Aquatic Mammals 2014, *40*(3), 225-231, DOI 10.1578/AM.40.3.2014.225

Bryde's Whale (*Balaenoptera edeni*) Vocalizations from Southeast Brazil

Luciana D. Figueiredo[1, 2] and Sheila M. Simão[1]

[1] *Laboratório de Bioacústica e Ecologia de Cetáceos, Departamento de Ciências Ambientais, Instituto de Florestas, Universidade Federal Rural do Rio de Janeiro, BR 465, km 7, Seropédica, RJ, 23890-000, Brazil*
E-mail: ldsigue@terra.com.br
[2] *Instituto Federal de Educação Ciência e Tecnologia do Rio de Janeiro, Rua Lucio Tavares 1045, Nilópolis, RJ, 26530-060, Brazil*

Abstract

The Bryde's whale (*Balaenoptera edeni*) is a species commonly documented along the southeast coast of Brazil, but nothing is known about their vocalizations in this area. Underwater recordings were gathered in an opportunistic manner when the species was present along the coast of the Rio de Janeiro State. A total of 143 min of recordings was analyzed, and five different call types were found. The most abundant call type consisted of a series of discrete pulses that was detected during the observation of a mother-calf pair. Other types of calls were recorded from solitary whales, including a flat tone with harmonics, a downswept tone, and two types of calls with multiple components. All recorded calls were short (< 2 s), with the exception of the series of pulses (> 7 s), with frequency ranges below 1 kHz. The call composed of a series of discrete pulses is likely linked to calf-adult interactions given that this call was previously reported in the presence of calves in the Gulf of California. This is the first description of the Bryde's whale vocal repertoire in the South Atlantic. The vocalizations described herein present generally identifiable characteristics of the species' calls; however, some variations may be specific to this area.

Key Words: Bryde's whale, *Balaenoptera edeni*, vocalization, whale call, Cabo Frio, southwest Brazil

Introduction

Although the occurrence of Bryde's whales (*Balaenoptera edeni* Anderson, 1978) has been reported in the tropical and temperate waters of the Pacific, Atlantic, and Indian Oceans, it is the least known of the large mysticetes (Kato & Perrin, 2009). Bryde's whale do not make long migrations, instead remaining in tropical and temperate waters throughout the year; however, there is no available information about where breeding groups occur or about the reproductive period of Bryde's whales (Kato & Perrin, 2009).

Cummings et al. (1986) were the first to report sound records for Bryde's whales in the Gulf of California. These sounds were very short tonal calls (mean duration of 0.42 s), occurring at a mean frequency of 124 Hz with slight upward or downward frequency modulations (Δf = 15 Hz). Edds et al. (1993) analyzed sounds from a captive juvenile stranded in the Gulf of Mexico on the coast of Florida, and from free-ranging adults and adult-calf pairs in the Gulf of California. Pulses, moans, and pulsed moans were recorded (Edds et al., 1993), some of which were longer in duration (~1.5 s) than the recordings made by Cummings et al. (1986). The call frequencies observed by Edds et al. (1993) ranged between 90 and 900 Hz. Two studies in the eastern tropical Pacific Ocean described tonal calls with harmonics that were longer in duration (~3 s) and lower in frequency (~60 Hz) than calls previously reported for the Bryde's whales (Oleson et al., 2003; Heimlich et al., 2005). Tonal calls with low frequency (20 to 26 Hz) and long duration (~5 s) were also associated with Bryde's whales along the northern New Zealand coast (McDonald, 2006).

In Brazil, Bryde's whales are found in coastal waters along the entire coast, with sightings most commonly made in the south and southeast (Zerbini et al., 1997). There are also reports of the species in oceanic waters (Andriolo et al., 2010), but nothing is known about their vocalizations. In this article, we describe the basic characteristics of Bryde's whale's vocalizations recorded in the Cabo Frio region (Rio de Janeiro State, Brazil), where the species is commonly found (Zerbini et al., 1997). We also compare these vocalizations to the repertoire previously described in the literature for this species.

Methods

The study area along the Cabo Frio coast is characterized by a change in the shoreline from a north-south to a southwest-northeast orientation with a steep slope (Figure 1) (De Leo & Pires-Vanin, 2006). Throughout the year, a mixture of Brazil Current waters and South Atlantic Central waters is present and is strongly influenced by the north-northeast wind regime, producing an upwelling phenomenon that is especially prevalent during the spring and summer (Carbonel, 1998). The survey area included depths ranging from 5 to 90 m.

