Revista Brasileira de Zoociências

Rev. Bras. Zoociências | e-ISSN 2596-3325 | 21(1) | 1-12 |2020

ARTIGO ORIGINAL

Surface activity of Humpback whales *Megaptera novaeangliae* (Cetacea, Mysticeti) on the northern coast of Bahia, Brazil

Leonardo Leão Versiani[1] & Cristiano Schetini de Azevedo[2*]

[1]*Centro Universitário de Belo Horizonte, Belo Horizonte, MG, Brazil.*
[2]*Laboratório de Zoologia dos Vertebrados, Instituto de Ciências Exatas e Biológicas, Universidade Federal de Ouro Preto, Ouro Preto, MG, Brazil.*

**E-mail para correspondência: cristianoroxette@yahoo.com*

RESUMO

Atividades de superfície de baleias jubarte *Megaptera novaeangliae* (Cetacea, Mysticeti) na costa norte da Bahia, Brasil. As atividades de superfície das baleias jubarte foram estudadas durante as épocas reprodutivas de 2008, 2009 e 2010, na costa norte da Bahia, Brasil, próximo ao distrito de Praia do Forte. Os níveis de atividade de superfície exibidos por 342 grupos de baleias foram avaliados de acordo com o estado do mar (medido pela escala de Beaufort) e cobertura de nuvens. Cinco comportamentos foram registrados: saltos, batida de cabeça, batida da cauda, batida da nadadeira peitoral e cauda parada fora da água. A maioria dos avistamentos ocorreu com o estado 2 do mar na escala de Beaufort, e com uma cobertura de nuvens de 26 a 50%. O comportamento mais registrado durante as atividades de superfície foi a batida de nadadeira peitoral. Os resultados mostraram que o comportamento de superfície das baleias jubarte não parece ser influenciado pelo estado do mar ou pela cobertura de nuvens.

Palavras-chave: Cobertura de nuvens, Escala de Beaufort, Estado do mar, Fatores ambientais

ABSTRACT

Surface activities of humpback whale groups were studied during the reproductive seasons of 2008, 2009 and 2010 on the northern coast of Bahia State, Brazil, near the district of Praia do Forte. The level of surface activity exhibited by 342 groups of whales was evaluated according to the sea state (measured on the Beaufort scale) and cloud coverage. Five behaviours were recorded: breaching, head slapping, tail slapping, pectoral flipper slapping and tail breaching. Most of the sightings occurred with a sea state classified on the Beaufort scale as 2, and with a cloud coverage of 26 to 50%. The most recorded level of surface activity was pectoral flipper slapping. The results showed that humpback whale behaviours do not seem to be influenced by the sea state or by cloud coverage.

Keywords: Beaufort scale, Cloud coverage, Environmental factors, Sea state

Recebido em: 27/02/2020
Aceito em: 29/05/2020

INTRODUCTION

Humpback whales (*Megaptera navaeanglia* Borowski, 1781) are characterized by their long pectoral fins (1/3 of the total body length), small dorsal fin, and head and lower jaw covered by tubercles (Palazzo Jr. & Both, 1988; Perrin et al., 2008; Deméré, 2014). It is a cosmopolitan species, with most of the breeding activities occurring in the tropical and subtropical oceans (mainly in the coastal waters within the 200 m isobath; Zerbini et al. 2006), and feeding occurring mostly in high latitudes (Ristau et al., 2020). Their southern populations are classified in seven reproductive stocks (from A to G) (IWC, 2001), with the stock A reproducing in the South Atlantic, at Abrolhos Bank, in the Brazilian coast (Andriolo, 2010a,b).

Along the Antarctic coast, humpback whales form different populations during the foraging season in the summer (Baker et al., 1995; Rizzo & Schulte, 2009; Andrews-Goff et al., 2018), but they migrate to the tropical areas during the winter to breed in shallow and warm waters near the coast of the continents (Lunardi et al., 2008, 2010; Zerbini et al., 2011; Gonçalves et al., 2018). One of these populations migrates to the Brazilian coast, concentrating in the Abrolhos Bank (southern Bahia State), which is considered the principal breeding area of the species (Rossi-Santos et al*.,* 2008; Wedekin et al., 2010; Ristau et al., 2020).

