Dolphin watching boats impact on habitat use and communication of bottlenose dolphins of Bocas del Toro, Panama during 2004, 2006-2010.

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Coastal bottlenose dolphin populations are frequently in contact with humans and are targeted by dolphin-watching boats. In the past 10 years dolphin watching has become a popular and profitable tourist attraction in Panama. Profitable wildlife observation can mutually benefit humans and wild animal populations, resulting in successful conservation. However, high observation intensities may nevertheless negatively affect animals. Dolphin watching is largely boat-based, and engine noise potentially elicits avoidance behaviors in dolphins and can interfere with important communicative and foraging acoustic signals. We studied the effect of engine noise on the occurrence, and behavior of bottlenose dolphins of Bocas del Toro, Panama. The study area was surveyed using predetermined strip transects that maximized the coverage of the Archipelago. Surveys ran from 7 a.m. to 5 p.m. and observations were made from a 10 m boat with a double 4-stroke 150hp engine. For each group sighted we estimated group size, predominant behavior, noted number of dolphin-watching boats interacting with the group, and recorded communicative signals (whistles) using a broadband recording system. Preliminary analysis suggest that the Bocas del Toro local dolphin population is small, probably with less than 150 individuals, half of which appear to be year-round residents. A yearly decrease in group size and number of groups sighted correlates with an increase in the number of boats interacting with the animals. The behavioral data indicates that dolphins tend to show more avoiding behaviors in the presence of dolphin-watching boats when compared to the research boat. Groups show increase in whistle emission and increased whistle modulation, frequency, and duration in the presence of dolphin-watching boats. Our results suggest that dolphin watching can negatively affect the bottlenose dolphins of Bocas del Toro, when numerous boats are involved. Although Bocas del Toro bottlenose dolphins are notably plastic in their behavior and acoustic communication the growing tourism development and associated increase in boats transiting the Archipelago may challenge their survival by increasing engine noise to levels that may render their habitat less habitable. Also, boat maneuvering may directly impact the dolphins. We have observed up to 25 boats following the same group and with most of the boats involved circling the animals and disrupting the activities as well as separating group members including calves from mothers. The Panamanian Government Conduct guidelines are appropriate to conserve the dolphin's acoustic environment, but few operators are well informed about these guidelines and their importance. Rapid action is urgently needed to ensure adherence to conduct guidelines, promoting less aggressive dolphin watching and thus help protecting the dolphin population, and simultaneously the operator's income.

INTRODUCTION

Numerous aquatic organisms use sound for communication and for active and passive monitoring of their environments (e.g., the spiny lobster, snapping shrimps, swim-bladder fishes, and marine mammals). The advantage of using sound resides in the low attenuation in water. Low absorption losses allow marine organisms to interact over long distances compared to terrestrial animals relying on airborne sounds (Richardson et al. 1995). It is this same property that accentuates the negative effects of underwater noise pollution, in both animal survival and human efforts to protect marine biodiversity (NRC 2003).

Sound is an important tool and byproduct of a broad range of human activities in marine environments (NRC 2003). In coastal areas, engine noise due to boat traffic has become a main source of underwater noise in many countries. Boat "noisiness" is due to air bubbles that collapse near the blades of the propellers with the most significant source of noise above 2 kHz (Popper 2003). In addition, increasing propeller rotation rate can also shift engine noise to higher frequencies increasing the potential for masking cetacean signals (Richardson et al. 1995, Bain and Dahlheim 1994). Erber (2002) estimated whale-watching boat engine levels to be 145 to 169 dB re 1µPa @ 1m, more than sufficient to mask important signals such as communicative whistles of dolphins (1 to 35 kHz).

Whale watching has become a highly profitable activity worldwide including Latin America (Hoyt and Iñiguez 2008). Profitable whale watching can mutually benefit humans and wild animal populations, resulting in successful conservation. However, high observation intensities may nevertheless negatively affect animals. Dolphin watching is largely boat-based, and engine noise potentially elicits avoidance behaviors in dolphins and can interfere with important communicative and foraging acoustic signals in areas where is growing without control. Although biological noise can mask signals, cetaceans have evolved ways to compensate for these noises. However, boat engine noise represents a new challenge these animals may not be able to circumvent. The only option may be to avoid contact with these noises in which case noise acts much like other pollutants in rendering habitats unsuitable. Because of this the International Whaling Commission (1995) and International Fund for Animal Welfare (1996) have recognized boat-based whale watching as potentially detrimental to cetaceans and their environment and have developed guidelines in an attempt to reduce the impact of the industry.