Acoustic recordings were gathered opportunistically during surveys to document the social organization and bioacoustics of long-beaked common dolphin (*Delphinus capensis*) in Arraial do Cabo from December 2010 to November 2012 (Simão, 2013). Surveys were conducted from a 6.5-m center-console, rigid-hulled inflatable boat, fitted with a 150-hp outboard engine. Haphazard routes were used to maximize area coverage. When a Bryde's whale was seen, the boat slowly approached it. When the boat was within approximately 100 m of the animal, the geographic position was recorded (Garmin E-Trex Vista CX GPS); the vessel's engine was switched off to reduce background noise; and recordings were collected. If the Bryde's whale moved away to the point where only its blow could be seen (~300 m), the acoustic recording was stopped and another approach was initiated.

Acoustic data were collected with an M-Audio MicroTrack 24/96 (96 kHz; 24 bit .wav files) digital recorder fitted with a C54 hydrophone (Cetacean Research Technology, Inc., Seattle, WA, USA; 0.008 to 100 kHz; -165 dB re 1 V/mPa) deployed to approximately 2 m depth. Photos of each Bryde's whale were taken using a Canon EOS D-40 camera (75 to 300 mm lens) for photo-identification. Bryde's whale behavior, group size, and composition were documented via a video camera (Sony DCR-SX 40). Acoustic recordings were collected only when other cetacean species were not visually documented in the area. Although it is theoretically possible that another species, not detected visually by our team, produced calls that we recorded, it is not likely.

All sound recordings were digitally transferred to *Raven 1.4* (Cornell Laboratory of Ornithology, Ithaca, NY, USA), and spectrograms (Hann, window size 313 ms, 3 dB bandwidth of 4.59 Hz, overlap coefficient of 70%, DFT size 32,768 samples, and 2,93 Hz) were created for analysis. Only vocalizations with a good signal-to-noise ratio

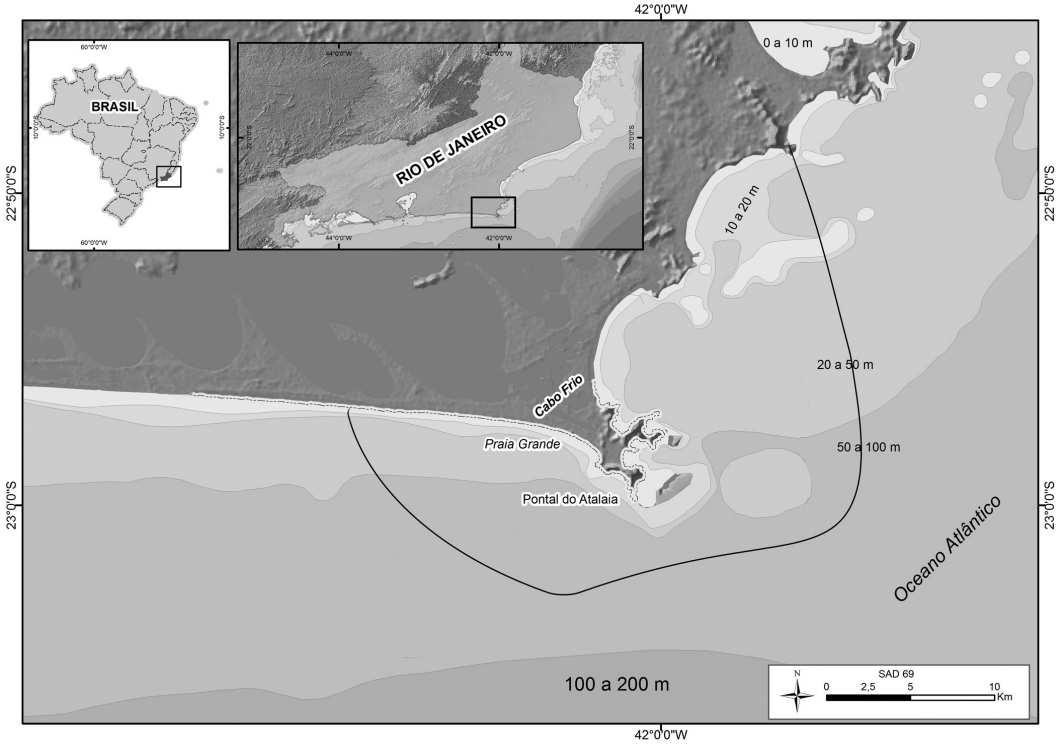

Figure 1. The Cabo Frio region; the marked area comprises the study area.