Humpback whales often display surface activities such as breaches and flipper slapping (caudal and pectoral) (Félix, 2004; Kavanagh et al., 2017). Surface activities are normally exhibited during the breeding season, but their function is not fully understood (Félix, 2004). Male competition, aggressiveness, sexual stimulation, wound or irritation responses, play, intra- or interspecific communication are some of the suggested functions for surface activities (Herman & Tavolga, 1980; Frankel et al., 1995; Dunlop et al., 2008; Felix & Botero-Acosta, 2012; Dunlop et al., 2017; Kavanagh et al., 2017; Schuler et al., 2019).

Surface activities are probably influenced by environmental factors, such as time of day, tidal cycle, phases of the moon and sea state (Herman & Antinoja, 1977; Félix, 2004; Pacheco et al., 2013). Humpback whales tend to display more surface activities when the sea state is classified as calm (Morete et al., 2003; Félix, 2004); the influence of the cloud coverage was never tested for humpback whales, but it diminished the number of sightings of Harbor porpoises (*Phocoena phocoena*) and mink whales (*Balaenoptera acutorostrata*) (Dolman et al., 2014) and influenced surface water temperature, diminishing the number of whales in the surface (Sheidat, 2004). Thus, this study aimed to evaluate if the surface activities of humpback whales are influenced by environmental factors (sea state and cloud coverage) in the northern breeding area in Bahia State's coast, Brazil.

MATERIAL AND METHODS

This study was conducted in the area of the Praia do Forte (12º34'S; 37º59'W), in the Mata de São João Municipality, Bahia, northeastern Brazil (Figure 1). Observational studies of whales are common in this area. According to Castro and Miranda (1998), the water temperature in the surface of water varies between 25° and 26°C during the winter and between 27° and 28°C during the summer.

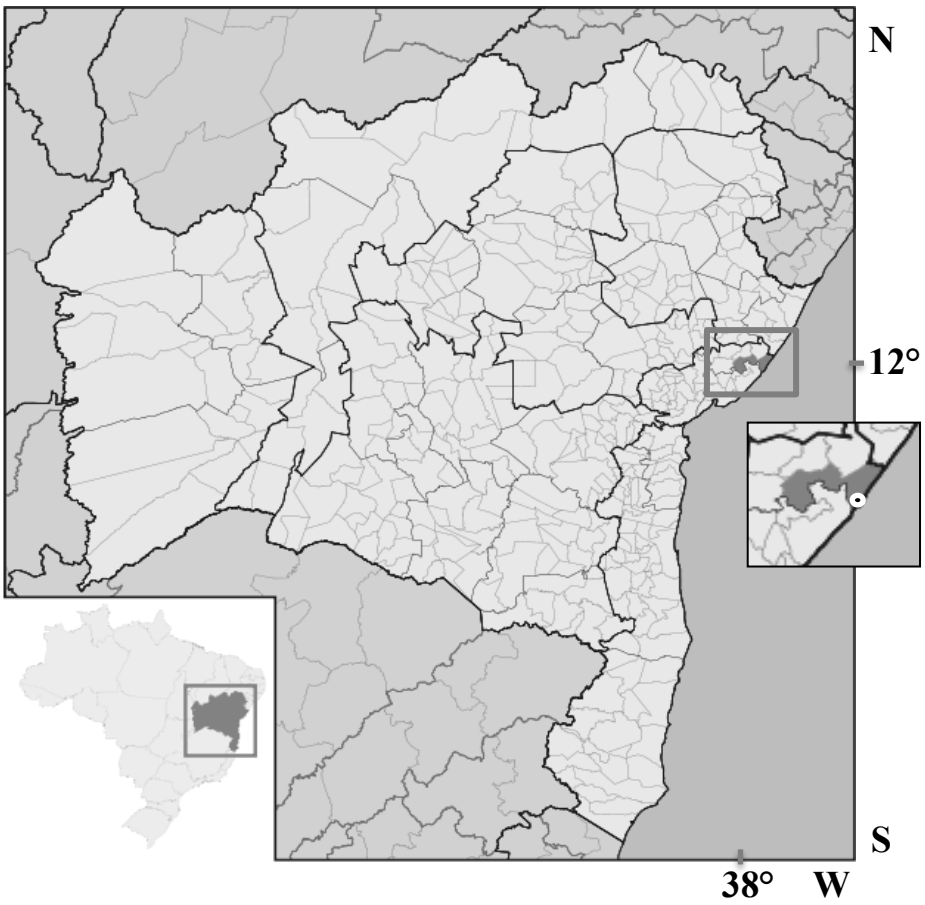

Figure 1: Study area on the northern coast of Bahia State, Brazil. The black/white dot shows the location of Praia do Forte, in the Mata do São João Municipality.

