Environmental Studies Program: Ongoing Study

Field	Study Information
Title	Addressing Data Gaps In Sea Turtle Hearing Sensitivity and Impacts of Sound (NT-20-02)
Administered by	Office of Environmental Programs
BOEM Contact(s)	Jacob Levenson (jacob.levenson@boem.gov)
Procurement Type(s)	Cooperative Agreement
Conducting Organization(s)	North Carolina State University (support contract with Blue World Research Institute)
Total BOEM Cost	$400,000
Performance Period	FY 2020–2022
Final Report Due	September 2024
Date Revised	October 13, 2023
Problem	Sounds produced by BOEM-authorized projects may impact sea turtles; a current lack of knowledge about their hearing sensitivity may lead to inaccuracies in species impacts in consultations with NMFS.
Intervention	Gather hearing data on targeted species to better inform ESA consultations.
Comparison	Without additional data we will continue to estimate acoustic impacts using surrogate species which may be erroneous.
Outcome	The outcome of this study would lead to an understanding of hearing sensitivity and acoustic behavioral ecology of sub-adult sea turtles for accurate impact assessments.
Context	Atlantic and Gulf of Mexico.

BOEM Information Need(s): BOEM is required to estimate potential acoustic impacts from industry sources. To do that (for any species), we start with a hearing curve (an "audiogram"). When we don't have hearing curves for particular species, we have to use what's known from surrogate species, which may be erroneous. Given the relative lack of information on hearing in turtles (Popper et al 2014), we are forced to use such approximations; knowing hearing sensitivity for key species will allow us to better estimate acoustic impacts of BOEM-authorized activities.

Background: In a draft biological opinion on G&G permitting in the Gulf of Mexico, NMFS identified a critical data gap regarding our knowledge of sea turtle hearing and impacts of sound: "Although all sea turtle species studied exhibit the ability to detect low frequency sound, the potential effects of exposure to loud sounds on sea turtle biology remain largely unknown" (Nelms et al. 2016). Relative to studies in other taxa, information on sea turtle hearing is in its infancy, as there are only published audiograms for a handful of species. An incomplete understanding of hearing sensitivity and physiological and behavioral impacts of sound across species and life stages may lead to incorrect estimates or assumptions about the magnitude of impacts from BOEM permitted activities. This data gap is most apparent in BOEM's biological consultations related to geophysical permitting: the Draft Biological and

Conference Opinion on BOEM's Oil and Gas Program Activities in the Gulf of Mexico consultation with NMFS produced an estimate of more than one billion sea turtle takes. Failing to address these significant data gaps may lead to similarly high numbers in the future.

Five ESA-listed species of sea turtles travel widely throughout the South Atlantic, Gulf of Mexico and the Caribbean and may be exposed to BOEM activities in multiple planning areas or in other countries. High intensity sounds can cause behavioral changes, physiological trauma, and even death in some vertebrate species (Richardson et al. 1995). Therefore, sounds from pile driving or G&G surveys could have impacts on these turtles. Sea turtles may use sound for navigation, locating prey or preferred habitat, predator avoidance, and environmental awareness (Piniak et al. 2016). They occupy different ecological niches throughout their life cycle, each characterized by unique acoustic conditions - yet no one knows how their hearing capabilities change throughout their lifetime.

Previous studies on hearing in several species of sea turtles have demonstrated that they detect low-frequency (<1000 Hz) acoustic and/or vibratory stimuli in air and underwater (Lavender et al. 2014, Piniak et al. 2016). This range of maximum sensitivity overlaps with several low-frequency anthropogenic sound sources such as: seismic airguns, offshore drilling, pile driving, and vessel traffic (Hildebrand 2009). Variation in threshold levels and frequencies of maximum sensitivity (i.e., the audiogram) between species and age classes exist. In addition, behavioral responses to anthropogenic sounds may vary throughout a turtle's lifetime. Breeding adult females may experience a lower stress response, as female loggerhead, hawksbill, and green turtles appear to have a physiological mechanism to reduce hormonal response to stress in order to maintain reproductive capacity at least during their breeding season, a mechanism apparently not shared with males (Jessop et al. 2004). BOEM has already invested in addressing data gaps in turtle hearing[1], however, several data gaps remain for various species and life stages. This proposal aims to fill those gaps.