(i.e., clearly distinguishable from the background noise) were analyzed.

Results

A total of 143 min of recordings were made during 10 different observations (14.3 min; range: 7 to 30.3 min) of Bryde's whales, and five types of calls were documented (Table 1). A series of discrete pulses (PS1; Figure 2 & Table 2) was recorded repeatedly during an observation of an adult/calf pair when no other Bryde's whales were seen in the area. The adult was photo-identified and seen again 230 d later, also with a calf, along the Rio de Janeiro city coast (Figueiredo et al., in press). Therefore, it was inferred that the adult was a female. The number of pulses per series ranged between two and six, except for two long series (12 and 25 pulses, respectively) that were observed about 2 min before the Bryde's whales moved out of the area. In a series, all pulses had approximately the same wide frequency range (142 to 798 Hz), but there was an apparent decrease in energy above 500 Hz.

One low-frequency tonal call (LFT; Figure 2 & Table 3) with one to four harmonics and a downsweep call (FMT; Figure 2 & Table 1) were recorded during the observation of a solitary Bryde's whale. This individual was photo-identified and seen again 43 d later, accompanied by a calf. On the second sighting, the adult and calf were the only Bryde's whales sighted in the area; the pair was followed for 3.15 h. The calf's body size was more than half as small as the adult's body size. It seems unlikely that such a small calf could stay with an adult for more than 3 h without nursing, which leads us to infer that this was a mother/calf pair—that is, it is likely that the adult was a female and was pregnant during our first recording session with this animal. Unfortunately, we could not collect sound recordings during the observation of this mother/calf pair because the sea conditions were too rough. The FMT call was documented only twice; the frequency range and duration of these two FMT calls were quite different between the first and second vocalizations at 430 to 336 Hz for 0.9 s and 915 to 500 Hz for 2.1 s, respectively. However, the calls were similar in contour shape, separated by only 70 s.

During one sighting, when a solitary Bryde's whale spontaneously approached and swam around the boat within 3 to 10 m over 8 min, two types of multicomponent tonal calls were identified. Each call occurred just once during the recording. The first call (TM1) had a predominantly flat tone at 55 Hz with two harmonics, and two secondary flat tones, not harmonically related, between the fundamental and the first harmonic (Figure 2). All tones were emerged in a burst wide-band noise. The total duration of the call was 1.14 s, and the call was produced when the Bryde's whale was very close (~3 m) to the boat. The second vocalization (TM2) began with an upper-frequency flat component at approximately 112 Hz, immediately followed by a slightly upswept tone beginning at approximately 96 Hz (Figure 2). The total call duration was 0.9 s and was produced as the Bryde's whale moved away from the boat. This

Table 1. Quantitative characterization of the five Bryde's whale call types from Cabo Frio region

Call type	N	Low frequency (Hz)	High frequency (Hz)	Bandwidth (Hz)	Duration (s)
PS1	115	225 (± 50)	555 (± 119)	330 (± 133)	0.788 (± 0.698)
LFT	10	8.5 (± 0,93).	19 (±1.39)	11 (± 0.95)	1.413 (± 0.461)
FMT	2	416 (± 114)	671 (± 342)	255 (± 228)	1.531 (± 0.797)
TM1	1	85.7	123.6	37.9	0.876
TM2	1	49.5	105.5	56	1.156

Table 2. Comparison of summary statistics for discrete pulse series emitted by Bryde's whales in the Gulf of California (Edds et al., 1993) and in the Cabo Frio region (as reported in this study; PS1); average values are in parentheses.