Data collection occurred between July and October (breeding season of the humpback whales in the coastal of Brazil) in three consecutive years: 2008, 2009 and 2010. Data recordings were made from a 14m-length wooden vessel, used during whale watching. Behavioural observations were made during daily trips that varied from 58 to 280 minutes (mean duration of 163 minutes). Whales were sighted and observed by a naked eye. A minimum of 100 m was maintained between the vessel and the whale during data recordings. Behavioural data were collected using the group-follow method (Mann et al., 2000; Azevedo et al., 2018), in 30-minutes sampling periods. All procedures of approaching and permanence

followed the recommendations of the Brazilian Agency of Environment and Natural Resources (IBAMA; Ordinance IBAMA Nº 117/96, 26 December 1996).

Surface activities were defined according to Félix (2004); that is, activities other than swimming and breathing, recorded at the ocean surface, which produce non-vocal noises. Five behaviours were recorded: breaching (an acrobatic display where the humpback uses its tail to launch itself out of the water then lands on the surface with a splash); head slapping (the humpback whale lunges forward with its head raised above the water); tail slapping (the humpback whale raises its tail flukes out of the water and slaps them forcefully on the surface of the water); pectoral flipper slapping (the humpback whale slaps the water's surface with one or both fins simultaneously); and tail breaching (an energetic display where the whale throws its tail out of the water and in the process, slaps its peduncle on the surface). Based on the number of exhibited behaviours and in the number of behavioural presentations, activity intensity levels were defined and divided in four categories: 1) highest level (level 1: if the whales exhibited one or more behaviours more than ten times during a recording session or if the whales exhibited at least three different behaviours during a recording session); 2) medium level (level 2: when the whales exhibited one or more behaviours, and they were exhibited at most nine times during a recording session); 3) low level (level 3: when the whales exhibited one or more behaviours occasionally; i.e., one or two times during a recording session); and 4) lowest level (level 4: when none behaviours were exhibited by the whales during a recording session) (Félix, 2004).

Groups of whales were separated into eight categories, based on behavioural characteristics and on observed attributes previously described for the species (Tyack & Whitehead, 1983; Baker & Herman, 1984; Clapham et al., 1992; Gómez, 2011; Félix & Novillo, 2015): (1) mother and calf (MC), (2) mother, calf and escort (MCE), (3) mother, calf and two escorts (MC2E), (4) mother, calf and more than two escorts (MCES), (5) singleton (S), (6) dyad (D), (7) triplets (T), and (8) more than three adults (MT).

Sea state and cloud coverage were measured when recording sessions started. Sea state was defined according to the Beaufort scale (Singleton, 2008) used in navigation to classify the sea surface aspect as a consequence of wind speed (Huler, 2004). This scale ranges from 0 (no wind and sea surface like a mirror) to 12 (hurricane winds and sea surface with high waves and water spray).

Cloud coverage was categorized as: 0 to 25% of coverage, 26 to 50% of coverage, 51 to 75% of coverage, and 76 to 100% of coverage. To investigate if the behaviours varied according to sea state and cloud coverage, data was analysed using a chi-square test using a level of significance of 95% ($\alpha = 0.05$) (Zar, 2009).

RESULTS

Whales were sighted 342 times, being 158 (46.19%) in 2008, 115 (33.63%) in 2009, and 69 (20.18%) in 2010. Most of the groups did not exhibit surface activities (195 groups in activity intensity level 4: 57.01%). Activity intensity level 3 was observed in 65 groups (19.01%), while activity intensity level 2 was observed in 49 groups (14.33%). The highest level of surface activity (level 1) was observed in 33 groups (9.65%) (Table 1).

In 2009, the highest recording of level 4 (no surface activities) (62.61%) and the lowest recording of level 1 (highest surface activities) (6.96%) were made (Table 1). In 2010, on the contrary, it was recorded the highest level of surface activities (level 1: 11.59%) and the lowest level of no surface activities (level 4: 53.62%) of all seasons evaluated (Table 1). The variation of the activity levels, however, did nor differed statistically between the years ($X^2 = 1.266$ for level 1; $X^2 = 0.804$ for level 2; $X^2 = 0.461$ for level 3 e $X^2 = 0.867$ for level 4; df = 2; $P > 0.05$ in all levels).

Table 1: Levels of surface activities of humpback whales in relation to breeding season (2008-2010) in the northern coast of Bahia, Brazil (absolute values and percentages).