However, early guidelines emphasized regulating approach distances, but with growing evidence that engine and propeller noise are the main causes of disturbance (e.g., Wartzok et al. 2004, Nowacek et al. 2001, Kruse 1991, Van Parijs and Corkron 2001, May-Collado and Wartzok 2008), new regulations incorporating noise level are necessary (IWC 1995, IFAW 1996). Some of these disturbances include longer dive duration and heading changes (Nowacek et al. 2001, Au and Perryman1982), decreased breathing synchrony (Hastie et al. 2003), decreased inter-animal distances (Bedjer et al. 1999), and disturbance in important behaviors such as resting and foraging (Visser et al. 2011, Constantine et al. 2004, Cordero-Montero and Lobo 2010). Watercraft noise can also elicit changes in vocal rate (Van Parijs and Corkeron 2001, Buckstaff 2004, Scarpati et al. 2001), call duration (Foote et al.2004, May-Collado and Wartzok 2008), signal diversity, and frequency (Lesage et al. 1999, May-Collado and Wartzok 2008) to avoid masking and to maintain group contact when boats are present. While some species show a greater vocal rate at the onset of approaches or after being disturbed by boats (Van Parijs and Corkeron2001, Buckstaff 2004), others species produce longer calls when noise reaches critical levels (Foote et al. 2004) and shifting in frequency (3.6 kHz to 5.2-8.8 kHz) when vessels are to close.

In Bocas del Toro, Panama there is a resident population of bottlenose dolphins estimated between 100 to150 animals. Half of these animals are believed to be year-round residents. Their predictability and site fidelity has promoted the establishment of several dolphin-watching operators, which have been growing exponentially in the past 15 years. The Government Conduct guidelines are appropriate to conserve the dolphin's acoustic environment (Resolution ADM/ARAP NO. 01, 2007) but few operators are well informed about these guidelines and their importance. Rapid action is urgently needed to ensure adherence to conduct guidelines, promoting less aggressive dolphin watching and thus help protecting the dolphin population, and simultaneously the operator's income. In this study we summarized some our findings about the effects of dolphin-watching activity and associated engine noise on the habitat use, communication, and occurrence of local bottlenose dolphins.

METHODS

The Archipelago of Bocas del Toro is located in the Caribbean coast of Panama. Our survey effort covered approximately 79.2 km2 within the inner part of the Archipelago, which is characterized by shallow and clear waters and bottom substrates consisting of sea grass, coral, and sand. The main mode of transportation between the islands and mainland is through powered boats with 50 and 150 hp engines and canoes. May-Collado and Wartzok (2008) found that underwater noise levels in Bocas del Toro were higher in Torito Bay, Drago, and Cerro Brujo. Our study focused on Bocas Torito Bay also known as Dolphin Bay. This is a closed bay with resident dolphins that are highly predictably attracting most of the dolphin watching operators. The bay is also considered an important nursery ground. We surveyed the area using a 10 m fiberglass boat with two engines (150 hp/4-stroke) from 7 a.m. to 5 p.m. following predetermined routes (Fig. 1). Survey effort varied between 7 days to 4 weeks at year depending on funding support. Once a group of dolphins was encountered the boat was approached slowly and in a parallel position to avoid dolphin disturbance (Würsig and Jefferson 1990, Resolution ADM/ARAP NO. 01, 2007). We maintained a distance of 30-50 m distance to the group before turning the engine off to initiate data collecting and photo-ID. This type of approach is standard in cetacean studies because it minimizes behavioral impact on the group (e.g., Würsig and Jefferson 1990). A group was defined as "a collection of conspecifics in a limited area, often engaged in similar activities and moving in the same general direction, maintained by social factors as a unit" (Wells et al.1999). We collected the following information: group size (minimum, maximum, and best estimation), photo-ID data, geographical position using a GARMIN GPS, predominant behavioral state at the moment of the encounter and during acoustical recording sessions, presence/absence of boats other than the research boat, and acoustic recordings.

