairs (33%, n = 51) (Figure 2).

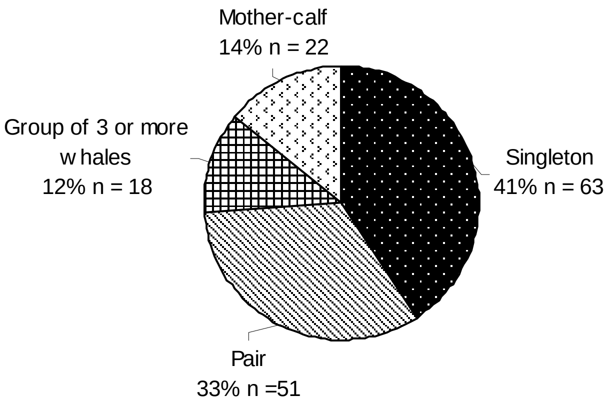

Figure 2. Percentage of tracking sessions per group type (n = 154).

Response of whales to the presence of boats

The presence of boats significantly affects the linearity (p<0.05, n = 184) and dive time (p<0.05, n = 177) of humpback whales (Table 3). The results of the multiple linear regression analysis specifically show that linearity significantly decreases and that dive time significantly increases when boats are present within 1000m of whales. Swim speed and re-orientation rate are not significantly different between tracking sessions with and without boats.

Variable	Without boats	With Boats	Significance
Speed (nm/h)	2.9 ± 1.31 n = 101	2.86 ± 1.19 n = 83	NS
Re-orientation rate (°/min)	11.09 ± 10.69 n = 101	8.62 ± 6.85 n = 83	NS
Linearity	**0.85 ± 0.16** n = 101	**0.80 ± 0.20** n = 83	***p < 0.05***
Dive time (in mins)	**2.71 ± 2.41** n = 97	**3.11 ± 1.94** n = 80	***p < 0.05***

***** Raw data presented in this table. Re-orientation rate, linearity and dive time were transformed for the purpose of statistical analysis.

Table 3. Behaviour of whales with and without boats present within 1000m of the group analysed with the multiple linear regression.

The distance of approach by boats does not affect significantly any of the behavioural variables assessed in this study (p>0.05, n = 184). The maximum number of boats recorded within 1000m of the whales during a tracking session has a significant effect on linearity (p<0.05, n = 184). Linearity decreases significantly as the maximum number of boats present within 1000m of whales increases.

Dive time (p<0.05, n = 177), speed (p<0.05, n = 184) and re-orientation rate (p<0.05, n = 184), are significantly different across group types. Groups of three adult whales or more swim faster, have shorter dive times, and change the direction of their path more often than any other group types. Groups containing a mother-calf pair have a significantly slower swim speed compared to other group types.

Out of the 30 groups of whales tracked both before and during interactions with boats, 93% showed a significant change in behaviour upon the arrival of boats (p<0.05, n = 28). The majority of groups (33%, n = 10) significantly changed two behavioural variables out of the four considered. The main behaviour to be affected by the arrival of boats was the whales' linearity, which was significantly different in the presence of boats for 77% of the groups considered in this analysis (n = 23).

For groups tracked during and after interactions with boats (n = 14), 78% changed their behaviour after the departure of boats ($p<0.05$, n = 11). The linearity was also the behaviour most likely to change after the departure of boats (64%, n = 9).

The analysis conducted on groups tracked both with and without boats did not show any specific trend in the direction of these behavioural changes. This may be due to the small data set available.

DISCUSSION

Whale-watching activities taking place in the Southern Lagoon of New Caledonia have a significant impact on the behaviour of humpback whales. In the presence of boats, humpback whales increase their dive time and decrease the linearity of their path. They significantly change their behaviour as soon as one boat is present within 1000m of the animals but the effect on linearity increases with the number of boats. Similar responses to approaches by boats have been documented for humpback whales (e.g. Baker and Herman, 1989) as well as for other cetacean species (e.g. Janik and Thompson, 1996; Nowacek *et al.*, 2001; Williams *et al.*, 2002; Lindquist *et al.*, 2008). Such behavioural changes render the whales' movements less predictable and they become more difficult to follow and watch.

Such impact is likely to be more problematic for mother-calf pairs, as they are particularly vulnerable to threats. The presence of boats may also disrupt vital activities such as nursing. A previous study showed that this type of group is usually watched for longer periods of time and at closer distances than other groups (Schaffar and Garrigue, 2008). With a high exposure to whale-watching boats and a demonstrated impact of these activities on the whales' behaviour, this important reproductive area could no longer represent such an appropriate environment for calving.

Changes in movement and surfacing patterns of cetaceans have been linked to avoidance strategies, commonly used by many different animal species to elude predators (Howland, 1974; Weihs and Webb, 1984). The decrease in linearity and the increase in dive time correspond respectively to horizontal and vertical avoidance strategies. In the case of humpback whales observed in this study, the combined use of these two techniques suggests that the presence of boats is likely to represent a major disturbance for whales from which they try to escape.

Behavioural changes induced by the presence of boats are also likely to have physiological effects on individuals. Vertical avoidance strategies can modify oxygen consumption and affect the whales' metabolism, as the animal has to use oxygen stores to deal with the decrease in breath intake (Lusseau, 2003). Horizontal avoidance will increase the distance covered by an animal between two points as its path will not be as direct (Williams *et al.*, 2002). In both cases, avoidance is likely to induce higher energetic costs and have long term effects for the cetacean populations exposed to whale-watching activities. The short-term behavioural impact demonstrated in this study could therefore have further implications for the small endangered population of humpback whales breeding in New Caledonia.

The analysis conducted on groups observed before, during and after interactions with boats shows that significant behavioural changes occur upon boats' arrival for 93% of the groups, and upon boats' departure for 78% of groups. This difference suggests that, for some groups, the effect induced by the presence of boats is likely to last after they have departed and that it may take some time for whales to return to their initial behaviour.

Considering the strong site fidelity of humpback whales observed in the Southern Lagoon of New Caledonia (Garrigue *et al.*, 2002; in review a), individual whales are likely to be exposed repeatedly to whale-watching activities over the years, and the impact of the presence of boats may therefore be cumulative. As some of the whales sighted in New Caledonia are known to migrate through the East coast of Australia (Garrigue *et al.*, 2000; in review b), it is also possible that these whales are exposed to whale-watching activities on different sites every year. The impact of whale-watching boats on humpback whales in New Caledonia cannot be considered as a discrete event.

The level of exposure of humpback whales to whale-watching boats is particularly high in New Caledonia: the length of encounters, the observation time and the distance of approach being all above the limits recommended and enforced around the world (Schaffar and Garrigue, 2008). It seems likely that the impact demonstrated is linked to such high exposure. Minimising the level of exposure and the impact of whale-watching activities on the behaviour of humpback whales breeding in the Southern Lagoon of New Caledonia is therefore essential. Whale-watching activities in New Caledonia have been unregulated for 13 years. In 2008, a code of conduct proposed by the government was signed by the majority of whale-watch tour operators and boat patrols were initiated for surveillance. Further research will be required to know whether these management measures are efficient in reducing the impact of the presence of boats on the behaviour of the whales. Considering the level of development reached by commercial whale-watching activities in New Caledonia since 1995, efforts to minimise the impact of whale-watching activities should be maintained and reinforced. The conservation of the New Caledonian population of humpback whales on this world heritage reproductive ground should be considered a priority.

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