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Assessment of the aerial behaviors of humpback whales, *Megaptera novaeangliae* (Borowski, 1781), in coastal areas in Northeastern Brazil

Guilherme Maricato[1]*, Liliane Ferreira Lodi[2] & Daniela Rodrigues Abras[3]

*[1]Graduate Program in Marine Biology, Faculdades Integradas Maria Thereza, Niterói, Rio de Janeiro, Brazil. *Autor para correspondência: guilherme.713@gmail.com.*

[2]Projeto Baleias & Golfinhos do Rio de Janeiro, Instituto Mar Adentro, Rio de Janeiro, Rio de Janeiro, Brazil. E-mail: lilianelodi@gmail.com.

[3]Projeto Baleia Jubarte, Instituto Baleia Jubarte, Caravelas, Brazil, Brazil and VIVA Baleias, Golfinhos e cia Association. E-mail: daniabras@gmail.com.

Abstract. Humpback whales (*Megaptera novaeangliae*) present great ability to perform aerial behaviors, which have been associated to several functions in their social context. The aim of this study was to analyze the aerial behaviors of humpback whales in Northeastern Brazil. From July to October 2013, 113 groups, totaling 272 individuals ($\bar{x}$ = 2.41; ± 1.52), were observed, including possible double counts. Groups consisting of more than three individuals showed a significantly higher level of aerial behaviors and a more varied aerial behavioral repertoire compared to smaller groups. No significant differences in aerial behaviors were found in relation to month, the presence of calves in groups or depth. Studies about aerial behaviors can provide valuable information about sociality in humpback whales since their communication system is not limited to sound and can differ according to the environment.

Key words: Breeding ground, non-vocal communication, percussive sound, South Atlantic Ocean, surface activity.

Resumo. Avaliação dos comportamentos aéreos de baleias-jubarte, *Megaptera novaeangliae* (Borowski, 1781), em áreas costeiras do Nordeste do Brasil. Baleias-jubarte (*Megaptera novaeangliae*) apresentam grande habilidade para realizar comportamentos aéreos, os quais têm sido associados a diversas funções em seu contexto social. O objetivo deste estudo foi analisar os comportamentos aéreos de baleias-jubarte no nordeste do Brasil. Entre julho e outubro de 2013, 113 grupos, totalizando 272 indivíduos ($\bar{x}$ = 2.41; ± 1.52), foram observados, incluindo possíveis contagens duplas. Grupos compostos por mais de três indivíduos apresentaram um nível de atividades aéreas significativamente maior e um repertório de comportamentos aéreos mais variado em relação a grupos menores. Não foram observadas diferenças significativas nos comportamentos aéreos em relação ao mês, à presença de filhotes nos grupos ou à profundidade. Estudos sobre comportamentos aéreos podem fornecer informações valiosas sobre a sociabilidade de baleias-jubarte, uma vez que o sistema de comunicação não se limita ao som e pode diferir de acordo com o ambiente.

Palavras-chave: Área de reprodução, atividade de superfície, comunicação não-vocal, Oceano Atlântico Sul, som percussivo.

Introduction

Mysticetes have a great ability to throw their bodies out of the water, and humpback whales (*Megaptera novaeangliae*) are not only known for breaching (Figure 1) but also for performing many other aerial behaviors (Whitehead, 1985a). In this species, aerial behaviors have been linked to a variety of social contexts, such as competition between males during the formation of competitive groups (e.g. Baker & Herman, 1984), mating (e.g., Craig *et al.*, 2002) and the refusal of approaching males by females (e.g. Whitehead, 1985a; b). These behaviors are also associated with the response to irritation caused by injuries (Whitehead, 1985a; b), the removal of ectoparasites (Félix *et al.*, 2006), muscle fortification (Whitehead, 1985b), the myoglobin development rate in young individuals (Cartwright *et al.*, 2016), the production of sound for communication or visual contact (Dunlop *et al.*, 2008) or a play signal (Würsig & Whitehead, 2009).

According to Whitehead (1985b), the aerial behaviors of *M. novaeangliae* occur more frequently on its breeding grounds than its feeding grounds, and groups of two or more adults exhibit a greater behavioral repertoire, which is related to sociality during the reproductive phase (Pacheco *et al.*, 2013). The breeding season is a crucial period in which the energy acquired on the feeding grounds must be used efficiently to maximize benefits, which implies that the aerial behaviors of these animals play an extremely im-

Figure 1. Humpback whale breaching on the north coast of Bahia, Northeast Brazil. Photo: Drª Liliane Ferreira Lodi.

portant role in the social organization of the species. Thus, the high-energy investment in aerial behaviors seems fully justified as it can increase the chances of mating (Félix, 2004).

