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Analysis of whistles produced by the Tucuxi Dolphin *Sotalia fluviatilis* from Sepetiba Bay, Brazil

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ABSTRACT

From July 2001 to June 2002, we recorded a total of 2h55min of Tucuxi Dolphin *Sotalia fluviatilis* vocalizations from Sepetiba Bay, Brazil (22°35′S−44°03′W). A total of 3350 whistles were analyzed quantitative and qualitatively and were divided into 124 types, by visual inspection of sonograms. The following parameters were measured: Initial Frequency, Final Frequency, Minimum Frequency, Maximum Frequency, Duration, Number of Inflections, Frequency at the Inflection Points, Frequency at 1/2, 1/4, and 3/4 of whistle duration, Presence of Frequency Modulation and Harmonics. Ascending type whistles (N=2719) were most common, representing 82% of the total. Dolphin behavior and average group size observed during recording influenced the whistle's quantitative and qualitative parameters. The results demonstrate the great diversity of whistles emitted and indicate a functional role of these vocalizations during the observed behaviors.

Key words: *Sotalia fluviatilis*, Cetacea, Delphinidea, vocal repertoire, whistles, behavior.

INTRODUCTION

There have been extensive studies on the intraspecific sound communication of the different cetacean groups, but there are few reports about Tucuxi Dolphin *Sotalia fluviatilis* vocalizations (Caldwell and Caldwell 1970, Alcuri and Busnel 1989, Kamminga et al. 1993, Ding et al. 1995, Sauerland and Dehnhardt 1998, Figueiredo 2000, Monteiro-Filho and Monteiro 2001, Azevedo and Simão 2002), and about the association of sound and behaviors in natural environment (Ding 1993, Schultz and Corkeron 1994, Ding et al. 1995).

The sea ecotype of *Sotalia fluviatilis* is distributed in coastal waters, from Nicaragua to the South of Brazil (Carr and Bonde 2001), and produces whistles of frequencies from 1.6 to 23.9 kHz (Richardson et al. 1995). In the Sepetiba Bay, there is a resident Tucuxi Dolphin population (Pereira 1999). They are seen in groups of 2 to 200 animals (pers. obs.). Since 1993, the Bioacoustics Laboratory team (Environmental Sciences Department of Universidade Federal Rural do Rio de Janeiro) has been researching their behavior and use of habitat, created a photo-identification catalogue (Pizzorno 1999), and recorded the sound emissions for quantitative and qualitative characterization and analysis. The research presented here will characterize the whistles of the Tucuxi population from the Sepetiba Bay.

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MATERIALS AND METHODS

The Sepetiba Bay is located in Southeastern Brazil at 22°35′S−44°03′W. The coastal lowlands have suffered for a long time of environmental problems related to general sanitation, dams settlement, industrialization and urban expansion (Goes 1998). The bay harbors a resident population of Tucuxi Dolphins.

Sound emissions were recorded during a period of one year, from July 2001 to June 2002. Field work usually took place once a week and included boat rides from Itacuruçá into the Sepetiba Bay along random routes. When the *Sotalia fluviatilis* groups were seen, the boat's engine was shut off and recordings were made with a hydrophone C54 (range: 12 Hz to 35 kHz) connected to a 20 m AF3X18(T) cable coupled to a Compaq Presario 1200 notebook computer with PCI board (sampling rate of 48 kHz). The kinds of behaviors (fishing, displacement, socialization and others) that occurred during the recordings, the number of individuals seen and their location, and all additional information that characterized recording conditions were recorded on a portable cassette.

In the laboratory, the digital recordings were transferred to a computer through a SoundBlaster 32 soundcard. The qualitative analysis was made using Cool Edit Pro 1.4 software, which provides graphic representation of sound signals. The whistles were classified into types by visual examination of the sonograms.

The quantitative analysis was made by reading the structural parameters on the spectrograms produced by the Cool Edit Pro software and storing them in files for statistical analysis. The following parameters were recorded for each whistle: Initial Frequency, Final Frequency, Minimum Frequency, Maximum Frequency, Frequency Modulation, Duration, Inflection Number, Frequency at 1/4, 1/2 and 3/4 of duration, Frequency in Inflection Points, Number of Harmonics and Amplitude Modulation.

We calculated the Whistle rate based on the average group size, the duration of each behavioral context and the number of whistles, to understand the behavior of each animal in each recording context.

RESULTS

A total of 3350 whistles were analyzed quantitative and qualitatively and were divided into 124 types, according to the appearance of the sonogram.

Ascending type whistles (N=2719) were most common, representing 82% of the total, Descending type whistles (N=240) were 7%, Low Modulation Frequency type whistles (N=348) were 10%, and other types of whistles (N=8), together with Duet type whistles (N=35), represented 1% of the total.

The acoustic parameters of the most frequently registered whistles (Ascending, Descending and Low Modulation Frequency Whistles; N=3310) were: Duration 9 to 2283 ms, Initial Frequency 1031 to 11066 Hz, Frequency at 1/4 2740 to 11110 Hz, Frequency at 1/2 2330 to 15112 Hz (Table I). There were as many as 9 inflections in these whistles; and 142 whistles had 1 to 10 harmonics.

The dolphin's behavior and average observed group size during recording influenced the whistles. We obtained a Whistle Rate of 0.27 whistles/min/animal during Milling behavior, 0.29 during Displacement, 1.17 for Deep Fishing, and 1.35 in Surface Fishing (Fig. 1).

DISCUSSION

As underwater sound propagates around 4.4 times faster than in the air, it is an ideal signal for communication in marine mammals (Kaufmann and Forestell 1993).

