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Extended duration acoustic tags provide insight into variation in behavioral response to noise by marine mammals

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Current estimates of the population level effects of noise exposure rely on model predictions to link exposures to health and vital rates. While noise exposure levels can be accurately modelled for controlled signal production, it is challenging to estimate the effects of cumulative noise exposure from multiple noise sources in the environment. In the wild, variation in background noise levels and in the motivational state of individual animals will impact their responsiveness to noise. Data collected over longer, more biologically relevant, time scales of weeks to months will improve our understanding of the variability in noise exposure and behavioral responsiveness of marine mammals. This study explores our ongoing work to extend the duration of fine-scale acoustic and movement tag data to explore these questions. Using data from humpback whales (*Megaptera novaengliae*) and manatees (*Trichechus manatus latirostris*), we demonstrate individual variability in behavior and noise exposure scaling from diel trends from a two day tag from a whale and spatial variability from a 44 day continuous manatee tag record. This study highlights the value of longer-term fine-scale data to better inform model predictions for disturbance to address challenging questions related to the cumulative impact of noise-induced behavioral responses on individual health.

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1. INTRODUCTION

Current estimates of the population level effects of noise exposure rely on model predictions linking exposure and behavioral and physiological changes to health and vital rates (Pirotta et al. 2018). While exposure levels can be accurately modelled for intentional signal production (i.e. sonar, seismic signals, construction activities) it is more challenging to estimate the effects of cumulative noise exposure experienced by marine mammals from multiple sources in their environment (Merchant et al. 2018). Controlled exposure experiments to study the impacts of a particular sound type often investigate short-term (< 1 day) behavioral responses of individuals to exposure of a particular sound source (Tyack et al. 2003). These studies produce dose-response curves that, combined with estimated exposure, are used to predict population level effects. In the wild, variation in background noise levels and in the motivational state of individual animals will impact their responsiveness to specific noise sources. The rate of behavioral disruption from sounds likely also plays an important role as to whether acute noise exposures result in negative health consequences. Data collected over longer, more biologically relevant time scales of weeks to months would improve our understanding of actual noise exposures experienced by free-ranging marine mammals (Mikkelsen et al. 2019) and the variability of behavioral responsiveness through time. The objective of this study is to demonstrate the feasibility of measuring the temporal and spatial variability in noise exposure and behavioral responsiveness of individual marine mammals through the use of non-invasive attachment of archival acoustic tags.

2. METHODS & RESULTS

A. DATA COLLECTION

Data collection consisted of field deployments of an archival digital acoustic tag (Dtag) (Mikkelsen et al. 2019) on two species; humpback whales (*Megaptera novaengliae*) off the coast of Massachusetts, USA and manatees (*Trichechus manatus latirostris*) in coastal waters in state of Florida, USA. The tags were attached via suction cup for humpback whales, following procedures described in Wiley et al. 2011. Tags were relocated after they fell off the humpback whales using a VHF transmitter embedded into the tag. For manatees, Dtags were integrated into peduncle belts which included a floating GPS unit and satellite transmitter being deployed on rehabilitated manatees during their release back to the wild (Adimey et al 2016). Manatee tags were recovered with the peduncle belt, after it was manually removed from the manatee.

B. NOISE ANALYSIS

Acoustic records from the Dtags were analyzed to assess exposure of the tagged animal to vessel noise and vessel approach. This assessment included manual counts of high signal-to-noise ratio (SNR) vessel passage events over hourly time intervals for manatees (**Figure 1**). Spectral probability densities (SPD) (Merchant et al. 2015) of the background noise levels were calculated from the tags for both species after excluding periods of self-noise from animal movement and periods when the tag was out of the water during surfacing events. These spectral probability densities were calculated for humpback whales based on time of day (daylight vs. night as defined in Parks et al. 2014) (**Figure 2**). The spectral probability densities were calculated for manatees based on geographic location (in shore areas with no vessels vs. active shipping channels) (**Figure 3**).

Figure 1. Spectrogram showing received sounds of a high SNR vessel approach on a Dtag deployed on a manatee in Florida in 2017.