In Brazil, different aspects of the humpback whales belonging to Breeding Stock A have been studied including their social group composition and behavior (e.g. Engel, 1996), population ecology (e.g Rossi-Santos *et al.*, 2008), responses of whales to boat traffic (e.g. Sousa-Lima & Clark, 2008) and estimated population size (e.g. Andriolo *et al.*, 2010). However, little is known about their aerial behaviors. Percussive (non-vocal) social sounds are part of the species' communication system, then studies about aerial behaviors may help to better understand the communication of these species sociality in a breeding area.

Given numerous functions of the aerial behaviors, the different levels and categories of these behaviors are related to group sizes and compositions, depths and seasonality. Then, the aim of this study was to qualitatively (type of display performed) and quantitatively analyze the aerial behaviors of humpback whales on the north coast of Bahia, Northeast Brazil.

Since the estimated population of the humpback whales that migrate annually to Brazil has been increasing in recent years (e.g. Andriolo *et al*., 2010), a better understanding of the aerial behaviors of this species in an area critical area for its persistence is important for a better understanding of the meaning of these behaviors in a social context.

Material and Methods

The north coast of Bahia is characterized by a narrow continental shelf approximately 15 km long with an average depth of 50 m; coral reefs extend in a straight line for 20 km from the coast (Rossi-Santos *et al.*, 2008).

The study area was delimited to the north by Subaúma (12°21'5.58"S; 37°32'41.82"W), in the municipality of Entre Rios, and to the south by Barra do Gil (13°46'16.36"S; 38°1'41.92"W), in the municipality of Vera Cruz (Figure 2); the linear distance between these two locations is approximately 167 km. In addition, data collection was restricted to the area within the 16 m and 200 m bathymetric contours.

Between July and October 2013, surveys were carried out aboard a 7.5 m long catamaran equipped with two 150 HP engines. The vessel operated in compliance with national regulations forbidding the driving of boats towards whales and the running of engines less than 100 m from the nearest animal to prevent any disturbance or injury (Ordinance Ibama 117/1996 as modified by Ordinance Ibama 24/2002).

The sample protocol adopted during the sightings was continuous sampling (for method definition see Mann, 1999). Whales were considered a group when the individuals remained within a radius of 100 m and displayed generally coordinated surfacing behavior (Mobley & Herman, 1985). Individuals less than half the total

