BOTTLENOSE DOLPHIN (*Tursiops truncatus*) PHONATIONS: HOW RECORDING AND USAGE ARE RELATED

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1 INTRODUCTION

The bottlenose dolphin, *Tursiops truncatus,* is one of the most studied cetacean because they are a worldwide species that lives in a variety of habitats of the world's oceans. Their phonations have also been studied for decades, however, there are still many things to be clarified and investigated.

Most bottlenose acoustic emissions are ultrasonic, having energy at more than 300 kHz [1]. Therefore, it has been suggested that broadband recording systems should be used [2,3]. This work demonstrates that the results obtained on how dolphins may be using their acoustic repertoire greatly depend on the recording system used, and that the frequency range of the recording system is not the only parameter to be considered while recording dolphin phonations.

2 METHODS

Data were collected in Laguna de Términos, a coastal lagoon in the southern Gulf of Mexico where bottlenose dolphins are the only cetacean inhabiting this area, and they are found all year round. In this coastal lagoon during 2004, bottlenose dolphin phonations were simultaneously recorded for 204 minutes when 21 herds were within 500m of a boat with the engine turned off. Two recording systems were used to detect and record dolphin phonations: a narrowband and a broadband system. The narrowband system consisted of a digital Sony TCD-D100 recorder sampling at 48kHz and 16 bits (frequency response up to 24 kHz) connected to an omnidirectional hydrophone (-196 $\pm$3 dB re1V/μPa from 1 Hz to 42 kHz). The broadband system consisted of an Avisoft Ultrasoundgate 116 data acquisition card sampling at 375 kHz and 16 bits (frequency response up to 187 kHz) connected to an omnidirectional hydrophone (-197 $\pm$3 dB re1V/μPa from 1 to 240 kHz).

The acoustic recordings obtained were analyzed using the Raven software to characterize the bottlenose dolphin acoustic repertoire according to the spectral characteristics of their phonations by computing a Fast Fourier Transform (FFT; narrowband recordings: 512 points, Hamming window, and an overlap of 50%; broadband recordings: 2048 points, Hamming window, and an overlap of 50%). Dolphin phonations were divided into three types: whistles (W), burst pulses (BP), and echolocation click trains (EC) [1,2,3,4], as shown in Figure 1. The criteria proposed by Bazúa-Durán[2] were used to separate individual whistles. Click trains were considered EC when the inter-click interval was greater than 10 ms and BP when the inter-click interval was smaller than 10 ms. Click trains were separated one from another when the silence in between click trains was four times greater than the inter-click interval of the train before and the train after the silence.

The number of W, BP and EC were standardized by minute to compare the repertoire obtained from the recordings of each system using non-parametric statistics (Wilcoxon, Z, and Chi-squared, X^2, tests). Finally, to describe the differences found between systems, the acoustic repertoire recorded with each system was compared in detail, i.e., second by second.