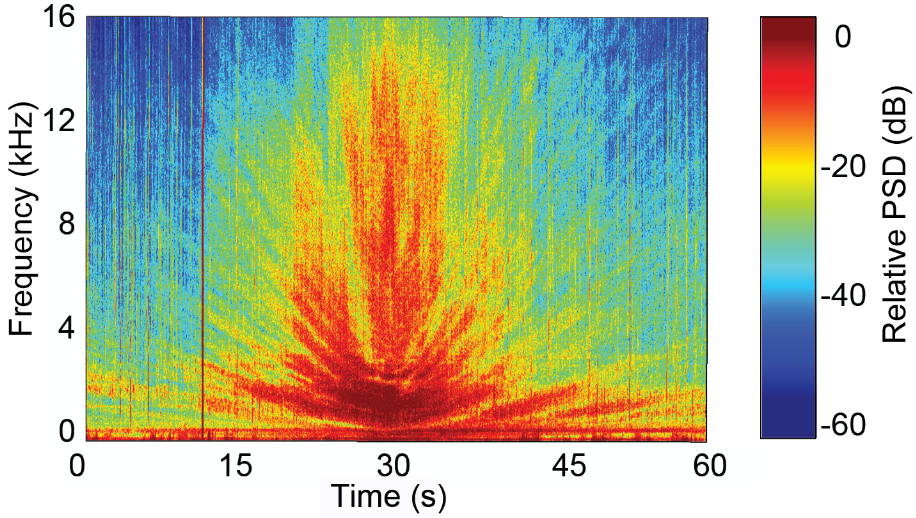


Figure 2. a) Dive profile from a juvenile male humpback whale ('Sprinkles') tagged on the feeding grounds off the Massachusetts coast in June 2018 over a 45-hour period.
b) The Spectral Probability Density (SPD) (Merchant et al. 2015) showing the diel variation in ambient soundscape over the 45 hour deployment, with higher noise levels during daylight hours. Note that the SPD shows the empirical probability density of sound levels in each frequency band.

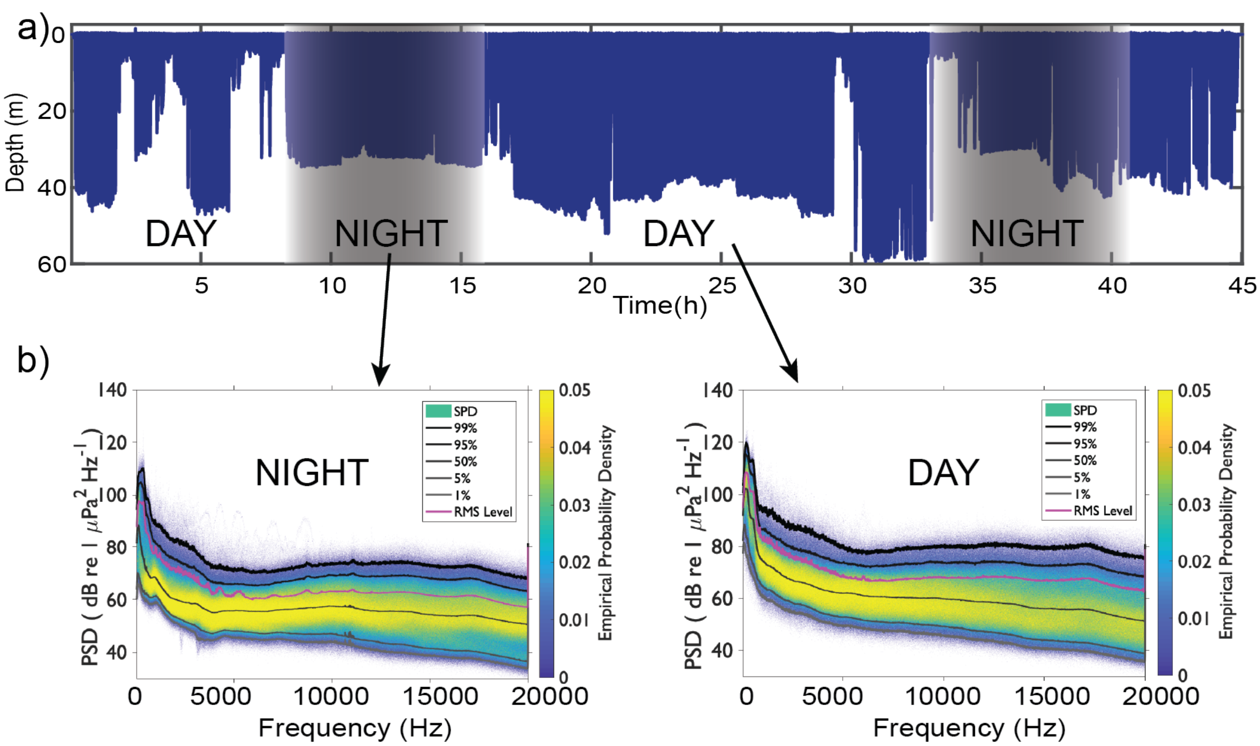
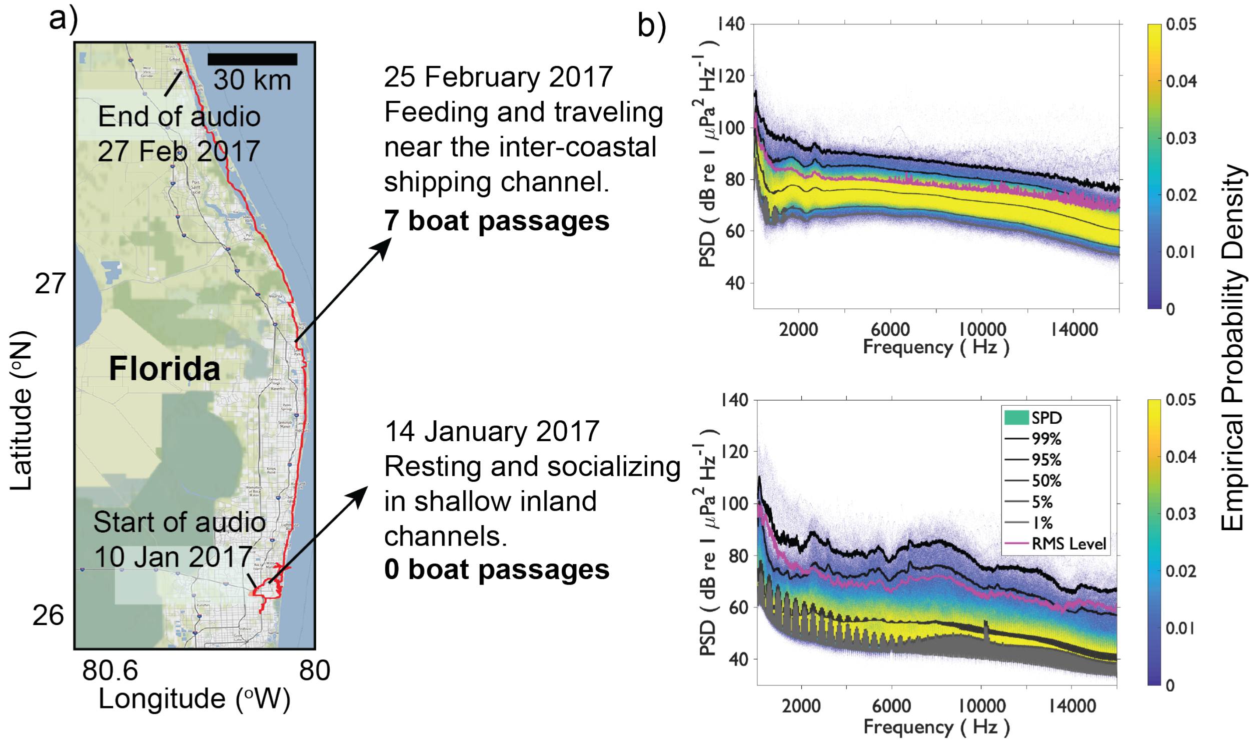