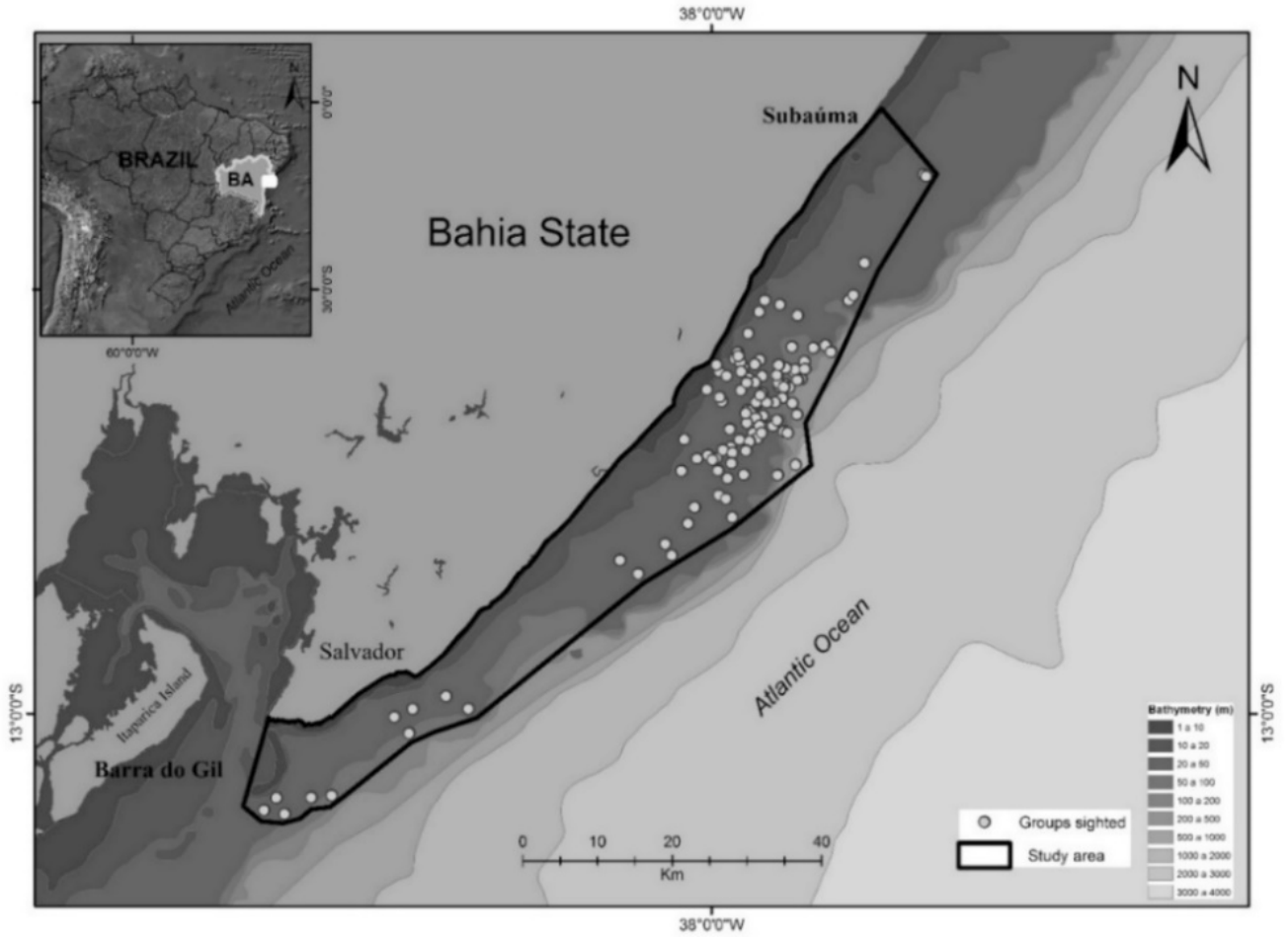

Figure 2. Groups sighted and study area between Subaúma (north limit) and Barra do Gil (south limit), north coast of Bahia, Northeast Brazil.

adult length and located near another whale were considered calves (Chittleborough, 1965).

Group size was classified into the following four categories according to the numerical composition: single, pair, trio, and three or more individuals. Although groups with calves were part of the analysis and were included in the numerical composition, the aerial behaviors of calves were not considered because they can be incorrectly interpreted, *i.e.*, calves perform the same maneuvers but differing to the adults as these are related to muscle development and learning social skills (Cartwright & Sullivan, 2009; Cartwright *et al.*, 2016). Therefore, aerial behaviors in groups with calves were only analyzed in relation to activity level without distinguishing the individual behaviors.

Aerial behaviors are defined as surface activities that include deliberate actions by whales aside from swimming and breathing, specifically, the display of appendages and other body parts above the water surface (Félix & Bo-

tero-Acosta, 2012). The aerial behaviors in this study were classified into the following five categories: Breach (BR), Spy Hop (SH), Head Slap (HS), Fin Slap (FS) and Tail Slap (TS), according to the terminology adopted by Engel (1996) and Félix & Botero-Acosta (2012).

The aerial behavior activity levels were divided into the following four categories based on Félix (2004): level 1 – high: behaviors repeated nine or more times; level 2 – medium: behaviors repeated up to eight times; level 3 – low: only one behavior performed; and level 4: no aerial behavior. The group activity level was the average number of behaviors performed ($\bar{x} = 8$).

The depth of the water at the location of the sightings was obtained with a Garmin Map 420s sonar GPS and grouped into the following five classes: up to 25, 26-50, 51-75, 76-100 and more than 100 meters.

A chi-squared test (χ^2) with a significance level (α) of 0.05 was used to detect significant differences in aerial behavior levels with group size, the activity levels of groups with and without calves, aerial behavior levels with depth, aerial behaviors and group size; and aerial behaviors by month.

Results

Surveys (N = 27) were conducted between 20 July and 8 October 2013. Humpback whales were observed on all survey days and during 50.7% of the total hours of effort. The sampling effort and sighting data are shown in Table 1. The location of the sighted groups is shown in Figure 2.

