An onboard acoustic data logger to record biosonar of free-ranging bottlenose dolphins.

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Abstract: The ecology of the odontocete echolocation system is not well understood despite a solid understanding of the system's operation. To gain insight into the functional uses of dolphin biosonar we have developed an acoustic data logger which utilizes a miniature DAT recorder and two suction-cup hydrophones. The first hydrophone is located 10 cm posterior of the blowhole, and the second 20 cm below the lateral base of the dorsal fin. The anterior 'high-frequency' hydrophone, designed specifically to record echolocation signals, has unity gain and a one-pole 10 kHz high pass filter. The 'ambient' hydrophone located at the base of the dorsal fin has +18 dB gain and has a one-pole 1 kHz high pass filter. To obtain echolocation recordings the 'high-frequency' hydrophone was filtered through a simple demodulator in one of the deployments. The package was attached to temporarily restrained animals which, after release, were followed to record behavioral data. During the two successful deployments to date the logger recorded animal vocalizations, surfacing events, the sounds of passing boats, and hydrodynamic sounds produced by the animal's fluke strokes.

INTRODUCTION

Odontocete cetaceans have been known for 37 years to use echolocation (Norris *et al.* 1961). The characteristics of the sonar system of the bottlenose dolphin, *Tursiops truncatus*, have been elucidated through intensive study of captive animals. Au (1993) reviews this research describing the dolphin transmission and receiving systems and documenting the characteristic acoustic features of the echolocation signals. We know also from these studies that the dolphins' sonar system is excellent for target detection, discrimination, and classification and for range discrimination (Au 1993). While the performance of the dolphin echolocation system is well characterized, its functional uses by wild animals are not well understood. Recent studies have begun to elucidate some details of odontocete echolocation use in the context of foraging (Verfuss and Schnitzler 1995; Miller *et al.* 1995). These studies document changes in echolocation signals and use patterns as the animals move through a predation sequence, a phenomenon also seen in foraging microchiropteran bats (Schnitzler & Henson 1980; Kick & Simmons 1984).

Bat research has successfully elucidated many of the operational and functional details of echolocation. In addition to a good understanding of the performance (Schnitzler & Henson 1980) and neural processing (Dear & Suga 1995), the ecology of the bat echolocation system is much more fully understood than is the odontocete system (Neuweiler 1983; Surlykke 1988). In fact, few data exist which can address even basic questions: how do odontocetes use echolocation for navigation and/or foraging? Do patterns of use change diurnally?

DATA LOGGER DESCRIPTION AND RESULTS

One reason that odontocete echolocation research has not progressed as quickly as bat research is the difficulty in obtaining individually identified recordings of animals echolocating on biologically relevant targets. To procure such recordings we have developed an onboard acoustic data logger utilizing a two-channel DAT recorder housed in aluminum and attached to the dorsal fin with a Track Pack ® (Figure 1). The recorder has a flat frequency response from 10 Hz-14 kHz, and each tape can store 120 stereo-minutes. The first suction-cup hydrophone (sensitivity -205 dB re 1 μPa) is located 10 cm posterior of the blowhole, and the second 20 cm below the lateral base of the dorsal fin (Figure 1). The anterior 'high-frequency' hydrophone, designed specifically to record echolocation signals, has unity gain and a one-pole 10 kHz high pass filter. The 'ambient' hydrophone has +18 dB gain and has a one-pole 1 kHz high pass filter. To obtain echolocation recordings the 'high-frequency' hydrophone was filtered through a simple demodulator in one of the deployments. This frequency shift circuit is similar to a single-side-band demodulator, consisting of a high-pass filter (HPF) with passband edge at 70 kHz and a multiplier (implemented by an analog switch), modulating the filtered signal with a 70 kHz square wave. The result is that the 70-85 kHz band is shifted to the 0-15 kHz band of the DAT recorder. The purpose of the HPF is to minimize distortion in the recorded signal due to aliasing of the 55-70 kHz band by the multiplier and the quality of the recording depends upon the stopband attenuation of the HPF. As the primary application of the frequency-shifted recordings was to be in estimating click rates, a high degree of alias rejection was not required. Given this and the small volume available in the tag for circuitry, we found that a straightforward combination of tunable notch and 3-pole active high-pass filters was satisfactory. VHF radio transmitters were mounted in the track pack for tracking the animal and recovering the package after it released via corrosible magnesium links. As part of the capture-release project in Sarasota, FL the package was attached to temporarily restrained animals which, after release, were followed to record behavioral data.