Year	Group	Level of surface activity				Total
		1	2	3	4	
2008	Singleton	3 (1.86%)	3 (1.86%)	8 (4.97%)	28 (17.39%)	42 (26.09%)
	Dyad	3 (1.86%)	19 (6.21%)	15 (9.32%)	31 (19.25%)	59 (36.64%)
	Triplet	-	4 (2.48%)	1 (0.69%)	5 (3.11%)	10 (6.21%)
	> 3 adults	6 (3.73%)	3 (1.86%)	4 (2.48%)	5 (3.11%)	18 (11.18%)
	Mother/calf	3 (1.86%)	1 (0.62%)	4 (2.48%)	8 (4.97%)	16 (9.94%)
	Mother/calf/escort	1 (0.62%)	1 (0.62%)	2 (1.24%)	8 (4.97%)	12 (7.45%)
	Mother/calf/2 escorts	2 (1.24%)	-	-	1 (0.62%)	3 (1.86%)
	Mother/calf/+2 escorts	-	1 (0.62%)	-	-	1 (0.62%)
2009	Singleton	2 (1.64%)	3 (2.46%)	5 (4.10%)	20 (16.39%)	30 (24.59%)
	Dyad	2 (1.64%)	3 (2.46%)	7 (5.74%)	26 (21.31%)	38 (31.15%)
	Triplet	2 (1.64%)	1 (0.82%)	3 (2.46%)	7 (5.74%)	13 (10.66%)
	> 3 adults	1 (0.82%)	1 (0.82%)	2 (1.64%)	3 (2.46%)	7 (5.74%)
	Mother/calf	2 (1.64%)	4 (3.28%)	2 (1.64%)	15 (12.30%)	23 (18.85%)
	Mother/calf/escort	-	2 (1.64%)	1 (0.82%)	4 (3.28%)	7 (5.74%)
	Mother/calf/2 escorts	-	1 (0.82%)	1 (0.82%)	2 (1.64%)	4 (3.29%)
	Mother/calf/+2 escorts	-	-	-	-	-
2010	Singleton	2 (2.94%)	4 (5.88%)	3 (4.41%)	7 (10.29%)	16 (23.52%)
	Dyad	3 (4.41%)	1 (1.47%)	2 (2.94%)	11 (16.17%)	17 (25.00%)
	Triplet	-	-	2 (2.94%)	5 (7.35%)	7 (10.29%)
	> 3 adults	2 (2.94%)	3 (4.41%)	1 (1.47%)	3 (4.41%)	9 (13.24%)
	Mother/calf	-	1 (1.47%)	2 (2.94%)	7 (10.29%)	10 (14.71%)
	Mother/calf/escort	-	3 (4.41%)	2 (2.94%)	2 (2.94%)	7 (10.29%)
	Mother/calf/2 escorts	1 (1.47%)	-	-	1 (1.47%)	2 (2.94%)
	Mother/calf/+2 escorts	-	-	-	-	-

Level 1: highest level (if the whales exhibited one or more behaviours more than ten times during a recording session or if the whales exhibited at least three different behaviours during a recording session); 2) medium level (when the whales exhibited one or more behaviours, and they were exhibited at most nine times during a recording session); 3) low level (when the whales exhibited one or more behaviours occasionally; i.e., one or two times during a recording session); and 4) lowest level (when none behaviours were exhibited by the whales during a recording session) (Félix, 2004).

Most of the sightings occurred with the sea classified in the Beaufort 2 (n = 141; 41.23%), followed by Beaufort 1 (n=137; 40.06%), and Beaufort 3 (n = 64; 18.71%) (Table 2). The level of surface activity exhibited in each Beaufort sea state did not differed statistically (X^2 = 0.453 for level 1; X^2 = 4.96 for level 2; X^2 = 0.45 for level 3 e X^2 = 0.861 for level 4; df = 2 and P > 0.05 in all cases).

Table 2: Levels of surface activities of humpback whales in relation to sea state (according to the Beaufort scale) in the northern coast of Bahia, Brazil, during the breeding seasons of 2008-2010 (absolute values and percentages).