Little data exist on the behavioral responses of sea turtles to sound, however several studies have examined sea turtle behavioral responses to the sounds produced by seismic airguns with mixed findings (O'Hara and Wilcox 1990, Moein et al. 1995, McCauley et al. 2000, Weir 2007, DeRuiter and Larbi Doukara 2012). For example, McCauley et al. (2000) observed that one green turtle and one loggerhead sea turtle in an open water pen increased swimming behaviors in response to a single seismic airgun at received levels of 166 dB re: 1uPa and exhibited erratic behavior at received levels greater than 175 dB re: 1uPa. DeRuiter and Larbi Doukara (2012) observed that 57% of loggerhead turtle exhibited a diving response after seismic airgun array firing at received levels between 175 and 191 dB re: 1uPa. However, Weir (2007) did not observe significant behavioral response to airgun arrays, but did observe responses to the presence of ships and O'Hara and Wilcox (1990) observed differing and erratic behaviors from loggerhead sea turtles. Studies conducted have largely focused on loggerhead sea turtles, and those that observed responses are often based on very few individuals. Additional controlled studies are needed to better determine the sound pressure levels predicted to cause significant behavioral responses in sea turtles.

Objectives: Improve the impact assessments for sea turtle species/age classes for which limited or no underwater hearing sensitivity data is available. Specifically,

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[1] OCS Study BOEM 2012-01156 Underwater hearing sensitivity of the leatherback sea turtle (Dermochelys coriacea): Assessing the potential effect of anthropogenic noise.

1. Address hearing sensitivity in the following species to fill highest-priority data gaps: Kemp's ridley (juveniles), hawksbill, loggerhead (hatchling and young juveniles).
2. Combine new data gathered from hearing sensitivity tests to determine which sounds (frequency and sound pressure level) are detectable by sea turtles and at what level they may elicit behavioral and hormonal responses.

Methods: Objective 1: Electrophysiological techniques will be used to measure sea turtle hearing sensitivity. Auditory evoked potentials (AEPs) are commonly used to detect the neurological basis of sound detection. In this technique, sounds are presented to an animal, and the electrical signals produced by neurons in the auditory pathway are measured; when an animal detects the sound, there is a peak in neurological activity. By sequentially presenting sounds of different frequencies and amplitudes, it is possible to determine the lowest-amplitude sound (at each frequency) that an animal can hear, thus building the hearing curve (audiogram). Such methods have been used to measure sea turtle, marine mammal, and fish hearing (Ladich et al 2013, Harms et al. 2009, Martin et al. 2012, Lavender et al. 2014, Piniak et al. 2016). For animals that are easy to capture and restrain (e.g., fish), sample sizes are typically in the 10s to 20s, for larger animals (e.g., marine mammals), sample sizes may be as few as less than 10 individuals. Objective 2: Using information on hearing behavioral responses to sound will be examined by monitoring sea turtle behavior (visually and/or with biologging tools) in response to a variety of acoustic stimuli and simulated anthropogenic sounds (e.g., airguns, pile driving, drilling, vessel noise, etc.).

Specific Research Question(s):

1. What are the behavioral response/hormonal impacts of acute sound on sea turtles?
2. What is the hearing range of juvenile Kemp's ridley and Hawksbill sea turtles, as well as Hawksbill hatchlings, and young juvenile loggerhead?

Current Status: Final report in preparation.

Publications Completed: None

Affiliated WWW Sites: N/A

References:

Ladich F, Fay RR. 2013. Auditory evoked potential audiometry in fish. Reviews in Fish Biology and Fisheries. 23(3):317–364.

Piniak WED, Mann DA, Harms CA, Jones TT, Eckert SA. 2016. Hearing in the juvenile green sea turtle (*Chelonia mydas*): a comparison of underwater and aerial hearing using auditory evoked potentials. PLoS ONE. 11(10):e0159711. doi:10.1371/journal.pone.0159711

Richardson WJ, Greene CR, Malme CI, Thompson DH. 1995. Marine mammals and noise. San Diego (CA): Academic Press. 576 p.