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TOO LOUD: A SINGING HUMPBACK WHALE RESPONDS TO SHIP NOISE

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ABSTRACT

Male humpback whales (*Megaptera novaeangliae*) engage in complex singing displays during the winter breeding season. This hierarchically structured song is composed of individual units arranged into phrases and themes that are produced for usually 12-18 minutes at a time and often repeated for multiple hours. Singing is presumed to be important for breeding, although its exact function remains a topic of debate. The effect of rising levels of anthropogenic noise in the ocean on humpback whale singing is still poorly understood. Here we report an incident where a singer instrumented with an acoustic tag was opportunistically exposed within a few hundred meters to noise from a transiting tugboat towing a barge between islands in Hawaii. The singing whale was recorded on the tag for several song cycles before, during and after exposure to the noise event. The recordings reveal that the whale persisted in singing normally at the beginning of the exposure, notably changed the unit and phrase structure while the vessels approached, and abruptly interrupted its singing when the vessels were closest. The whale returned to normal singing once the vessel noise abated. These results shed additional light on how humpback whales respond to anthropogenic noise.

Keywords: *humpback whale, vessel noise, singing, disturbance*

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1. INTRODCTION

Anthropogenic noise is a rising concern for many aquatic species that rely on sound for mediating life functions, such as sensing the environment, finding prey, and communicating with conspecifics [1]. One of the most ubiquitous sources of underwater noise globally is vessel noise, with ambient levels at low frequencies (10-100 Hz) increasing in some regions in the world at a rate of 3 dB/decade [2-3]. Marine mammals are thought to be particularly sensitive to anthropogenic noise due to their reliance on sound for communication and navigation [4]. Humpback whales (*Megaptera novaeangliae)* are one species impacted by anthropogenic noise, and vessel noise specifically, due to their common occurrence in relatively shallow coastal waters where vessel traffic is often high.

The Hawaiian Islands are an island-state dependent on vessel transportation for many aspects of the economy and locally popular activities (fishing, recreation, etc.). The islands are also the principal breeding ground of the north Pacific humpback whale population. Consequently, interactions between vessels and whales are common in Hawaii and thus offer an opportunity to examine the effects of vessel noise on whale behavior. Here we report on an event in which a singing male humpback whale that had been tagged with an instrumented acoustic tag was opportunistically exposed to elevated levels of engine noise from a transiting commercial tugboat towing a barge within a few hundred meters of the whale, providing the opportunity to observe and measure the whale's reaction. We show that although the whale continued to produce its song, some notable behavioral and acoustic changes occurred during the exposure.

2. METHODS AND RESULTS

A male humpback whale associated with another whale of unknown sex was tagged using an Acousonde acoustic tag at 10:01 local standard time on 28 March 2018 off west Maui, Hawaii (Lat/Long: 20°43.772, -156°38.369) as part of a long-term study of humpback whale behavior (Fig. 1). Acousonde tags are attached non-invasively using suction cups and record a variety of data including sound, 3-D movement via a tri-axial accelerometer and magnetometer, depth, and temperature. After being tagged, the whale was focal followed by the research vessel at a 200-300 m distance and any notable behaviors or interactions were recorded. At 10:36 the tagged whale disaffiliated from the companion whale and at 10:44 he became stationary and began singing. This was acoustically confirmed by positioning the vessel above the whale's estimated location and hearing singing through the hull of the vessel. The tagged whale continued to sing for nearly four hours while performing stereotyped, mostly stationary dives and repeating the song sequence a total of 17 times.

Figure 1. Tagged whale showing the position of the tag. NOAA permit # 20043. Photo: Anke Kügler

At approximately 13:30 a Young Brothers Co. tugboat towing an approximately 100 m-long barge loaded with shipping containers was observed approaching the whale's position from the northwest at a distance of roughly 3 km. At 13:40 the tugboat's position was determined to be approximately 650 m from the whale's position using a digital rangefinder. At 13:43 the tugboat's position was measured to be 433 m from the last known location of the whale, but by 13:47 the whale was observed surfacing approximately 800 m from the research vessel, indicating that the whale had moved during the previous several minutes. By 13:55 the whale became stationary again and singing was again confirmed acoustically by hearing song above the water where the whale was last observed surfacing. The whale's position and singing were confirmed again at 14:07, 14:35 and 14:48. No other whales were observed within at least 1-2 km of the tagged whale until 15:23 when a new whale was observed approximately 450 m from the tagged whale's location. At 15:30 the two whales were observed interacting.