Beaufort Scale	Level of surface activity				Total
	1	2	3	4	
1	13 (9.49%)	11 (8.03%)	26 (18.98%)	87 (63.50%)	137 (40.06%)
2	15 (10.64%)	27 (19.15%)	26 (18.44%)	73 (51.77%)	141 (41.23%)
3	5 (7.81%)	11 (17.19%)	14 (21.88%)	34 (53.12%)	64 (18.71%)
Total	33 (9.65%)	49 (14.33%)	66 (19.30%)	194 (56.72%)	342 (100%)

Level of surface activity 1: highest level (if the whales exhibited one or more behaviours more than ten times during a recording session or if the whales exhibited at least three different behaviours during a recording session); 2) medium level (when the whales exhibited one or more behaviours, and they were exhibited at most nine times during a recording session); 3) low level (when the whales exhibited one or more behaviours occasionally; i.e., one or two times during a recording session); and 4) lowest level (when none behaviours were exhibited by the whales during a recording session) (Félix, 2004). Beaufort scale 1: ripple with the appearance of scales are formed, but without foam crests; 2) small wavelets still short, but more pronounced; crests have a glassy appearance and do not break; 3) large wavelets; crests begin to break; foam of glassy appearance; perhaps scattered white horses (Singleton, 2008).

Most of the sightings occurred with a cloud coverage less than 50% (n = 230, 67.25%); observations with the sky covered by 26-50% of clouds were more common (n = 123, 35.96%) than observations with the sky covered by 51-75% of clouds (n = 46, 13.45%) (Table 3). Surface activity in each cloud coverage varied, but no statistical differences were found (X^2 = 0.409 for level 1; X^2 = 4.873 for level 2; X^2 = 1.971 for level 3 and X^2 = 0.335 for level 4; df = 3 and P > 0.05 in all cases).

Table 3: Levels of surface activities of humpback whales in relation to cloud coverage in the northern coast of Bahia, Brazil, during the breeding seasons of 2008-2010 (absolute values and percentages).

Cloud coverage (%)	Level of surface activities				Total
	1	2	3	4	
0-25	9 (8.41%)	10 (9.35%)	24 (22.43%)	64 (59.81%)	107 (31.29%)
26-50	11 (8.94%)	18 (14.63%)	25 (20.33%)	69 (56.1%)	123 (35.96%)
51-75	6 (13.04%)	8 (17.39%)	7 (15.22%)	25 (54.35%)	46 (13.45%)
76-100	7 (10.61%)	14 (21.21%)	10 (15.15%)	35 (53.03%)	66 (19.30%)
Total	33 (9.65%)	50 (14.62%)	66 (19.30%)	193 (56.43%)	342 (100%)

Level of surface activity 1: highest level (if the whales exhibited one or more behaviours more than ten times during a recording session or if the whales exhibited at least three different behaviours during a recording session); 2) medium level (when the whales exhibited one or more behaviours, and they were exhibited at most nine times during a recording session); 3) low level (when the whales exhibited one or more behaviours occasionally; i.e., one or two times during a recording session); and 4) lowest level (when none behaviours were exhibited by the whales during a recording session) (Félix, 2004).

DISCUSSION

Sea state and cloud coverage did not influence the surface activities of humpback whales, not corroborating the results found by Herman & Antinoja (1977) and Scott &Winn (1979). These authors reported an increase in the surface activities in a rough sea, relating it to an increase in the water turbidity and in sound pressure levels due to turbulent waters, especially in the shallow waters used by the whales in the breeding season. In the present study, the highest classification of the sea state was 3, what in the Beaufort scale means light winds that provoke waves of 60 cm high at maximum (Huler, 2004). Calm waters means good possibilities to acoustic communications (Preisig, 2006; Jones, 2019), consequently, a low need to exhibit surface activities. The calm waters probably influenced the level of surface activities recorded for humpback whales during this study.

The functions of the surface activities exhibited by the humpback whales remain speculative, but many researchers suggest that they play a role in the social organization of the groups (Félix, 2004; Dunlop et al., 2017; Kavanagh et al., 2017; Schuler et al., 2019). Dunlop, Cato & Noad (2008) related that the rate of exhibition of the behaviour “breaching” was higher for solitary males or solitary whales of unidentified sex, suggesting that this behaviour have a function in the inter-group communication. “Slapping” was more recorded in groups of whales composed by mother-calf and mother-calf-escort, suggesting a function in the intra-group communication. Whitehead (1983, 1985) reported higher rates of surface activities in groups of more than two whales. Fiori et al. (2020) observed pairs, trios, and groups up to nine individuals expressing surface activities. These activities were related to agonistic behaviours and reproductive behaviours. One interesting result found by Fiori et al. (2020) was the influence of swimmers on surface activity of humpback whales: for mothers with calves, the amount of surface activity decreased significantly in the presence of swimmers, and for groups with no calves, surface activity increased significantly. These results showed the impacts of swim-with-the-whales tourism activities. In the present study, only groups of whales were recorded, but since data on group compositions were not collected, no correlations could be made.