	Cabo Frio (N = 115)	California (N not given)
Frequency range (Hz)	142-798	700-900
Pulse duration (ms)	75-136 (90)	25-40
Interpulse interval (ms)	95-218 (130)	50-100
Pulses per series	2-25 (4.2)	4-11
Series duration (s)	0.29-7.3 (0.79)	Not given
Intercall interval (s)	0.43-8.1 (4.4)	1-64
Bandwith (Hz)	158-846 (330)	100

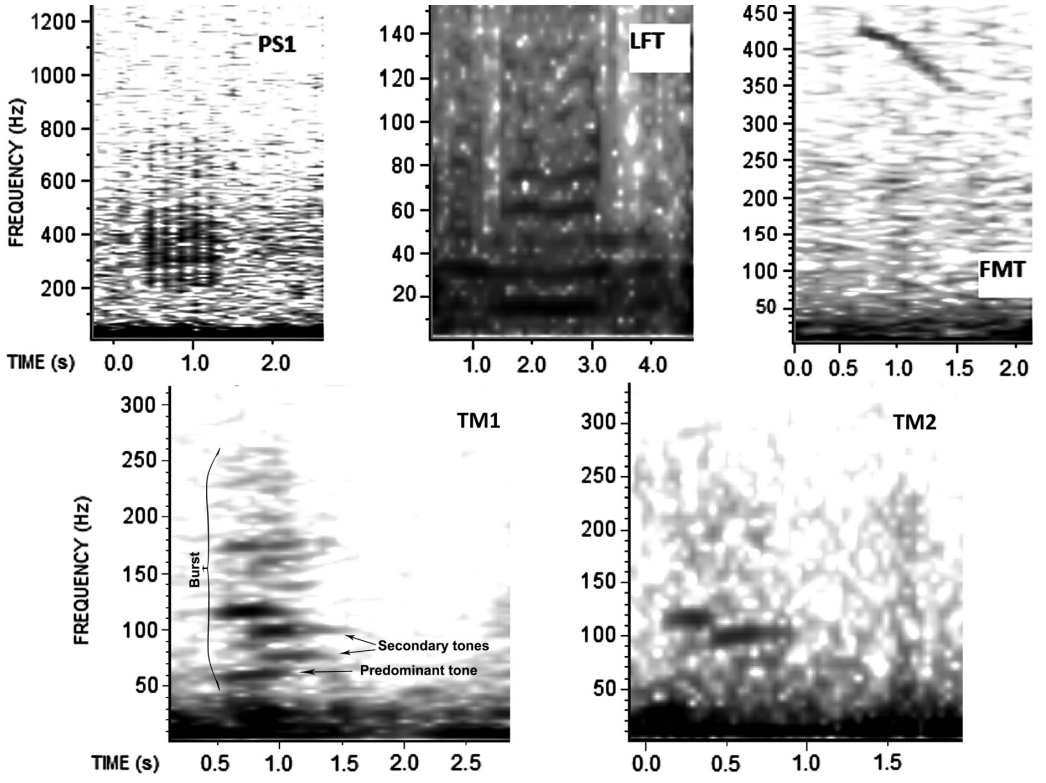

Figure 2. Spectrograms of five calls made by Bryde's whales in the Cabo Frio region, Brazil

Table 3. Comparison of summary statistics for tonal harmonic calls made by Bryde's whales as described in previous studies (Be3, Be5, Be7, Be8b, and Harmonic tone) and in this study (LFT); minimum and maximum values are given in parentheses.

Call type	N	Frequency (Hz)	Duration (s)	Harmonics number	Intercall interval (s)	Reference
LFT	10	11 (10-14)	1.45 (0.81-2.24)	1-4	15.3 (0.27-96)	--
Be3	18	25.6 (24.4-26.9)	1.7 (1.0-4.0)	2-4	2.28 (0.45-8.65)	Oleson et al., 2003
Be5	6	26.2 (26-26.8)	1.7 (1.3-2.2)	4-8	5.5 (1.5-15.88)	Oleson et al., 2003
Be7	51	44.3 (43.7-48.7)	1.6 (0.8-2.5)	2-4	2.83 (0.4-7.08)	Oleson et al., 2003
Be8b	4	46 (137-192)	0.37 (0.3-0.41)	Several	0.29 (0.25-0.33)	Oleson et al., 2003
Harmonic tone	114	25.4 (20.7-25.8)	2.1 (0.5-3.2)	3	6.3 (2-44.3)	Heimlich et al., 2005

was the first animal sighted on this day, and no other animals were visible in the area during and immediately following this recording session.

