Project Title: Functional Measures of Sea Turtle Hearing
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Darlene R. Ketten
dketten@whoi.edu
Woods Hole Oceanographic Institution
Biology Department
Woods Hole, MA 02543
Phone: (508) 289-2731

Soraya Moein Bartol
Virginia Institute of Marine Science

ABSTRACT

In this study, sea turtle hearing is investigated from two perspectives: morphometrically by analyzing variations in auditory anatomy among stages and species and physiologically by brainstem evoked potential techniques. Sea turtles employed in this work were provided by NMFS Sea Turtle Stranding and Salvage Network. Auditory brainstem responses (ABRs) were collected from multiple species and life stages of live sea turtles using an stimulus coupled directly to the turtle's tympanum underwater. A three electrode array was used to record the evoked responses to stimuli. Anatomical data were obtained by computerized tomography (CT and MRI) and by conventional histology

ABRs were obtained from 12 hatchling through sub-adult turtles (*Lepidochelys kempi, Chelonia mydas, Caretta caretta*). The data show that juvenile green turtles have a slightly broader hearing range (100-800 Hz; best sensitivity 600-700 Hz) than sub-adults (range 100-500 Hz). Kemp's Ridleys had a more restricted range (100-500 Hz) with most sensitive hearing at 100-200 Hz. Although this project suggests there are measurable age and species variations in response to underwater sound, the overall results are consistent with prior results for aerial and vibrational stimuli (*C. mydas*, 200-700Hz, Ridgway et al, 1969; *C. caretta*, 250-1000 Hz, Bartol et al, 1999).

Scientific and Technical Objectives

For a number of years, sea turtles have been presumed to be reasonably immune to acoustic impacts. However, relatively little is documented or understood about the hearing ability of any sea turtle species or their dependency on sound, passive or active, for survival cues. Complicating this picture is the fact that sea turtles occupy a wide range of habitats, and each life stage of sea turtles has exceptional differences in gross morphometry of auditory structures and in the physical parameters of their habitat. The primary goal of this project is to determine the hearing range and sensitivity of several species of sea turtles at multiple life history stages. Sea turtle hearing is investigated from two perspectives: morphometrically by analyzing variations in auditory anatomy among stages and species and physiologically by using brainstem evoked potential techniques to directly measure sea turtle hearing. From this investigation, we will provide a quantitative base for assessing potential impact on multiple species of sea turtles and across habitats and longitudinally through developmental stages.

Approach

Both live and dead sea turtles were obtained through NMFS Sea Turtle Stranding and Salvage Network. We used this network to obtain samples from stranded and incidentally caught turtles of all life stages.

Data from both computerized tomography (CT) and magnetic resonance imaging (MRI) are used to describe the functional morphology of the sea turtle ear. These scans were carried out on both live and post-mortem subjects. Scan data was transferred to an SGI or SUN workstation for image reformatting and reconstruction.

Specimens that were available for histology had both ears removed as soon as possible post-mortem. The ears were processed as a unit and juveniles and smaller species were processed as whole heads whenever feasible. Sections will be reconstructed as a complete, contiguous series. The sections will be examined by light microscopy and digitized. Digitized structures are stored as X-Y coordinate files that can be reconstructed as 3D images.

Auditory brainstem responses (ABRs) were collected from multiple species and life stages of live sea turtles. A stimulus of known frequency was delivered by the computer to a sound source secured directly to the turtle's tympanum. A three electrode array was used to record the evoked responses to stimuli.