Activity level 4 was observed with the highest frequency and predominantly in singles, while activity levels 1 and 2 had higher frequencies in groups of more than three individuals

Table 1. Number of surveys carried out, nautical miles traveled, observation effort (in minutes), sighting effort (in minutes), minimum and maximum time of sighting effort (in minutes), number of sighted groups, number of sighted individuals, minimum and maximum size groups and number of sighted groups per hour effort during surveys carried out between July and October on the north coast of Bahia.

Data	Months				Total
	July	August	September	October	
Surveys	5	8	9	5	27
Nautical miles	400	328	236	196	1,160
Observation effort	1,551	2,546	3,230	1,843	9,170
Sighting effort	808	1,601	1,603	607	4,619
Min-max sighting effort	15-65	15-90	15-127	15-69	15-127
Nº of sighted groups	21	39	36	17	113
Nº of sighted ind.	52	99	88	33	272
Min-max group size	1-6	1-9	1-7	1-5	1-9
Sighted groups/hour effort	0.81	0.92	0.67	0.55	0.74

(Table 2). There were significant differences in the frequency of the aerial behavior levels with group size ($\chi^2 = 0.03$; df = 15; p = 7.261).

Table 2. Frequency of the aerial behaviors levels from humpback whales (*Megaptera novaeangliae*) according to group sizes.

Group sizes	Level 1	Level 2	Level 3	Level 4
1	12.9	12.9	3.2	71.0
2	8.3	18.8	12.5	60.4
3	-	28.6	21.4	50.0
> 3	25.0	55.0	5.0	15.0

Activity levels were analyzed with regard to the presence or absence of calves. Activity level 1 was not observed in groups with calves, and the frequency of activity level 4 was highest independent of the presence or absence of calves (Table 3). There was no significant difference between the frequency of the aerial behavior levels performed by the groups with and without calves ($\chi^2 = 0.14$; df = 7; p = 2.167).

Table 3. Frequency of the aerial behaviors levels performed by humpback whales (*Megaptera novaeangliae*) groups according to presence or absence of calves in the group.

Calves	Level 1	Level 2	Level 3	Level 4
Presence	-	11.5	7.7	80.8
Absence	14.9	28.7	10.3	46.1

Activity level 4 prevailed in water with depths of 1-25 m, 26-50 m and 51-75 m, while activity level 1 reached its highest frequency when the water depth was more than 100 m (Table 4). However, there were no significant differences in the frequency of the aerial behavior levels among the depth classes ($\chi^2 = 0.54$; *df* = 19; *p* = 10.117).

Table 4. Frequency between aerial behaviors levels from humpback whales (*Megaptera novaeangliae*) according to depths (in meters).

Depths (m)	Level 1	Level 2	Level 3	Level 4
1-25	14.3	-	14.3	71.4
26-50	5.2	27.5	12.1	55.2
51-75	5.9	17.6	5.9	70.6
76-100	20.0	60.0	-	20.0
> 100	40.0	-	20.0	40.0

Breach was the aerial behavior observed at the highest frequency independent of group size, whereas Fin Slap and Tail Slap were observed more often in groups of two or more individuals than in singles. Spy Hop and Head Slap where more frequently observed in groups of more than three individuals (Table 5). There were significant differences in the frequency of

the aerial behavior levels with group size (χ^2 = 0.00; *df* = 19; *p* = 10.117).

Table 5. Frequency of the aerial behaviors from humpback whales (*Megaptera novaeangliae*) associated with group sizes. BR - Breach, SH - Spy Hop, HS - Head Slap, FS - Fin Slap, TS - Tail Slap.

Group sizes	BR	SH	HS	TS	FS
1	66.7	-	24.2	7.6	1.5
2	55.7	-	1.5	11.5	31.3
3	50.0	-	8.3	25.0	16.7
> 3	31.6	5.2	20.2	18.4	24.6

In July, the most frequently observed behavior was Breach, while Spy Hop was only observed in September. Head Slap and Tail Slap were observed more often in August, and Fin Slap was most frequent in October (Table 6). However, there was no significant difference in the frequency of aerial behaviors among months (χ^2 = 0.74; *df* = 19; *p* = 10.117).

Table 6. Frequency of the aerial behaviors from humpback whales (*Megaptera novaeangliae*) performed between July and October 2013. BR: Breach, SH: Spy Hop, HS: Head Slap, FS: Fin Slap, TS: Tail Slap.