Discussion

Our acoustic data were gathered in an opportunistic way, which resulted in a small sample size. Furthermore, unlike the sounds emitted by other baleen whales, Bryde's whale vocalizations seem to be quite short, commonly less than 3 s, and are typically not very loud relative to background noise (Heimlich et al., 2005). These factors can make the detection of Bryde's whale vocalizations somewhat difficult, especially in a coastal environment. Nevertheless, these are the first Bryde's whale vocalizations recorded in the South Atlantic Ocean, and important characteristics for these calls can be highlighted.

Of the five Bryde's whale vocalization types recorded in the Cabo Frio region, three vocalizations (LFT, TM1, and TM2) had universal characteristics readily identifiable for the species, including a predominant tone with little frequency modulation, a duration of 1 to 3 s, and a frequency below approximately 120 Hz (Heimlich et al.,

2005). The discrete pulse series described herein had higher frequencies, like the discrete pulses reported by Edds et al. (1993); however, this call may be made exclusively by calves. The downsweep call (FMT) was quite different from the low-frequency vocalizations characteristic of the species; however, because nothing is known about the vocalizations of Bryde's whales in the South Atlantic Ocean, the universal vocalization characteristics previously reported for the species in other oceans may not be applicable to this study population.

Pulse calls have previously been detected for other baleen whales such as the fin whale (*B. physalus*; Clark et al., 2002), blue whale (*B. musculus*; Rivers, 1997), and minke whale (*B. acutorostrata*; Mellinger et al., 2000). For the Bryde's whale, pulse calls were reported in the Gulf of California (Edds et al., 1993) and in the northwest Pacific Ocean near the coast of Japan (Oleson et al., 2003). Edds et al. (1993) also reported discrete pulses; however, those vocalizations were somewhat different from the pulsed calls found in this study. The pulse and the inter-pulse durations described by Edds et al. (1993) were smaller, the bandwidths were narrower, and the final pulse was at a lower frequency than those reported in this study. Also, the discrete pulses were repeatedly recorded in a series on two occasions when a calf was alone near the surface (Edds et al., 1993), and they were loudest when the calf was closest to the hydrophone. The authors hypothesized that the low repetition rate observed in the discrete pulse series was because of the context in which the call was produced (adult-calf interactions) or due to an immature sound production apparatus (Edds et al., 1993). This type of vocalization was not detected in later studies, but this may be due to the narrow dataset's frequency range (Heimlich et al., 2005) or to the apparent silence of mother/calf pairs and juvenile whale groups (Oleson et al., 2003). The discrete pulse series found in our study occurred in only one recording made when a mother/calf pair was followed; this agrees with the adult-calf interaction context proposed by Edds et al. (1993).

Harmonic tonal calls, such as the LFT type, have also been previously reported in the Bryde's whales' repertoire in the eastern tropical Pacific Ocean (Oleson et al., 2003; Heimlich et al., 2005), the southern Caribbean Sea, and the northwest Pacific Ocean (Oleson et al., 2003). Despite the fact that the LFT call had a lower frequency average, this call type was very similar to the previously described "Be3" type (Oleson et al., 2003) and to the "harmonic tone" (Heimlich et al., 2005).

One type of downsweep call (known as "Be6") was reported for a Bryde's whale population in the eastern tropical Pacific Ocean (Oleson et al., 2003). For this call type, downsweeps form sequences with one to four sweeps, separated by approximately 0.5 s per call in a frequency range (57.1 to 232.7 Hz) below that of the two FMT call types reported herein. Single sweeps with characteristics similar to the FMT call type have been attributed to minke whales in a previous study (Gedamke et al., 2001) near Australia, also in a lower frequency range (50 to 250 Hz). Although both species of minke whales (*B. acutorostrata*, *B. bonaerensis*) may occur along the Rio de Janeiro coast (Zerbini et al., 1997), we do not believe that this species produced the FMT calls observed here because no minke whales were sighted in the Cabo Frio region during the two years of surveys and because a Bryde's whale individual was observed during the recordings of these calls. Therefore, this could be a new call type for the species, at least in this ocean.

