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Descriptive parameters of pulsed calls for the spinner dolphin, *Stenella longirostris*, in the Fernando de Noronha Archipelago, Brazil

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*The aim of this work is to describe the repertoire of calls utilized by the spinner dolphins (*Stenella longirostris*) in the southern Atlantic Ocean. We measured four acoustic parameters of the fundamental frequency of each call: (i) duration; (ii) frequency amplitude; (iii) minimum frequency; and (iv) maximum frequency. We also classified calls by their shape contour by visual inspection of the spectrograms. The obtained values for call duration were 0.046 to 2.08 seconds (mean 0.433, standard deviation (SD) 0.433), amplitude of 0.13 to 2.01 kHz (mean of 0.36, SD 0.29), minimum frequency of 0.22 to 1.80 (mean 0.55, SD 0.29), maximum frequency of 0.46 to 7.50 (mean 1.00, SD 0.89). We classified 73 calls by spectral contour, identifying six basic types of discernible calls, showing heterogeneity among the call types, with C1, C2 and C3 calls presenting higher frequencies, 21, 30 and 23%, respectively. We found that the calls of* S. longirostris *in the Fernando de Noronha Archipelago are more diverse and complex than previously recognized for spinner dolphins and further studies worldwide can reinforce the broad use of this sound for the species repertoire.*

Keywords: pulsed calls; spinner dolphin; *Stenella longirostris*; Brazil.

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INTRODUCTION

Dolphins are known to produce a large variety of sounds, usually grouped into three major categories (Popper, 1980; Richardson *et al.*, 1995): (i) echolocation clicks, that are pulsed sounds of very short duration (Au, 1992); (ii) pure tone whistles (e.g. Tyack 1998; Janik, 2000); and (iii) an array of sounds, less distinct, of burst pulsed broadband signals, such as screams (Schevill & Watkins, 1966), harsh metallic cries (Steiner *et al.*, 1979), barks and calls (Norris *et al.*, 1994; Richardson *et al.*, 1995).

Most efforts on acoustic investigations of wild dolphins are being carried out on whistles, which it seems are a unique evolutionary characteristic sound of the Delphinidae (Podos *et al.*, 2002). On the other hand, the pulsed calls of dolphins are often briefly discussed in general studies concerning repertoire descriptions (e.g. Norris *et al.*, 1994; Van Parijs *et al.*, 2000; Monteiro-Filho & Monteiro, 2001). Little is known also about the properties of burst pulses. The spectral, temporal, and amplitude characteristics of pulsed calls have been only marginally explored (Lammers *et al.*, 2003).

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For the spinner dolphin, *Stenella longirostris* (Gray, 1828), the literature also brings much information on whistles and clicks (Bazúa-Durán & Au, 2002; Lammers & Au, 2003; Bazúa-Durán, 2004). Lammers *et al.* (2003) provide a revision of previous qualitative and quantitative studies on pulsed calls and click trains for *S. longirostris*.

The aim of this work is to describe the call vocalizations (type (iii) described above) utilized by *S. longirostris* in the Fernando de Noronha Archipelago, which is regularly visited by groups of spinner dolphins that exhibit different types of reproductive behaviour, with larger mating groups being very acoustically active, emitting loud whistles, clicks, and burst-pulsed signals (Silva Jr *et al.*, 2005).

MATERIALS AND METHODS

Study site

The observations and recordings were made in the south-west Atlantic in the Fernando de Noronha Archipelago, off north-eastern Brazil (03°50′S 32°25′W), 345 km east of the São Roque Cape in north-eastern Brazil. Observation sessions were mostly carried out at Santo Antonio's Bay, a 5–15 m deep bay (see Maida & Ferreira, 1997; Carleton & Olson, 1999, for detailed description) (Figure 1).