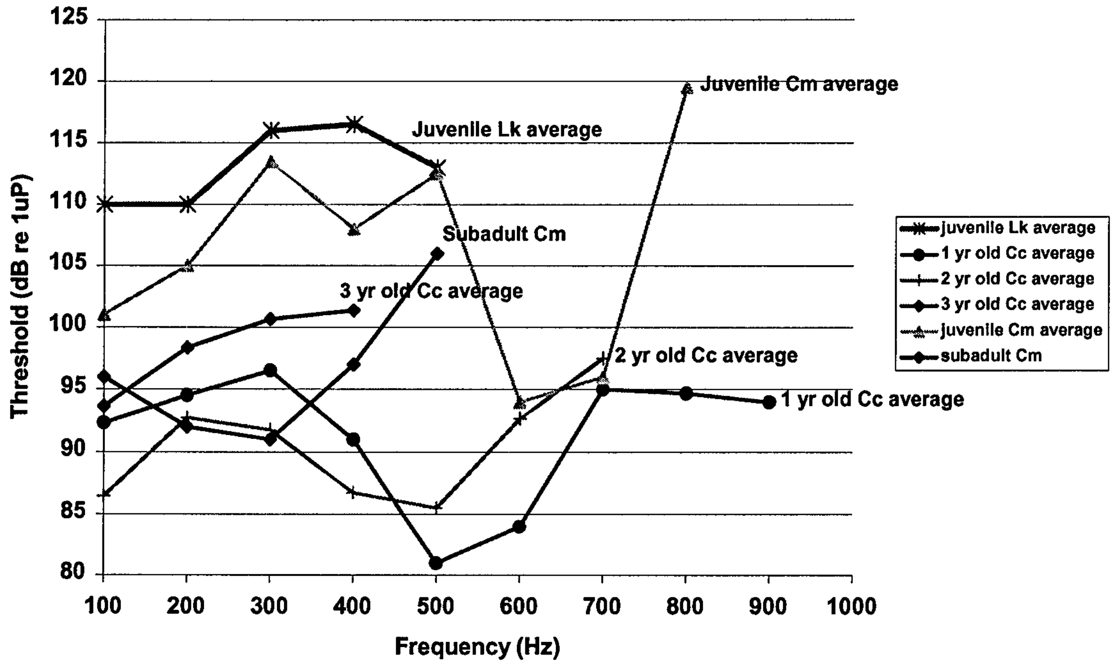
Accomplishments

ABR data have been analyzed for 12 individuals from 3 3 species of sea turtles (hatchling loggerheads, juvenile loggerheads, greens, and Kemp's ridleys, and sub-adult greens) using a correlation technique to identify the response to sound. Traditionally, a major weakness in the analysis of ABR data is the subjective manner at which threshold is determined (i.e. when the response can no longer be seen by the observer). However, ABR tracings have been found to be very consistent for an individual and repeatable at a specific frequency and decibel level. By always recording two tracings at each frequency and intensity, the two tracings should result in a high correlation if a response is present. Furthermore, a low correlation should occur between a stimulus trial and a control (trial with no sound). By comparing the equality of these two correlations we effectively took the "guess work" out of the ABR analyses.

All turtles tested responded to sounds in the low frequency range, from at least 100 Hz to no greater than 900 Hz. The smallest of turtles tested, the hatchling loggerheads, have the greatest range of hearing, from 100-900 Hz. Their most sensitive hearing ranged from 500-600 Hz. As the loggerhead turtles aged, their hearing reduced in range. The 2 year old loggerhead responded to sounds ranging from 100-700 Hz while the 3 year old loggerhead (physically the size of a large juvenile) responded to sounds between 100-400 Hz. We also observed a size/age difference in the range of hearing for the green sea turtles. The smaller juvenile green sea turtles responded to sounds between 100-800 Hz (most sensitive hearing range from 600-700 Hz) while the larger sub-adult green sea turtles had a more constricted range of hearing, from 100-500 Hz (similar to the larger loggerhead sea turtles). Finally, the two juvenile Kemp's ridleys had a more restricted range (100-500 Hz) with their most sensitive hearing falling between 100-200 Hz.

It is difficult to compare these data to previous research. This project is the only one that has attempted to record brainstem responses to underwater sound. However, the literature on sea turtle responses to aerial and vibrational sound reports that juvenile C. mydas can hear frequencies between 200-700Hz (Ridgway et al, 1969) and juvenile C. caretta from 250-1000 Hz (Bartol et al, 1999).

Audiograms of *C. mydas*, *L. kempi*, and *C. caretta*



Problems/Issues

No major problems reported.

Peer-Reviewed Journal Articles

No journal articles reported.

Books or Book Chapters

Gordon M S, Bartol S M (eds). Experimental Approaches to Conservation Biology. University of California Press, Berkeley; 2004. 358 p.

Technical Reports (Non-refereed Publications)

No technical reports reported.

Abstracts/Presentations/Posters/Conference Proceedings

2003 Ketten, D.R. , I. Fischer, S. Cramer, S.M. Bartol, and J. OMalley Water, Fats, and Acoustic Impedance: Soft tissue adaptations for underwater hearing in turtles, seabirds and marine mammals. 23rd International Symposium on Sea Turtle Biology and Conservation, Kuala Lampur.

2003 Moein Bartol, S. and Ketten, D. R. Auditory Brainstem Responses of Multiple Species of Sea Turtles. Symposium on Environmental Consequences of Underwater Sound, San Antonio, Texas.

Awards/Honors/Invention Disclosure

No awards/honors reported.

Patents Submitted

No patents submitted reported.

Patents Issued

No patents issued reported.

Technology Transfer

No technology transfer reported.

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15. SUBJECT TERMS

Sea turtles, ABR, evoked potentials, underwater hearing

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