Months	BR	SH	HS	TS	FS
July	68.1	-	21.8	8.7	1.4
August	44.7	-	25.1	26.3	3.9
September	35.4	6.3	7.3	15.6	35.4
October	53.6	-	1.2	3.7	41.5

Discussion

Activity level 4 occurred with the highest frequency in singles. Although the sex of the individuals was not determined, solitary males invest more time singing underwater (Mobley & Herman, 1985) and, probably, less time on the surface performing aerial behaviors. Singing has several functions, such as a sexual display to attract females or as a signal in territorial competitions between males (Parsons *et al*., 2008). Moreover, acoustic signaling is significantly more effective than visual signaling in the marine environment because sound attenuates more slowly and spreads further, traveling great distances (Dunlop *et al*., 2008).

In groups of more than three individuals, activity levels 1 and 2 predominated, indicating a direct link between the aerial behavior level and group size (Whitehead, 1983; Félix, 2004). Usually, groups of more than three individuals are classified as competitive; males in these groups can either cooperate or compete for access to females through aggressive behaviors that are often observed on the water surface (e.g. Baker & Herman, 1984; Parsons *et al*., 2008).

Groups with calves did not reach activity level 1. Mother-calf pairs tend to be less active with adults exhibiting protective behavior (Clapham, 1996). On the north coast of Bahia, single and pairs of humpback whales are com-

monly sighted in waters shallower than 75 m (Rossi-Santos *et al*., 2008). Activity level 4 occurred at a higher frequency, and level 1 occurred at a lower frequency in waters with depths up to 75 m. Activities were usually performed by groups of three or more individuals in contrast to depth classes greater than 75 m. Groups of three or more individuals typically occurred in deeper waters compared to other group sizes, a result that was also reported for humpback whales in Madagascar (Ersts & Rosenbaum, 2003). Competitive groups select deeper waters to avoid collisions with the seabed and because shallow waters may discourage courting males, as reported in gray whales, *Eschrichtius robustus* (Jones & Swartz, 1984).

Regarding the different aerial behaviors, Breach reached the highest frequency in all group sizes, which was also reported by Félix (2004) and Pacheco *et al*. (2013) in Ecuador and Peru, respectively. Breach predominated relative to other behaviors in singles more than in other group sizes, which was also reported in eastern Australia, suggesting that breaching may be an inter-group signal (Dunlop *et al*., 2008).

On the north coast of Bahia, Head Slap obtained its highest frequency in singles but was also commonly observed in groups of three or more individuals. Groups of two individuals performed Fin Slap at a higher frequency when compared to other group sizes, as also noted along the coast of Peru (Pacheco *et al*. 2013). Groups of three or more individuals exhibited Tail Slap at a higher frequency than smaller groups, suggesting that this behavior is a demonstration of aggression between males competing for social dominance and proximity to females within the group (Whitehead, 1985a; b). Females, when receptive, could use aerial behaviors to attract males, promote competition and/or choose a partner, thus optimizing their contact with males during the breeding season (Cerchio *et al*., 2005).

Among the analyzed behaviors, Spy Hop occurred with the lowest frequency and was only observed in groups of three or more individuals in September. While Spy Hop is a non-vocal behavior, its lower frequency is understandable since percussive sounds, such as those produced by humpback whales through other aerial behaviors, can be heard several kilometers away and would thus complement vocalizations as part of a varied repertoire of social sounds (Herman & Tavolga, 1980; Dunlop *et al*., 2008).

The complex nature of humpback whale sociality on the breeding grounds requires long-term study. The characteristics of aerial behaviors, such as their sound, may present different dynamics with different group sizes. Additionally, Félix & Botero-Acosta (2012) suggest that determining the sex of individuals during periods of surface activity can provide valuable information about the social behavior of breeding groups. A better understanding of the structure and social behavior of *M. novaeangliae* requires an intense, integrated approach that involves individual identification (although there are a number of difficulties and limitations due to the unexpected nature of aerial displays), tissue collection (both

cases should involve focal animals and not only active groups), photo identification and the collection of bioacoustical data.

Although the songs of humpback whales have been extensively studied worldwide, percussive social sounds (the non-vocal social sound repertoire) have received little attention (Dunlop *et al*., 2008). This study provides a basis for more detailed studies on the non-vocal social sound repertoire and shows that humpback whales have a complex communication system (e.g. Sousa-Lima & Clark, 2008; Herman, 2016) that is not limited to song and can vary according to the environment.

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