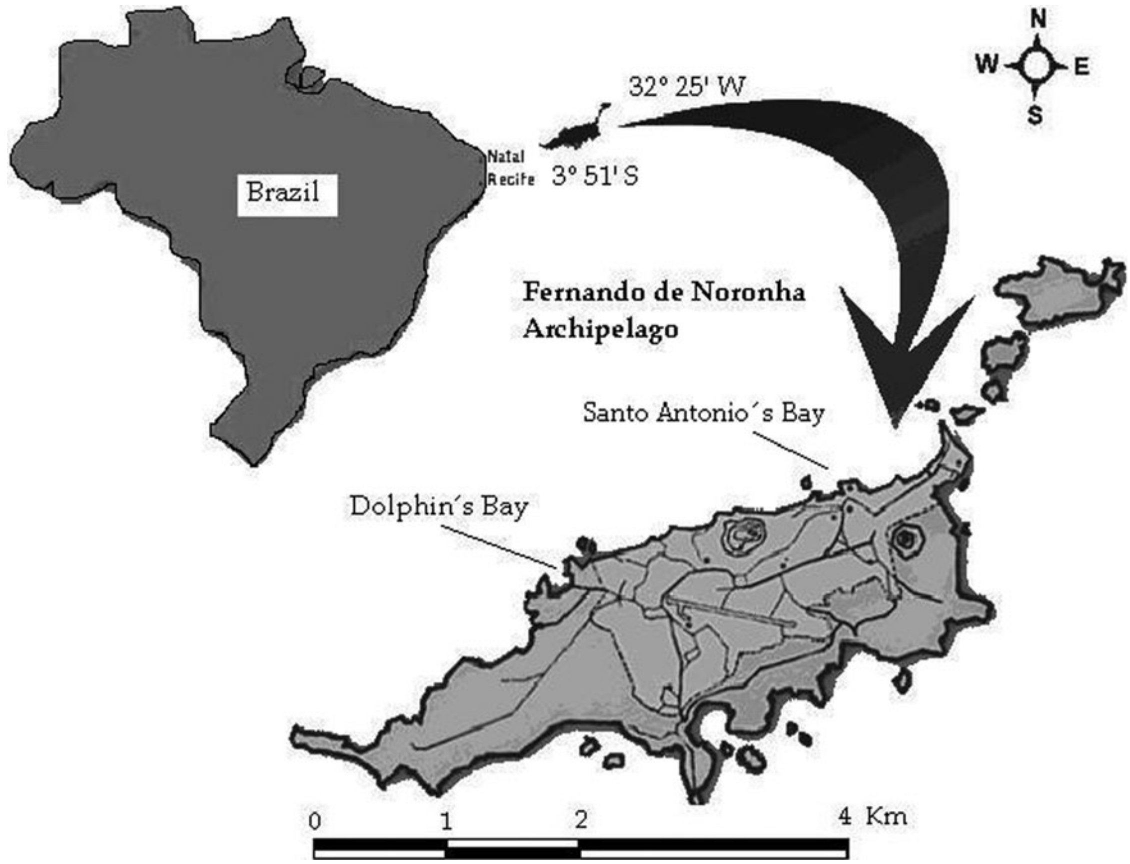

Fig. 1. Map of Fernando de Noronha Archipelago. The recordings and behavioural observations of spinner dolphins were made at Santo Antonio's Bay.

Recordings

Vocalizations were recorded from a small inflatable boat, using a portable Sony TCD-5M cassette recorder and a High Tech HTI-94-SSQ Series 2 wire hydrophone. This recording system has a frequency response up to about 17 kHz, suitable for detecting and recording most delphinid sounds. Dolphin groups were located and approached, and the motor disengaged before recordings were made. High quality signals, those with a suitable signal/noise ratio, were registered using the tape counter of the recorder. Acoustic data were acquired during June 2004, in a total survey effort of 25 h (6 h of recordings).

Acoustic sample

At the laboratory, we reviewed all the tapes, using the tape counter additional information to locate the presence of calls. The selected recordings were previewed using a real-time spectrograph (CANARY 1.2, Cornell Bioacoustics Workstation). Calls were digitized from the tape recorder direct on to a Macintosh desktop computer. Spectrograms for each call were generated using fast-Fourier transformations (FFT = 512) at a 21 KHz sampling rate.

Measurements

Four acoustic parameters were measured from spectrographs, using an on-screen cursor, for the fundamental frequency of each call: (i) duration; (ii) frequency amplitude; (iii) minimum frequency; and (iv) maximum frequency.