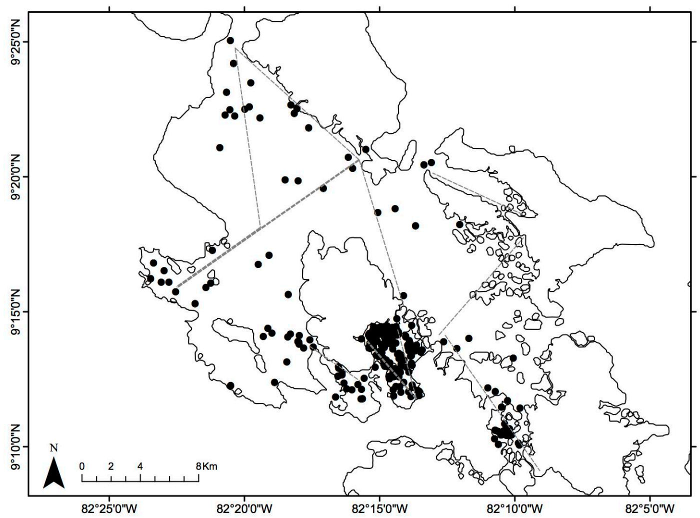

Figure 1. Predetermined routes surveyed with the distribution of dolphin sightings between 2004, 2006 and 2009.

Habitat use: Habitat use was estimated based on behavioral observations made from the research boat continuously and in synchrony with each acoustic file as described in the next paragraph. We focused on three predominant behavioral states: social, traveling, and foraging events (see May-Collado and Ramirez 2005, May-Collado 2010, Lusseau 2003). Behavioral data was collected using instantaneous scan sampling every 3 minutes to estimate the predominant behavior during acoustic recordings (see May-Collado 2010). Groups were followed between 20 min to 2h. Whale-watching boats approaching towards a group within a distance of 500 m were considered acoustically interacting with the group, since noise is within their audibility range at that distance. To account for group identity we photo-id all group members using 'random' and 'focal' techniques with a digital camera Canon EOS 10D, 6.3 Megapixel SLR and a digital Canon Rebel, with a 75-300 mm zoom lens

Recordings: Signals were recorded using a broadband system consisting of a RESON hydrophone 4033 (-203 dB re 1 V/lPa, 1 Hz to 140 kHz; RESON Inc., Goleta, California) connected to an AVISOFT recorder and Ultra Sound Gate 116 (sampling rate 400–500 kHz, 16 bit; Avisoft Bioacoustics, Berlin, Germany) that sent the signals to a laptop computer. Dolphin whistles were recorded continuously (in 3-min files) with a sampling rate between 384 and 500 kHz. Behavioral data was collected in association with these acoustic files. Selected whistles were analyzed in RAVEN 1.2 (2003– 2007; Cornell Lab of Ornithology) with a fast Fourier transform size of 1,024 points, an overlap of 50%, and using a 512- to 522-sample Hann window. To estimate whistle rate and acoustic variables (frequency, time, and modulation) we selected whistles that had a complete contour.

Statistics: Although we tried to reduce disturbance to the group as we first approached the group, we were unable to estimate if our boat had an effect on dolphin whistle structure. Therefore we restricted analysis to simply comparing whistle rate, behavior occurrence, group occurrence and size between presence of a single boat (the research boat, engine off) and multiple boats (2–15 whale-watching boats, including our research boat). We also look at changes in group occurrence and size in association with dolphin-watching boat interacting at a given time between years. For the whistle rate and group occurrence we also considered the presence of calves since the bay is considered an important nursery ground. Group occurrence, size, and behavioral occurrence were corrected based on survey effort in this case using day as effort unit.

RESULTS

Group occurrence and size: Groups occurrence decreased after 2007 likely associated with a substantial increase on the number of dolphin watching boats (for all years r=28, p>0.05) (Fig.2a). Although not significant, there seems to be a negative association between the number of boats interacting with dolphin group size (r=-70, p=0.09) (Fig.2b). There is a trend in that group encounter and size has decreased with a yearly increasing number of dolphin watching boats visiting Dolphin Bay.

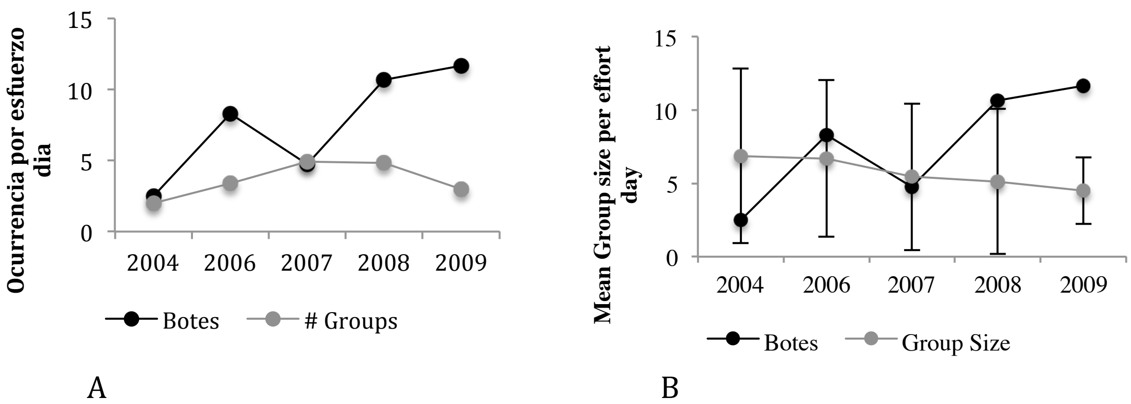

Figure 2. Yearly group occurrence, group size, and number of boats interacting with dolphins corrected by survey effort in days.