Oleson et al. (2003) and Heimlich et al. (2005) reported calls composed of two distinct, simultaneous, and harmonically unrelated frequencies in the Bryde's whale vocalization repertoire in the eastern tropical Pacific Ocean. Based on this evidence, Oleson et al. (2003) suggest the possibility of two independent, yet simultaneously excited, resonance modes for this species. The simultaneous but independent production of two sounds, known as *biphonation*, has been documented in birds (e.g., Fee et al., 1998) and mammals (e.g., Volodina et al., 2006). In cetaceans, biphonation has been suggested for bottlenose dolphins (*Tursiops truncatus*; Cranford, 2000), killer whales (*Orcinus orca*; Tyson et al., 2007), minke whales (Gedamke et al., 2001), North Atlantic right whales (*Eubalaena glacialis*; Tyson et al., 2007), and bowhead whales (*Balaena mysticetus*; Tervo et al., 2011). In our study, two call types with characteristics of biphonation (TM1 and TM2) were observed one time each. They were recorded when a single Bryde's whale was very close to the boat and when no other Bryde's whales were seen in the area. This very small sample size precluded a more detailed analysis. Nevertheless, the presence of these vocalizations enhances the possibility that Bryde's whales also produce biphonation and that the vocalization repertoire for this species is more complex than previously thought.

Future studies specifically dedicated to the collection and analysis of the vocalizations and behavior of Bryde's whales along the Brazilian coast are needed. Such information could be an important indicator of population identity, especially when combined with genetic data (Mellinger & Barlow, 2003).

Acknowledgments

We thank Rodrigo Hipólito Tardin (FAPERJ Grant e-26/100.866/2011) for being the best partner for field research. We thank Marco Aurelio Crespo and the students (Nátaly Correa, Jéssica Ferreira, Carine Galvão, Israel Maciel, Elaine Oliveira, and Yure Pessoa) of the Laboratório de Bioacústica e Ecologia de Cetáceos (LBEC/DCA/IF/UFRRJ) for their valuable support in the field. We express our gratitude to Sérgio C. Moreira for providing Figure 1, and to Dr. Russ Sharif for the *Raven 1.4* support. The authors gratefully acknowledge research grants from Conselho Nacional de Desenvolvimento Científico e Tecnológico-CNPq (Grant #479348/2010-3). The field work for this research was licensed by Instituto Chico Mendes de Conservação da Biodiversidade (No. 26851-1/2011).

Literature Cited

Andriollo, A., Rocha, J. M. da, Zerbini, A. N., Simões-Lopes, P. C., Moreno, I. B., Lucena, A., . . . Bassoi, M. (2010). Distribution and relative abundance of large whales in a former whaling ground off eastern South America. *Zoologia*, *27*(5), 741-750. http://dx.doi.org/10.1590/S1984-46702010000500011

Carbonel, C. (1998). Modelling of upwelling in the coastal area of Cabo Frio (Rio de Janeiro – Brazil). *Revista Brasileira de Oceanografia*, *46*(1), 1-17. http://dx.doi.org/10.1590/S1413-77391998000100001

Clark, C. W., Borsani, J. F., & Notarbartolo di Sciara, G. (2002). Vocal activity of fin whales, *Balaenoptera physalus*, in the Ligurian Sea. *Marine Mammal Science*, *18*(1), 286-295. http://dx.doi.org/10.1111/j.1748-7692.2002.tb01035.x

Cranford, T. W. (2000). In search of impulse sound sources in odontocetes. In W. W. L. Au, A. N. Popper, & R. R, Fay (Eds.), *Hearing by whales and dolphins* (pp. 109-155). New York: Springer-Verlag. 485 pp.

Cummings, W. C., Thompson, P. O., & Ha, S. J. (1986). Sounds from Bryde, *Balaenoptera edeni*, and finback, *B. physalus*, whales in the Gulf of California. *Fishery Bulletin*, *84*(2), 359-370.

De Leo, F. C., & Pires-Vanin, A. M. S. (2006). Benthic megafauna communities under influence of the SACW (South Atlantic Central Water) intrusion onto the Brazilian southeastern shelf: A comparison between an upwelling and a non-upwelling ecosystem. *Journal of Marine Systems*, *60*(3-4), 268-284. http://dx.doi.org/10.1016/j.jmarsys.2006.02.002

Edds, P., Odell, P. K., & Tershy, D. B. R. (1993). Calls of a captive juvenile and free-ranging adult-calf pairs of Bryde's whales, *Balaenoptera edeni*. *Marine Mammal Science*, *9*(3), 269-284. http://dx.doi.org/10.1111/j.1748-7692.1993.tb00455.x

Fee, M. S., Shraiman, B., Pesaran, B., & Mitra, P. P. (1998). The role of nonlinear dynamics of the syrinx in the vocalizations of a songbird. *Nature (London)*, *395*, 67-71. http://dx.doi.org/10.1038/25725

Figueiredo, L. D., Tardin, R. H., Lodi, L., Maciel, I. S., Alves, M. A. S., & Simão, S. M. (in press). Site fidelity of Bryde's whales (*Balaenoptera edeni*) in Cabo Frio region, southeastern Brazil, through photoidentification technique. *Brazilian Journal of Aquatic Science and Technology*.