Complementarily, we also classified calls by their shape contour by visual inspection of the spectrograms. Methods to describe and categorize pulsed calls for spinner dolphins are further documented by Lammers *et al.* (2003).

RESULTS

Seventy-three pulsed calls were selected for digitization and measurements, chosen by a suitable noise/signal ratio, so that timing and frequency parameters could be discerned from background noise. The intensity of these sounds was variable, always with harmonics scored from 1 to 20, and peak of energy on the basis or lower frequencies. Pulsed calls were produced in bouts or associated with whistles. The acoustic data were recorded on reproductive/mating groups, commonly observed in the area (Silva Jr *et al.*, 2005) engaged many times in courtship behaviours.

Descriptive parameters of the calls

The fundamental frequency of the calls had the duration of 0.046 to 2.08 s (mean 0.433, SD 0.433), amplitude of 0.13 to 2.01 kHz (mean of 0.36, SD 0.29), minimum frequency of 0.22 to 1.80 (mean 0.55, SD 0.29), maximum frequency of 0.46 to 7.50 (mean 1.00, SD 0.89).

Shape contour analysis

We identified six basic types of discernible calls (Figure 2), as summarized in Table 1. Variant C1 (N = 13) consisted of

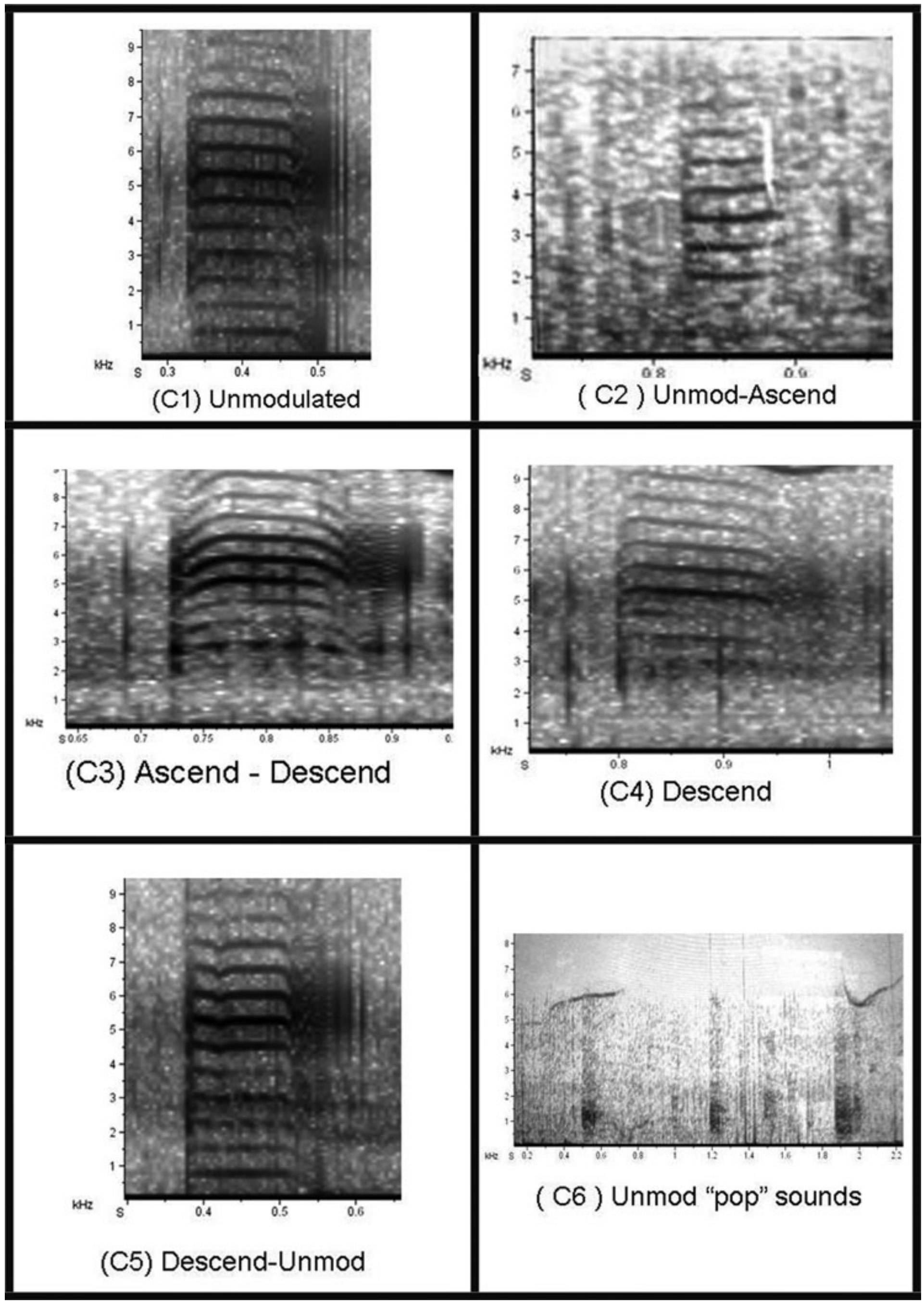

Fig. 2. Representative spectrograms of the different call types, identified by the shape contour inspection, emitted by the spinner dolphins, at Fernando de Noronha Archipelago, north-eastern Brazil.

a tonal sound, unmodulated, a mean duration of 0.282 s and a mean amplitude of 3.15 kHz (0.55 to 3.7 kHz). Variant C2 (N = 24) began unmodulated then ascending, a duration of 0.161 s, frequencies ranging from 0.52 to 6.21 kHz and a mean amplitude of 5.69 kHz. Variant C3 (N = 17) presented a contour with ascending frequency modulation, which then descended, 0.64 s of duration and a mean amplitude of 6.81 kHz (0.55 to 7.36). Variant C4 (N = 5) was characterized by a short note with descending frequency modulation, with duration of 0.101 s and the frequency ranging from 0.97 to 3.71 kHz. Variant C5 (N = 7) corresponded to a call with descending frequency modulation turning to unmodulated, with duration of 0.106 s, and amplitude of 5.21 kHz, ranging from 0.77 to 5.99 kHz. We could identify a sixth particular class of sound, the variant C6 (N = 7), we called 'pop' sounds, with unmodulated frequency, much shorter in duration (0.095–0.878) than others and highly repetitive.

