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Short Note

An Underwater Recording Stethoscope Based on an Omnidirectional Hydrophone for Use in Dolphin Rehabilitation and Diagnosis

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Prolonged or persistent stress may compromise the immune system, leaving animals susceptible to disease and infection (Apanius, 1998; Cowan & Curry, 2008). Stress-induced immunosupression is of particular interest to rehabilitation facilities treating ill and/or injured marine mammals because the effects associated with the stress response may hinder attempts at therapy (Clark et al., 2006). Recognizing sources of stress and implementing strategies for mitigating those factors should be essential aims of rehabilitative care. Examples of psychological stressors for wild animals include exposure to novelty (Grandin, 1997) and sampling procedures which, for marine mammals, may include removal from the water (St. Aubin & Dierauf, 2001). The aim of this study was to develop a tool that enhances the quality of auscultation under water for use in dolphin rehabilitation and diagnosis.

An omnidirectional hydrophone was used as an underwater recording stethoscope to acoustically examine the internal organs of cetaceans. This tool can be used to listen to, amplify, and record sounds arising within the heart, lungs, abdomen, and other internal organs of marine mammals while submerged under water. The hydrophone (Model C54XT) was modified by attaching a custom silicon suction cup (hydrophone and suction cup manufactured by Cetacean Research Technology, Seattle, WA, USA), partially enclosing the tip of the apparatus (Figure 1). The suction cup secured the device against the skin, minimizing restraint. The usable frequency range of the hydrophone was 0.006 to 82 (+2/-20 dB) and 92 to 250+ kHz, set at 350 Hz (0.35 + 6 kHz) for recording sessions. Effective sensitivity was -180 dB re 1V/µPa. The suction cup measured 8 cm in diameter with a 2-cm

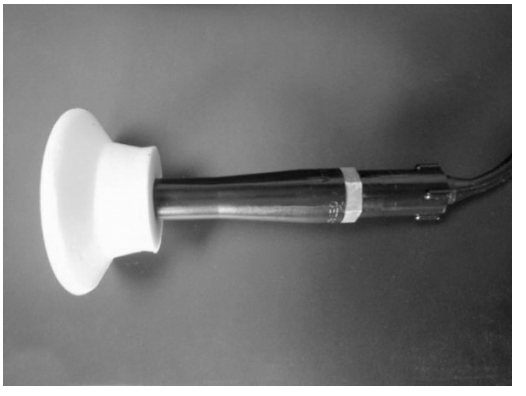

Figure 1. Cylindrical hydrophone fitted with a silicon suction cup

insertion point where the hydrophone attached. A Sony TCM-200DV handheld standard cassette voice recorder with external microphone jack and KOSS UR40 earphones was used to record hydrophone readings. This tool may effectively amplify and record auscultation of submerged cetaceans, reducing novel and prolonged stress associated with removal from water.

While in rehabilitative care under the Texas Marine Mammal Stranding Network (TMMSN), the cardiac response of an adult male melon-headed whale (*Peponocephala electra*) was monitored using the underwater recording stethoscope before, during, and after an intramuscular injection. The melon-headed whale was housed at the Texas State Aquarium (Corpus Christi, Texas) rehabilitation facility from 26 March through 30 March 2006 in a 12.19-m diameter fiberglass pool. For the procedure, the melon-headed whale

was captured by experienced personnel and held in a stationary position in the pool for the duration of the recording session. All controllable noise levels were minimized, including shutting off the pool pump and filtration system, and reducing unnecessary talking and movement throughout the rehabilitation area. The stethoscope was affixed to the melon-headed whale under water, eliminating potential air bubbles, and positioned slightly left of the ventral midline between the melon-headed whale's pectoral fins where the heartbeat could be clearly detected (Figure 2). To obtain the most accurate position for the hydrophone, headphones were used during the application of the apparatus. Behaviors associated with stress were not observed in the melon-headed whale during placement of the suction cup; however, this animal was critically ill and may not be representative of a typical response. Using the underwater stethoscope, we monitored and recorded the heart rate of the melon-headed whale for 9 min and 54 s. We were able to distinguish the rate and rhythm of respirations from the same recording.

Figure 2. Placement of the underwater stethoscope slightly left of the ventral midline between the pectoral fins

A trial involving a juvenile male common bottlenose dolphin (*Tursiops truncatus*) undergoing rehabilitation at the TMMSN was also carried out. The bottlenose dolphin was rescued and initially placed in rehabilitative care at the Texas State Aquarium facility on 1 November 2008. On 3 January 2009, the bottlenose dolphin was transferred to the TMMSN rehabilitation facility at Moody Gardens Aquarium in Galveston and placed in a similar 12.19-m diameter fiberglass pool where it remained until 24 August 2009. The underwater stethoscope was placed on the bottlenose dolphin prior to a routine medical procedure for a total recording time of 30 s. This particular medical procedure required removal from water, so the underwater stethoscope was removed and recording concluded before the procedure was performed. For this recording, the bottlenose dolphin was captured by experienced personnel and held in a stationary position in the pool for the duration of the recording session. Noise by personnel in the rehabilitation area was kept to a minimum. The stethoscope was attached to the bottlenose dolphin under water and positioned slightly left of the ventral midline between its pectoral fins. One staff member listened via headphones connected to the recording device, while a second staff member applied the apparatus. This bottlenose dolphin displayed behaviors associated with stress during capture, including thrashing and jaw popping, prior to the application of the device and continued exhibiting these behaviors when the apparatus was attached. Sounds arising from both the heart and the lungs were distinguishable on this recording.

During both procedures, the hydrophone was connected to a digital recorder for *post hoc* analysis. Subsequent trials including a rough-toothed dolphin (*Steno bredanensis),* two more common bottlenose dolphins, and a second melon-headed whale confirmed that, in addition to the heart and lungs, sounds arising from the intestines could also be distinguished, although recordings were not obtained during these particular trials.

Based on preliminary findings, a hydrophone with a suction cup attachment can be used as an underwater recording stethoscope to aid in diagnosing and monitoring the health of small wild stranded odontocetes undergoing rehabilitation. This device has the potential to detect conditions such as cardiac arrhythmia, pneumonia, and intestinal obstruction, which cause changes in quality or pattern of sound (Kumar, 2007; Reichert et al., 2008). Because increased stress associated with removing marine mammals from water may generate irregular respiration rates and increased heart rates, evaluating lung and cardiac function while animals remain in the water will likely provide more reliable readings. Traditional water-resistant and waterproof stethoscopes also allow auscultation of animals that are submerged underwater; however, this new device has the added advantage of intensifying and recording internal sound production. Recording allows *post hoc* analysis and facilitates data sharing which may be used to establish accurate baseline measures from which abnormalities can be detected. The suction cup also allows independent attachment to the skin, reducing the need for firm restraint of animals during examinations. Modifications to the underwater recording stethoscope are currently being arranged in an effort to improve recording clarity and to enable wireless transmission for biotelemetry application on free-swimming odontocetes. Additionally, the potential for this device to be adapted to monitor cardiac activity in place of complex electrocardiograms (ECG) during dry veterinary procedures is under consideration.

Acknowledgments

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