During the two successful deployments to date the logger recorded echolocation clicks (Figure 2), whistles (Figure 3), surfacing events, the sounds of passing boats, and hydrodynamic sounds produced by the animals' fluke strokes (Figure 2). The predominant activity observed for both subjects was traveling; no foraging or social behaviors were observed. One subject, a mature female, swam with her two-year old calf throughout the experiment, and both mother and calf surfaced with another dolphin one time. She may have exchanged sounds with her calf or another animal as whistles of alternating intensity were recorded. The second subject, a 9 year old female, did not behaviorally interact with any other animals, but she was well within acoustic range (<100 m) of other animals during the follow.

FIGURE 1. Data logger attached with a Track Pack ®. Arrows show the positions of the hydrophones. The ambient sensor remained attached throughout all deployments, but the high frequency sensor released shortly before package release.

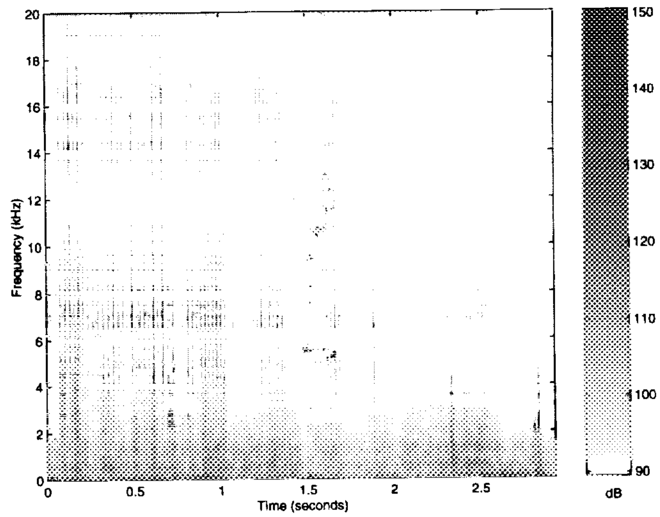

FIGURE 2. Echolocation clicks recorded by the 'ambient' hydrophone. The best clicks were recorded during the non-demodulator deployment. The received sound levels were calculated using a system component calibration (figures 2 & 3). The fluke strokes appear as oscillations in the 'noise floor' (<4 kHz).

A slightly modified package is scheduled for further deployments in June, 1998. The modifications include a carbon fiber housing, a clock circuit to control the sampling interval, and pitch-roll-heading and depth sensors.

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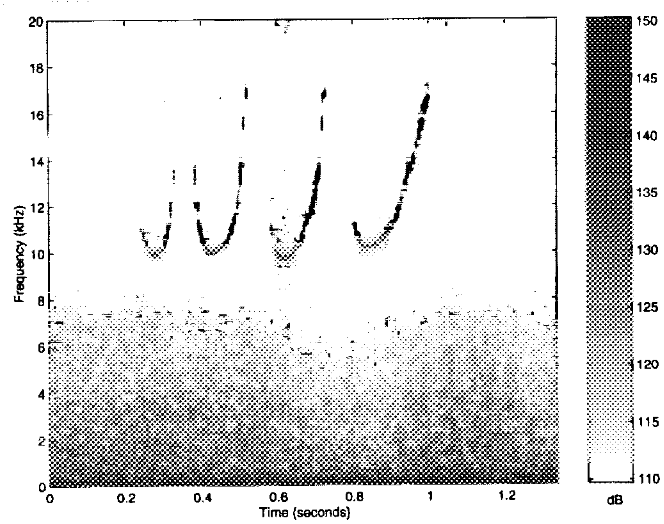

FIGURE 3. Whistles recorded by the 'ambient' hydrophone. Due to the directionality and frequency of clicks as compared to whistles it is not surprising that the whistles produced a greater received level. Note the difference in received level scale.

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