The relative frequency (percentage) of occurrence for classes of shapes (N = 6) for 43 simple calls of the spinner dolphin at Fernando de Noronha, is illustrated in Figure 3, showing heterogeneity instead of predomination among the identified call types, with C1, C2 and C3 calls presenting higher frequencies, 21, 30 and 23%, respectively.

Table 1. Simple call types, identified by shape visual inspection, emitted by the spinner dolphin, *Stenella longirostris*, in the Fernando de Noronha Archipelago, north-eastern Brazil, with sampled number, types of modulation, and physical parameters (frequency, kHz; time, seconds (s)).

Call type	Sampled number	Fundamental frequency range (kHz)	Duration range (s)	Modulation
C1	13	0.22–1.27	0.050–0.878	Unmodulated
C2	24	0.31–1.54	0.057–0.563	Unmodulated/ascending
C3	17	0.26–1.29	0.105–1.145	Ascending/descending
C4	5	0.95–1.34	0.092–0.110	Descending
C5	7	0.48–1.33	0.091–0.122	Descending/unmodulated
C6	7	0.30–0.97	0.095–0.878	Unmodulated, shorter

DISCUSSION

In this study, we found that the calls of *Stenella longirostris* in the Fernando de Noronha Archipelago are diverse and more complex than previously recognized for spinner dolphins. We found six discernible types of call, varying in duration from 0.050 to 2.29 s (mean = 0.467), ranging between 0.20 and 9.31 kHz, with harmonics and high energy at lower frequencies.

In the literature, few studies have presented information on this class of sound. Norris *et al.* (1994) characterized the burst pulsed signals as the most complex spectral class of sounds, varying in duration from 0.2 to 4.0 s (mean = 0.5), ranging between about 5 and 60 kHz.

Lammers *et al.* (2003) found that the social signals produced by spinner and spotted dolphins span the full range of their hearing sensitivity, are spectrally varied, and that the burst pulses are probably produced more frequently than reported by audio-range analyses.