Environmental factors certainly influence the propagation of the surface activities’ sounds through the water, but probably characteristics like temperature, depth, and salinity are more important in the rate of exhibitions than the variables studied here (Nia & Delphi, 2011; Sanjana et al., 2014), thus, further studies should be conducted to evaluate this hypothesis.

ACKNOWLEDGEMENTS

The authors thank Instituto Baleia Jubarte for authorization to use their facilities and database, and Dr. Robert Young for invaluable suggestions to this note. Projeto Baleia Jubarte is sponsored by Petróleo Brasileiro S.A. (Petrobras). Authors would also like to thank important contributions made by the anonymous reviewers.

REFERENCES

Andrews-Goff, V.; Bestley, S.; Gales, N.J.; Laverick, S.M.; Paton, D.; Polanowski, A.M.; Schmit, N.T. & Double, M.C. 2018. Humpback whale migrations to Antarctic summer for aging grounds through the south-west Pacific Ocean. **Scientific Reports 8**: 12333.

Andriolo, A.; Kinas, P.G.; Emgel, M.H.; Martins, C.C.A. & Rufino, A.M. 2010a. Humpback whales within the Brazilian breeding ground: distribution and population size estimate. **Endangered Species Research 11**: 233-243.

Andriolo, A.; Rocha, J.M.; Zerbini, A.N.; Simões-Lopes, P.C.; Moreno, I.B.; Lucena, A.; Danilewicz, D. & Bassoi, M. 2010b. Distribution and relative abundance of large whales in a former whaling ground off Eastern South America. **Zoologia 27**: 741-750.

Azevedo, C.S.; Barçante, L. & Teixeira, C.P. 2018. **Comportamento Animal: uma introdução aos métodos e à ecologia comportamental**. Curitiba, Editora Appris. 220 p.

Baker, C.S. & Herman, L.M. 1984. Aggressive behavior between humpback whales (*Megaptera novaeangliae*) wintering in Hawaiian waters. **Canadian Journal of Zoology 62**: 1922-1937.

Baker, C.S.; Florez-Gonzalez, L.; Rosenbaum, H.C. & Bannister, J. 1995. Molecular genetic identification of sex and stock structure among Humpback whales of the southern hemisphere. **Report of the International Whaling Commission 47**: 1-20.

Castro, B.M. & Miranda, L.B. 1998. Physical Oceanography of the Western Atlantic Continental Shelf Located Between 4°N and 34°S, Coastal Segment (4,W), pp. 209-251. In: Robinson, A.R. & Brink, K.H. (Eds.). **The Sea**. New York, John Wiley and Sons. 1090 p.

Clapham, P.J.; Palsboll, P.J.; Mattila, D.K. & Vasquez, O. 1992. Composition and dynamics of humpback whale competitive groups in the West Indies. **Behaviour 122**: 182-194.

Deméré, T. 2014. Family Balaenopteridae. In: Mittermeier, R.A. & Wilson, D.O. (Eds.). Handbook of the Mammals of the World, volume 4. Barcelona, Lynx Editions. 614 p.

Dolman, S. J.; Hodgins, N. K.; Macleod, C. D.; Pierce, G. J. & Weir, C. R. 2014. Harbour porpoises (*Phocoena phocoena*) and minke whales (*Balaenoptera acutorostrata*) observed during land-based surveys in the Minch, north-west Scotland. **Journal of the Marine Biological Association of the United Kingdom 94**: 1185-1194.

Dunlop, R.A.; Cato, D.H. &. Noad, M.J. 2008. Non-song acoustic communication in migrating humpback whales (*Megaptera novaeangliae*). **Marine Mammal Science 24**: 613-629.

Dunlop, R.A.; Noad, M.J.; McCauley, R.D.; Kniest, E.; Slade, R.; Paton, D. & Cato, D.H. 2017. The behavioural response of migrating humpback whales to a full seismic airgun array. **Proceedings of the Royal Society B 284**: 20171901.

Félix, F. 2004. Assessment of the level of surface activity in humpback whales during the breeding season. **LAJAM 3**: 25-36.

Félix, F. & Botero-Acosta, N. 2012. Evaluating humpback whale (*Megaptera novaeangliae*) social behaviour through sexing active individuals. **Aquatic Mammals** 38(3): 311-316.