Gedamke, J., Costa, D. P., & Dustan, A. (2001). Localization and visual verification of a complex minke whale vocalization. *The Journal of the Acoustical Society of America*, *109*(6), 3038-3047. http://dx.doi.org/10.1121/1.1371763

Heimlich, S. L., Mellinger, D. K., Nieukirk, S. L., & Fox, C. G. (2005). Types, distribution, and seasonal occurrence of sounds attributed to Bryde's whales (*Balaenoptera edeni*) recorded in the eastern tropical Pacific, 1999-2001. *The Journal of the Acoustical Society of America*, *118*(3), 1830-1837. http://dx.doi.org/10.1121/1.1992674

Kato, H., & Perrin, W. F. (2009). Bryde's whale. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (2nd ed., pp. 158-162). San Diego: Academic Press. 1,352 pp.

McDonald, M. A. (2006). An acoustic survey of baleen whales off Great Barrier Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, *40*, 519-529. http://dx.doi.org/10.1080/00288330.2006.9517442

Mellinger, D. K., & Barlow, J. (2003). *Future directions for acoustic marine mammal surveys: Stock assessment and habitat use* (NOAA OAR, NOAA/PMEL Contribution 2557). 37 pp.

Mellinger, D. K., Carson, C. D., & Clark, C. W. (2000). Characteristics of minke whale *Balaenoptera acutorostrata*, pulse trains recorded near Puerto Rico. *Marine Mammal Science*, *16*(4), 739-756. http://dx.doi.org/10.1111/j.1748-7692.2000.tb00969.x

Oleson, E. M., Barlow, J., Gordon, J., Rankin, S., & Hildebrand, J. A. (2003). Low frequency calls of Bryde's whales. *Marine Mammal Science*, *19*(2), 407-419. http://dx.doi.org/10.1111/j.1748-7692.2003.tb01119.x

Rivers, J. A. (1997). Blue whale, *Balaenoptera musculus*, vocalization from waters off central California. *Marine Mammal Science*, *13*(2), 186-195. http://dx.doi.org/10.1111/j.1748-7692.1997.tb00626.x

Simão, S. M. (2013). Organização social e bioacústica do golfonho-comum-de-bico-longo, *Delphinus capensis* (Cetacea: Delphinidae) em Arraial do Cabo. [Social organization and bioacoustics of long-beaked common dolphin, *Delphinus capensis* (Cetacea: Delphinidae) in Arraial do Cabo]. Unpublished report. Brasilia, Brazil: Conselho Nacional de Desenvolvimento Científico e Tecnológico.

Tervo, O. M., Christoffersen, M. F., Parks, S. E., Kristensen, R. M., & Madsen, P. T. (2011). Evidence for simultaneous sound production in the bowhead whale (*Balaena mysticetus*). *The Journal of the Acoustical Society of America*, *130*(4), 2257-2262. http://dx.doi.org/10.1121/1.3628327

Tyson, R. B., Nowacek, D. P., & Miller, P. J. O. (2007). Nonlinear phenomena in the vocalizations of North Atlantic right whales (*Eubalaena glacialis*) and killer whales (*Orcinus orca*). *The Journal of the Acoustical Society of America*, *122*(3), 1367-1373. http://dx.doi.org/10.1121/1.2756263

Volodina, E. V., Volodin, I. A., Isaeva, I. V., & Unck, C. (2006). Biphonation may function to enhance individual recognition in the dhole, *Cuon alpines*. *Ethology*, *112*, 815-825. http://dx.doi.org/10.1111/j.1439-0310.2006.01231.x

Zerbini, A. N., Secchi, E. R., Siciliano, S., & Simões-Lopes, P. C. (1997). A review of the occurrence and distribution of whales of the genus *Balaenoptera* along the Brazilian coast. *Reports of the International Whaling Commission*, *47*, 407-417.