Figure 3. a) A 44 day GPS track (red line) of an adult female manatee 'Vivian' Jan-Feb 2017. b) The number of close vessel approaches and the Spectral Probability Density of the environmental sound varied spatially with human habitat use.



C. MOVEMENT & BEHAVIORAL RESPONSIVENESS

Estimates of fluke stroke rate and heading change were calculated for a period of 120 seconds (2 minutes) before and after the point of maximum RL for high SNR vessel passages for manatee tags using 50 Hz accelerometer data from the tags. An example behavioral response showing the jerk, calculated as the differential of the three acceleration axes as defined in Mikkelsen et al. 2019, as a proxy for behavioral response to vessel passages from an adult female manatee from 25 February 2017 after close vessel approaches is shown in **Figure 4**.

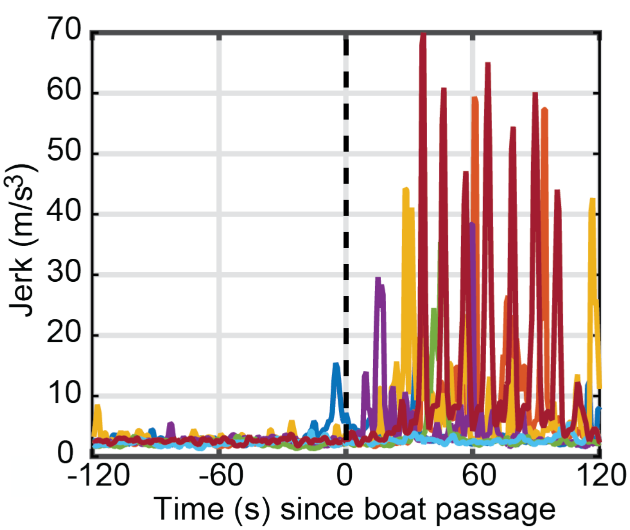


Figure 4. ***Plot showing the variation in behavioral response of a single tagged manatee from 120 seconds before to 120 seconds after seven high SNR vessel approaches. Different colors represent different vessel approaches.***

3. CONCLUSIONS

The goals of this study were to quantify the variability in noise exposure and behavioral responsiveness of free-ranging marine mammals both in time and space. These data are crucial to better inform studies of the potential population level consequences of disturbance from noise events in specific populations. The two case studies presented highlight diel variation in both noise exposure for humpback whales feeding off the coast of Massachusetts and spatial variation in vessel exposure for manatees in the coastal waters of Florida. Based on our findings, we highlight that controlled exposure experiments need to consider the prior noise and disturbance baseline experienced, both spatially and temporally, by the focal study animal to better interpret behavioral responsiveness. We suggest that longer acoustic tag recordings allow for improved assessment of noise exposure and variability in behavioral responsiveness to assess health impacts.

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