Félix, F. & Novillo, J. 2015. Structure nad dynamics of humpback whales competitive groups in Ecuador. **Animal Behavior and Cognition 2**(1): 56-70.

Fiori,L.; Martinez, E.; Orams, M.B. & Bollard, B. 2020. Using unmanned aerial vehicles (UAVs) to assess humpback whale behavioral responses to swim-with interactions in Vavau's Kingdom of Toga. **Journal of Sustainable Tourism**. On line first. https://doi.org/10.1080/09669582.2020.1758706.

Frankel, A. S.; Clark, C.W.; Herman, L.M. & Gabriele, C.M. 1995. Spatial distribution, habitat utilization, and social interactions of humpback whales, *Megaptera novaeangliae*, off Hawaii, determined using acoustic and visual techniques. **Canadian Journal of Zoology 73**: 1134-1146.

Gómez, O.R. 2011. Behavioral description on surface nad characterization of humpback whales (*Megaptera novaeangliae*) during the breeding season 2006 I. Colombian Pacific coast. **Revista de Biodiversidade Neotropical 1**(2): 105-115.

Gonçalves, M.I.C.; Carvalho, G.H.; Danilewicz, D. & Baumgarten, J.E. 2018. Movement patterns of humpback whales (*Megaptera novaeangliae*) reoccupying a Brazilian breeding ground. **Biota Neotropica 18**(4): e20180587.

Herman, L.M. & Antinoja, R.C. 1977. Humpback whales in the Hawaiian breeding waters: population and group characteristics. **Whales Research Institute 29**: 59-85.

Herman, L.M. & Tavolga, W.N. 1980. The communication systems of Cetaceans, pp. 149-209. In: Herman, L.M. (Ed.). **Cetacean Behavior: mechanisms & functions**. New York, John Wiley & Sons. 480 p.

Huler, S. 2004. **Defining the wind: the Beaufort scale, and how a 19th-Century admiral turned science into poetry**. Crown, New York. 304 p.

IBAMA. 1996. **Portaria nº 117/96**. Diário Oficial da União, Brasília: DF.

IWC. 2001. Report of the sub-committee on the comprehensive assessment of whale stocks. InDepth assessments international whaling commission. **Journal of Cetacean Research and Management 3**: 177-208.

Kavanagh, A.S.; Owen, K.; Williamson, M.J.; Blomberg, S.P.; Noad, M.J.; Goldizen, A.W.; Kniest, E.; Cato, D.H. & Dunlop, R.A. 2017. Evidence for the surface-active behaviors in humpback whales (*Megaptera novaeangliae*). **Marine Mammal Science 33**(1): 313-334.

Jones, N. 2019. The quest for quieter seas. **Nature 568**: 158-161.

Lunardi, D.G.; Engel, M.H. & Macedo, R.H.F. 2008. Behavior of humpback whales, *Megaptera novaeanglia* (Cetacea: Balaenopteridae): comparisons between two coastal areas of Brazil. **Revista Brasileira de Zoologia 25**: 159-164.

Lunardi, D.G.; Engel, M.H.; Marciano, J.L.P. & Macedo, R.H. 2010. Behavioural strategies in humpback whales, *Megaptera novaeangliae*, in a coastal region of Brazil. **Journal of the Marine Biological Association of the United Kingdom 90**: 1693-1699.

Mann, J.; Connor, R.C.; Tyack, P.L. & Whitehead, H. 2000. **Cetacean Societies: field studies of dolphins and whales**. Chicago, The University of Chicago Press. 448 p.

Morete, M.E.; Freitas, A.; Engel, M.H.; Pace III, R.M. & Clapham, P.J. 2003. A novel behavior observed in humpback whales on wintering grounds at Abrolhos Bank (Brazil). **Marine Mammal Science** 19: 694-707.

Nia, S.A. & Delphi, M. 2011. Mechanism of sound propagation in seawater. **International Journal of Current Research 3**: 95-99.

Pacheco, A.S.; Silva, S.; Alcorta, B.; Balducci, N.; Guidino, C.; Llapapasca, M.A. & Sanchez-Aslazar, F. 2013. Eraial behavior of humpback whales *Megaptera novaeangliae* at the southern limit of the southeast Pacific breeding area. **Revista de Biologia Marina y Oceanografía 48**(1): 185-191.