Comparing our results with those presented in Norris *et al.* (1994), we found similar mean durations for the spinner dolphin calls, despite the smaller maximum value for duration. For the total range of the burst pulsed signals, Norris *et al.* (1994) presented values much higher than those of this present study. We interpret this as a possible bias when classifying and grouping any class of sounds of different manners among distinct researchers. Furthermore, differences in the recording system and in environmental characteristics can also influence the obtained range of frequencies.

Due to the limitation of band recordings of our equipment we were unable to compare our results with those reported by Lammers *et al.* (2003). However, these authors report that the high frequency peaks for burst pulsed sounds for spinner dolphins are about 32 kHz.

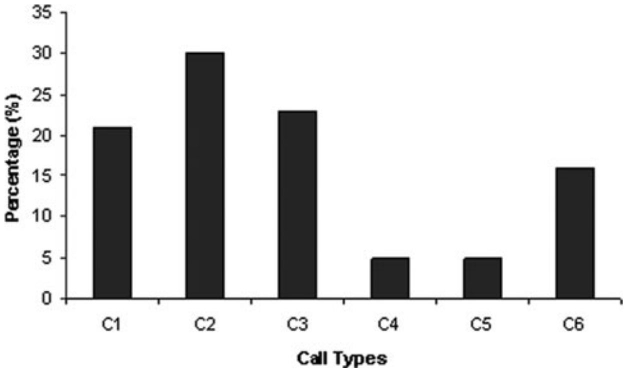

Fig. 3. Relative frequency (percentage) of occurrence for classes of call shapes of the spinner dolphin at Fernando de Noronha, Brazil.

Such differences found between the calls for the spinner dolphin of Brazil (present study) and Hawaii (Norris *et al.*, 1994) could reflect differences in dolphin ecology and behaviour. Despite the fact that spinner dolphins use oceanic shores and beaches similarly, in Kealakekua Bay dolphins are observed either feeding or resting, while in Fernando de Noronha, the dolphins reach the bay in the early morning just to rest and breed, for their feeding is in the adjacent open ocean during the night time (Silva Jr *et al.*, 2005). Also, to date, mating groups producing excessive noises during copulation are commonly observed in Noronha waters (Silva Jr *et al.*, 2005). So, all these behaviours associated with specific bottom relief as well as different trophic relationships (Silva Jr *et al.*, 2007) may also shape dolphin communication.

Ecological influences reflected in distinct geographical repertoires, are well described for other cetacean species such as the humpback whale (Winn *et al.*, 1981), the blue whale (Stafford *et al.*, 2001) and the bottlenose dolphin (Ding *et al.*, 1995; Morisaka *et al.*, 2005).

Discrete pulsed calls are also considered as the most common social sound pattern for the killer whales (Ford & Fisher, 1982). Pulsed calls are very complex with energy at 500 Hz to 25 kHz and pulse repetition rates up to 5000 per second. The duration of pulsed calls range from 0.05 to 10 s, but most are 0.5–1.5 s long (Schevill & Watkins, 1966; Ford & Fisher, 1982). Complexity on the use of calls is also mentioned in the literature for other Delphinidae, such as those of *Orcinus orca* (Ford, 1991), *Delphinapterus leucas* (Sjare & Smith, 1986), *Monodon monoceros* (Ford & Fisher, 1978), *Globicephala macrorhynchus* and *G. melas* (Rendell *et al.*, 1999), and for *Sotalia guianensis* (Monteiro-Filho & Monteiro, 2001).

In the present study, we could verify that some calls seems to occur in specific contexts, such as the C6—'pop' call type, simultaneously with clicks and whistles, during euphoric sound production of the animals. It is probable that the calls are related to reproductive groups that are actively moving and producing intense sounds, as preliminarily commented by Silva Jr *et al.* (2005).

Many aspects of the behavioural use and context of the spinner dolphin sounds remain unknown. New research efforts in other areas worldwide, where the good water visibility allows gathering accurate behavioural information, as initiated by Norris *et al.* (1994) in Hawaii, should be continued, as well as in Midway Atoll (Karczmarski *et al.*, 2005) and French Polynesia (Poole, 1995) emphasizing bioacoustics to reinforce the complexity of the spinner dolphin sound repertoire.

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