Habitat Use: There are significant differences in how animals use the bay (x^2=117.8, d.f.=5, p<0.05). The most common behaviours observed in Bocas del Toro are traveling (35%), foraging (23%) and social events (22%). Approximately 62% of the boat-dolphin encounters were with dolphin watching boats, followed by private boats (16%) and transport boat (14%). In terms of group composition about 41.7% of the observed groups had calves and 58.3% consisted of just adult animals. Overall, dolphin groups interacting with dolphin watching boats tended to spend more time traveling (x^2=6.13, d.f.=2, p<0.05). However, groups with calves did not show more avoidance behaviour than with the research boat.

Whistle emission and structure: Groups show increase in whistle emission and increased whistle modulation, frequency, and duration in the presence of dolphin-watching boats. Overall whistle rate was higher in presence of boats. Groups without calves have a higher whistle rate than groups with calves when exposed to dolphin watching boats (Mann-Whitney U Test= 306, 500; N=59, p=0.04) (Fig.3). Dolphin whistle structure varied between encounters with the research and dolphin watching boats. In general, dolphins in the presence of multiple dolphin watching boats produced longer (X^2= 6.27, d.f.=1, p=0.012) whistles showing higher maximum frequency ($X^{2=}$13.67, d.f.=1, p=0.0002), mean number of inflection points (X^2=5.36, d.f.=1, p= 0.021), and coefficient of frequency modulation (X^2=3.92, d.f.=1, p=0.048).

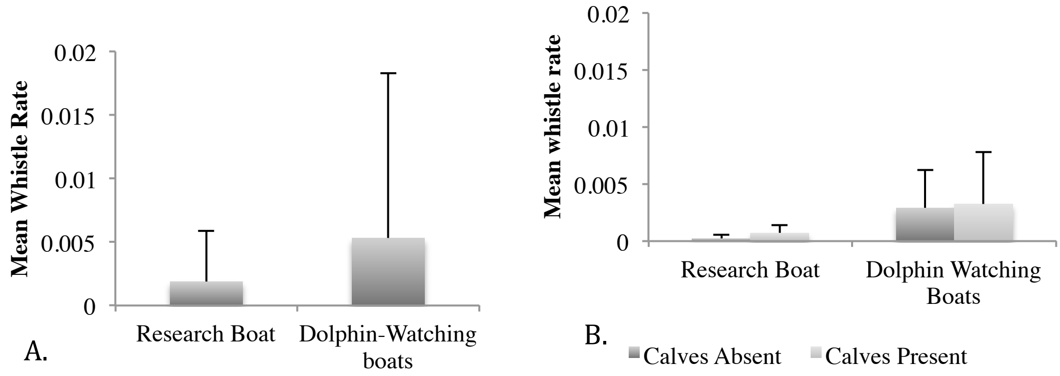

Figure 3. Mean whistle rate emitted by groups present with multiple dolphin-watching boats and the research boat. A=shows the overall mean values between research and dolphin-watching boats and B= details the information based on calve presence/absence.

DISCUSSION

Our work provides preliminary evidence that dolphin watching is negatively affecting the bottlenose dolphins of Bocas del Toro, when numerous boats are involved. This result is congruent with previous studies in that multiple boats have a greater influence on dolphin behavior and communication than a single boat (e.g., Tseng et al. 2011, Nowacek et al. 2001). Although, the relationship between number of dolphin watching boats and group occurrence and size was not significant there is a trend in that an increase in number of dolphin watching boats may be related to a decreased in the number of group sightings and group size. A recent study evidenced that small groups tend to show more avoidance behaviors in the presence of whale watching boats than larger groups (Tseng et al. 2011).