Current studies on sound emissions attempt to understand the behavioral significance of various acoustic signals by noting the specific behavior and/or context in which they occur (Au 2000). Research on the function of whistles show that they are used to establish or maintain vocal or physical contact among dolphins (Tyack 1991).

Whistles are narrow band continuous tonal sounds of modulated frequency with frequencies below 20 kHz (Richardson et al. 1995). Whistles may

TABLE I

Descriptive statistics for acoustic parameters of Tucuxi Dolphin's whistles in Sepetiba Bay. The frequency variables were given in Hz and the duration in ms.

	Range	Mean	Standard Deviation	Coefficient of Variation
Initial Frequency	1, 031 – 11, 066	10,704	4,973	46.5
Frequency at 1/4	2, 740 – 12, 069	11,110	4,722	39.1
Frequency at 1/2	2, 330 – 15, 112	13,661	6,186	45.3
Frequency at 3/4	2, 053 – 21, 700	15,368	6,441	41.9
Final Frequency	3, 200 – 16, 834	13,312	5,863	34.8
Minimum Frequency	1, 031 – 10, 987	10,521	4,518	42.9
Maximum Frequency	1, 171 – 17, 490	13,312	4,850	27.7
FM	1 – 7, 213	7,054	12,803	177.5
Duration	9 – 2, 282	789	3,119	395.3
Nr Inflexions	0 – 9	1.3	1	110.5
Nr Harmonics	1 – 10	1.4	1	68.3

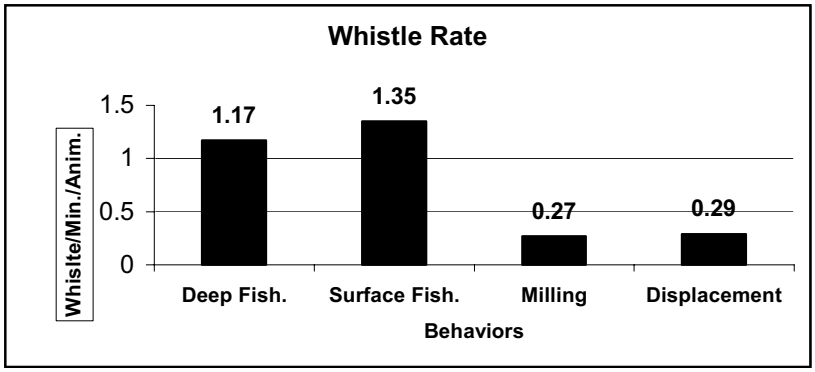

Fig. 1 – Whistles rate observed in the population of Tucuxi Dolphin in the Sepetiba Bay.

be classified as "social sounds". They are used for intraspecific communication (Herman and Tavolga 1980). It is possible to identify several categories in sound emissions occurring in different activities and, thus, find out expressive differences in the vocalization's type and frequency during these different activities (Shane et al. 1986).

The most common whistle, the Ascending type, also appeared the most common in other studies on *Sotalia fluviatilis* from Sepetiba Bay (pers. obs.), Guanabara Bay (Azevedo and Simão 2002), as well as for the river ecotype from Negro river (Norris et al. 1972) and from Marañon and Tigre rivers (Ding 1993). This is also reported to be the most common whistle type for other odontoceti species: *Tursiops truncatus* from Portugal (Dos Santos et al. 1995) and Australia (Janik and Slater 1998), *Stenella longirostris* from Hawaii (Brownlee and Norris 1994) and *Globicephala melas* from North Atlantic (Taruski 1979).

The whistles emitted by Tucuxi Dolphins from Sepetiba Bay had a high frequency and long dura-

tion, similar to those from Guanabara Bay (Azevedo and Simão 2002). In both cases this may reflect the large sample size, which provided more information on the acoustic parameters of the whistles. The study of the whistle parameters showed that the Duration, Modulation Frequency and Numbers of Inflections had the greatest variability in both Sepetiba and Guanabara Bays populations. During Milling and Displacement behaviors, where the animals were less cohesive, the Whistle Rate was lower than during Fishing behaviors where the individuals had more contact and used cooperative strategies to catch fish (Richardson et al. 1995, Thompsen et al. 1999). During fishing the Tucuxi Dolphins emitted more sounds (Monteiro-Filho 2000).

These results demonstrate the great diversity of whistles emitted by the Tucuxi Dolphin from Sepetiba Bay and they indicate a functional role of these whistles during the observed behaviors.

RESUMO

De julho de 2001 até junho de 2002, foram gravados um total de 2h55min de vocalizações do Golfinho-Tucuxi *Sotalia fluviatilis* da Baía de Sepetiba, Brasil (22°35′S−44°03′W). Um total de 3350 assobios foram analisados quantitativa e qualitativamente e foram divididos em 124 tipos, pelo aspecto visual nos sonogramas. Os seguintes parâmetros foram medidos: Freqüência Inicial, Freqüência Final, Freqüência Mínima, Freqüência Máxima, Duração, Número de Inflecções, Freqüência nos Pontos de Inflecção, Freqüência a 1/2, 1/4, e 3/4 da duração do assobio, Presença de Modulação da Freqüência e Harmônicos. O tipo de assobio Ascendente (N=2719) foi o mais comum, representando 82% do total. O comportamento dos golfinhos e a média do tamanho do grupo observado durante as gravações influenciaram os parâmetros de freqüência dos assobios quantitativa e qualitativamente. Os resultados demonstram grande diversidade dos assobios emitidos e indicam papel funcional destas vocalizações durante os comportamentos.

Palavras-chave: *Sotalia fluviatilis*, Cetacea, Delphinidea, repertório vocal, assobios, comportamento.

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