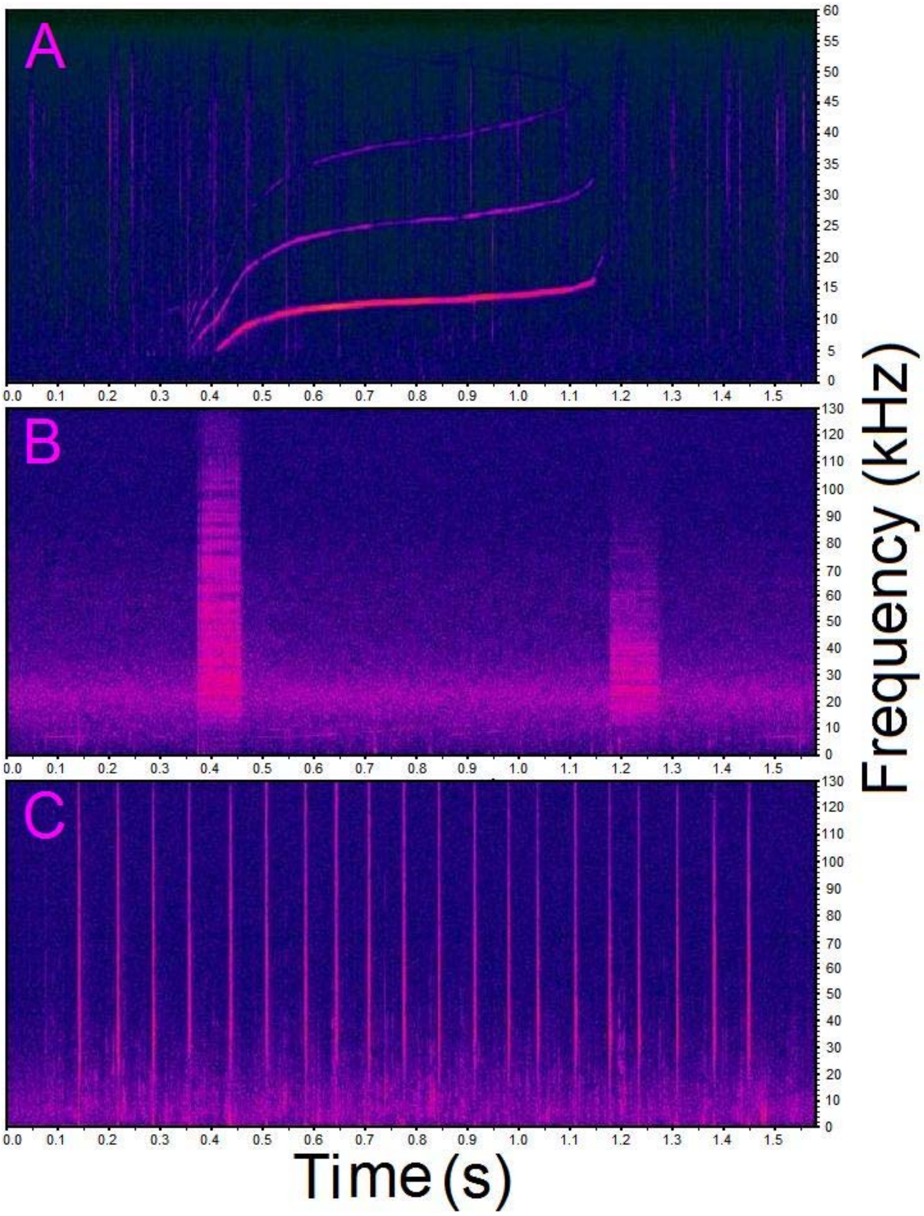

Figure 1. Spectrogram of dolphin phonations: (A) Whistle with harmonics, (B) Burst pulses, and (C) Echolocation click train

3 RESULTS AND DISCUSSION

3.1 Comparison between recording systems

As expected and shown in Table 1, the number of phonations recorded with both systems was not the same (X^2=85.97, $p < 0.005$). More phonations were recorded with the broadband system due to its broader frequency response. The number of EC recorded was considerably larger with the broadband than with the narrowband system (Z = 9.9, $p < 0.000001$). However, even though Lammers *et al.* [3] suggested that most BP were ultrasonic, the number of BP recorded was not different between systems (Z = 0.6, $p < 0.5$); about a third of the BP recorded had energy only below 20 kHz. Additionally, the number of W recorded was greater with the narrowband than with the broadband system (Z = 4.4, $p < 0.000008$), when we expected the recorded number to be the same with both systems. Therefore, some phonations were not captured by the broadband system, especially those that had energy only below 20 kHz.