The behavioural data indicates that dolphins tend to show more avoiding behaviours in the presence of dolphin-watching boats when compared to the research boat. We did not find significant differences in avoidance behaviours (defined as travel events) of groups with and without calves in relation to boat interactions. In contrast, a few recent studies have shown that groups with small calves tend to spend more time traveling than groups without calves (Tseng et al. 2011). Our results are likely hinder by small sampling size and not taking into consideration the vessel size, engine hp, mode of approach, but more importantly we did not measure other avoidance behaviours such as breathing rate, diving duration, and changes in the spatial distribution group members. However, it is important to noticed that in other dolphin species the overall activity budget has not change in relation to boat traffic (Tosi and Ferreira 2009). This may suggest that in some areas dolphins may become habituated to boat traffic but until we consider other avoidance behaviours it remains unclear if this is the case for the bottlenose dolphins of Bocas del Toro.

Boat traffic is high in Bocas del Toro and has a relatively ample spatial distribution that overlaps with dolphin habitat (Barragan-Barrera 2010). The question that remains to be answer is if dolphins react differently to dolphin watching boats that targets them directly compare to any other type of boat traffic. Other bottlenose dolphin populations have responded to high dolphin watching boat traffic by avoiding areas with these boats (Lusseau 2005). Preliminary observations from the past three years suggest that bottlenose dolphins in Bocas del Toro may be starting to spend less time in Torito Bay where dolphin-watching activities focused. However, these observations remain to be tested in the near future.

Although Bocas del Toro bottlenose dolphins are notably plastic in their behaviour and acoustic communication the growing tourism development and associated increase in boats transiting the Archipelago may challenge their survival by increasing engine noise to levels that may render their habitat less habitable. As mentioned before, Torito Bay is where dolphin-watching concentrates because is where animals are easily found on daily basis. However, Torito Bay is also considered an important nursing area for the local dolphin population. Our results on dolphin acoustic response to boat shows that dolphins whistle more in the presence of multiple dolphin watching boats. In contrast with Van Parijs and Corkeron (2001) we did not find that groups with calves whistle more in the presence of dolphin watching boats than the research boat. We hypothesized that this may due to signal masking by the engine noise. Calves emit higher frequency signals in comparison to bigger conspecifics that are more prone to transmission loss. Therefore, they are harder to detect and adult signals. If this is the case, mothers and calves can be acoustically isolated when more than two boats are close to them. To evaluate if this is the case during this season fieldwork we will evaluate if there are differences at the onset, during, and after the interactions with dolphin-watching boats. Previous studies have found dolphins increase whistling rate after a boat move through the area (Van Parijs and Corkeron 2001). Dolphin communication is plastic and populations avoid signal masking differently. While in Boca del Toro, dolphin whistle duration, frequency, and modulation increased when the dolphins are interacting with multiple dolphin-watching boats (May-Collado and Wartzok 2008) in Japan Indo-Pacific bottlenose dolphins emit low frequency and less modulated whistles in noisy environments. The difference in respond may be related largely due to the ambient noise source characteristics. Animals respond differently to noise sources contributing to geographic variation in communicative signals.

An important factor that has not been evaluated is boat manoeuvring. Inappropriate boat manoeuvring has shown to directly impact on dolphin behaviour (Cordero-Montero and Lobo 2010, Taubitz 2007). We have observed up to 25 boats following the same group and with most of the boats involved circling the animals and disrupting the activities as well as separating group members including calves from mothers. Panamanian Conduct guidelines are appropriate to conserve the dolphin's acoustic environment, but few operators are well informed about these guidelines and their importance. Rapid action is urgently needed to ensure adherence to conduct guidelines, promoting less aggressive dolphin watching and thus help protecting the dolphin population, and simultaneously the operator's income.

ACKNOWLEDGEMETS

Thanks to Jorge Urban and Miguel Iñiguez for their invitation to the meeting. We are indebted to R. Collin, G. Jacome, I. Agnarsson, C. Parson, M. Heithaus, D. Wartzok, M. Donnelly, J. D. Palacios, E. Brown, E. Taubitz, J. May-Barquero for their support in the field, logistics, and review of manuscripts. Thanks to K. Rasmussen for the distribution map. We also thank the staff at the Smithsonian Research Station at Bocas del Toro. This project was carried out with permission from the Autoridad Nacional del Ambiente (ANAM; permit SE/A-101-07). Funding for this project came from the C. Parson Lab at GMU, Latin American Student Field Research Award from the American Society of Mammalogists, a Judith Parker Travel Grant, Lener-Gray Fund for Marine Research of the American Museum of Natural History, Cetacean International Society, Project Aware, Whale and Dolphin Conservation Society, the Russell E. Train Education Program–World Wildlife Fund, and a Dissertation Year Fellowship, Florida International University to LJMC.

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