Palazzo Jr., J.T. & Both, M.C. 1988. **Guia dos Mamíferos Marinhos do Brasil**. Porto Alegre, Sagra. 160 p.

Perrin, W.F.; Wursig, B.& Thewissen, J.G.M. 2008. **Encyclopedia of Marine Mammals** (2nd ed.). New York, Elsevier. 1352 p.

Preisig, J. 2006**. Acoustic propagation considerations for underwater acoustic communications network development**. In: Proceedings of the First ACM International

Workshop on Underwater Networks (WUWNet'06), 2006, Los Angeles, USA. p. 1-5.

Ristau, N.G.; Martins, C.C.A.; Luvizotto-Asntos, R.; Balensiefer, D.; Sousa, G.; Marmontel, M. & Farias, I.P. 2020. Sharing the space: veriew of humpback whale occurrence in the Amazonian equatorial coast. **Global Ecology and Conservation 22**: e00854.

Rizzo, L.Y. & Schulte, D. 2009. A review of humpback whale's migration patterns worldwide and their consequences to gene flow. **Journal of the Marine Biological Association of the United Kingdom 89**(5): 995-1002.

Rossi-Santos, M.R.; Neto, E.S.; Baracho, C.G.; Cipolotti, S.R.; Marcovaldi, E. & Engel, M.H. 2008. Occurrence and distribution of humpback whales (*Megaptera novaeangliae*) on the north coast of the State of Bahia, Brazil, 2000-2006. **Journal of Marine Science 65**: 667-673.

Sanjana, M.C.; Latha, G.; Thirunavukkarasu, A. & Raguraman, G. 2014. Acoustic propagation affected by environmental parameters in coastal waters. **Indian Journal of Geo-Marine Sciences 43**(1): 17-21.

Schuler, A.R.; Piwetz, S.; Di Clemente, J.; Steckler, D.; Mueter, F. & Pearson, H.C. 2019. Humpback whale movements and behavior in response to whale-watching vessels in Juneau, AK. **Frontiers in Marine Science 6**: 710.

Scott, G.P. & Winn, H.E. 1979. **Comparative evaluation of aerial and shipboard sampling techniques for estimating the abundance of humpback whales (*Megaptera novaeangliae*)**. Rhode Island, University of Rhode Island Press.

Sheidat, M.; Castro, C.; Gonzalez, J. & Williams, R. 2004. Behavioural responses of humpback whales (*Megaptera novaeangliae*) to whalewatching boats near Isla de la Plata, Machalilla National Park, Ecuador. **Journal of Cetacean Research and Management 6**(1): 63-68.

Singleton, F. 2008. The Beaufort scale of winds: its relevance and its use by sailors. **Weather 63**: 37-41.

Tyack, P. & Whitehead, H. 1983. Male competition in large groups of wintering humpback whales. **Behaviour 83**: 132-154.

Wedekin, L.L.; Neves, M.C.; Marcondes, M.C.C.; Baracho, M.C.; Rossi-Asntos, M.R.; Emgel, M.H. & Simões-Lopes, P.C. 2010. Site fidelity and movements of humpback whales (*Megaptera novaeangliae*) on the Brazilian breeding ground, southwestern Atlantic. **Marine Mammal Science 26**(4): 787-802.

Whitehead, H.P. 1983. Structure and stability of humpback whale groups off Newfoundland. **Canadian Journal of Zoology 61**: 1391-1397.

Whitehead, H.P. 1985. Humpback whale breaching. **Investigations on Cetacea 17**: 117-155.

Zar, J.H. 2009. **Biostatistical Analysis** (5th edn.). New Jersey, Prentice Hall. 944 p.

Zerbini, A.N.; Andriolo, A.; Heide-Jørgensen, M.P.; Pizzorno, J.L.; Maia, Y.G.; VanBlaricom, G.R.; DeMaster, D.P.; Simões-Lopes, P.C.; Moreira, S. & Bethlem, C. 2006. Satellite-monitored movements of humpback whales *Megaptera novaeangliae* in the southwest Atlantic Ocean. **Marine Ecology Progress Series 313**: 295-304.

Zerbini, A.N.; Andriolo, A.; Heide-Jorgensen, M.P.; Moreira, S.C.; Pizzorno, J.L.; Maia, Y.G.; VanBlaricom, G.R. & DeMaster, D.P. 2011. Migration and summer destinations of humpback whales (*Megaptera novaeangliae*) in the western South Atlantic Ocean. **Journal of Cetacean Research and Management 3**: 113-118.