	DAT		USG		"real"	
# Echolocation click trains/min	**4.03**	(64%)	**7.00**	(78%)	**7.19**	(75%)
# Whistles/min	**1.91**	(30%)	**1.53**	(17%)	**1.94**	(19%)
# Burst pulses/min	**0.4**	(6%)	**0.44**	(5%)	**0.61**	(6%)
# ALL/min	**6.34**	(100%)	**8.98**	(100%)	**9.74**	(100%)

Table 1. Number of phonations per minute for each category obtained with both recording systems, the narrowband system (DAT) and the broadband system (USG), and for the "real" repertoire constructed by blending the recordings of both systems

Differences found between systems were when: 1) a phonation was recorded with one system and not with the other, and when: 2) some phonations were counted as two phonations in the recordings of one system when in the other they were counted only as one phonation, therefore, they did not coincide. These differences found between systems were due to differences in the frequency range of the recording systems (76% of the differences) and due to differences in the intensity of the phonations recorded (24% of the differences). As W are less intense than BP or EC [1,4], when the gain of the broadband system was adjusted for recording BP or EC without saturation, this system may have not been able to record the less intense W, as well as the less intense EC and/or BP. In addition, the dynamic range (DR) of the broadband recording system is narrower than that of the narrowband system (DR = 86 dB vs. >87 dB, respectively). Therefore, differences in the number of phonations recorded related to the phonations' intensity could have been caused by the dynamic range or the gain settings of each system. In conclusion, it is not possible to capture all dolphin phonations with a single recording system; the recording system used in a study influences enormously the results obtained.

As shown in Table 1, in order to better represent the acoustic repertoire of bottlenose dolphins, a "real" repertoire was constructed with the recordings of both systems. This "real" acoustic repertoire consisted of more EC, W and BP than the repertoires obtained with the recordings of each system by itself. The "real" acoustic repertoire differed significantly with those obtained with both systems (for DAT: X^2=48.47, $p < 0.005$; for USG: X^2=9.55, $p < 0.05$). However, the number of W was not significantly different between the narrowband system and "real" repertoires ($Z = 0.4$, $p < 0.7$) and the number of EC was also not significantly different between the broadband system and "real" repertoires ($Z = 2.9$, $p < 0.003$). The narrowband system captured better dolphin W, while the broadband system captured better dolphin EC. Both systems captured different types of BP; the narrowband system captured better dolphin BP with energy only below 20 kHz, whereas the broadband system captured better dolphin BP with energy beyond 25 kHz. Therefore, in order to describe the acoustic repertoire of bottlenose dolphins, it is necessary to employ at least two different recording systems simultaneously.

3.1.1 Use of dolphin phonations

Nevertheless, it was found with both systems that dolphins emitted considerably more EC (0.7 EC/min/dolphin) than W (0.1 W/min/dolphin) or BP (0.03 BP/min/dolphin) in all behavioral states (feeding, resting, socializing, and traveling) and herd sizes. Phonation periods were larger than silence ones (60% vs. 40%), being dolphins more acoustically active during feeding [5] (0.33 phonations/min/dolphin), resting (0.32 phonations/min/dolphin), and socializing (0.28 phonations/min/dolphin) than while traveling (0.21 phonations/min/dolphin). Bottlenose dolphins in Laguna de Terminos are not as silent as originally thought, probably due to the reduced visibility and shallow depth of Laguna de Terminos, suggesting that bottlenose dolphins are actively inspecting their environment acoustically, choosing when and where to produce their phonations.

Previous studies describing how dolphins are using their acoustic repertoire may have been influenced by the restrictions posed by the recording system used [5,6,7]. Therefore, detailed studies using appropriate acoustic recording systems are needed in order to understand how these animals are using their acoustic sense to communicate and inspect their environment in the large variety of habitats of the world's oceans.

4 FINAL REMARKS

The results presented here indicate that the recording tool used greatly influences the description of the dolphin acoustic repertoire. In order to better understand how dolphins are using their acoustic sense it is necessary to use the appropriate recording tools, and probably also a suitable analysis tool. Currently, the FFT is used to extract the spectral information of dolphin phonations. It is necessary to test other signal processing methods to extract such information [8] in order to elucidate if the acoustic repertoire is represented in a different way with other signal processing methods [9].

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