An examination of the dive profile recorded by the tag revealed that the whale's stereotyped diving behavior seen during the nine song cycles prior to the arrival of the tugboat and barge changed when noise from the tugboat became prominent (Fig. 2). The whale's dive depth became more variable and the dive corresponding to the tugboat's closest approach was abruptly cut short by several minutes. Following the tugboat's passage, the whale's dive profile returned to a more consistent pattern.

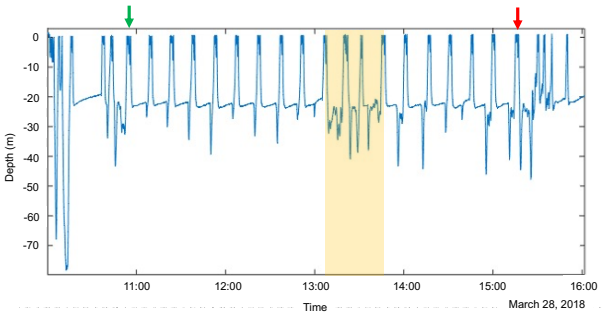

Figure 2. The whale's dive profile between 10:01 and 16:00 showing the period before, during (highlighted yellow) and after the tugboat's passage. The arrows indicate when the whale began (green) and stopped (red) singing.

A similar trend was observed in the whale's vectorial dynamic body acceleration (VeDBA), which is a measure of overall activity derived from the tri-axial accelerometer data [5-6]. VeDBA was consistent and cyclical during the period before the arrival of the tug and barge, but increased and became variable when noise from the tugboat was present in the tag's recordings (Fig. 3). Once the noise abated, VeDBA returned to a consistent and cyclical pattern until approximately 15:25 when the tagged whale began interacting with another whale.

Finally, notable changes were also seen in the structure of the whale's song when the tug and barge were near. Figure 4 shows the spectrogram of the song as it was produced by the whale before, during and after the

elevated noise levels produced by the tugboat. The song pattern was very similar among song cycles before and after the vessels passed nearby, both in terms of the types of units produced as well as in the structure of phrases and themes. On the other hand, when the tugboat's noise was greatest, the whale continued to sing, but produced song units, phrases, and themes that it had previously not used. The song duration was also abruptly reduced from approximately 13 minutes to 8 minutes when the tugboat was several hundred meters from the whale.

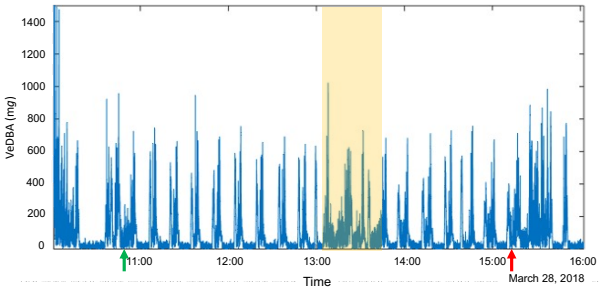

Figure 3. Variations in the whale's vectorial dynamic body acceleration measured by the tag's tri-axial accelerometer with the period corresponding to the tugboat's passage highlighted in yellow. The arrows indicate when the whale began (green) and stopped (red) singing.

1. DISCUSSION

These opportunistic observations reveal that singing humpback whales are impacted by elevated levels of vessel engine noise. The behavioral responses observed included repositioning away from the vessel's proximity and modification of the song produced. This finding adds to the results reported by Tsujii et al. [7] who used bottom-moored acoustic recorders to localize singing humpback whales in relation to shipping traffic. Their findings revealed that whales reduced or stopped singing when a ship passed within 500-1200 m, or in some cases after it had passed. In contrast, Girola et al. [8] reported that, although humpback whales changed the source level of singing in response to wind noise, they did not make changes in response to vessel noise. However, that study focused on the lack of a Lombard effect in relation to vessel noise and did not examine changes in song structure. In addition, the noise considered was from a fishing boat rather than commercial shipping and was therefore lower in amplitude. Thus, the findings presented here are intermediate between those reported by Tsujii et al. [7] and Girola et al. [8] in the sense that this whale continued to sing in the presence of elevated shipping noise but did modify the song structure substantially. Whether a change in the source level of units also occurred (i.e., a Lombard effect) is the focus of an ongoing analysis. Combined, these findings suggest that humpback whale response to vessel engine noise is probably more nuanced than previously reported. In other words, the response of singing whales to engine noise can fall somewhere in between cessation of song [7] and no apparent change [8]. Continued work is needed to determine at what noise threshold whales begin to become impacted by vessel noise and what other factors (e.g., age, habituation, reproductive status, behavior, etc.) may play a role.

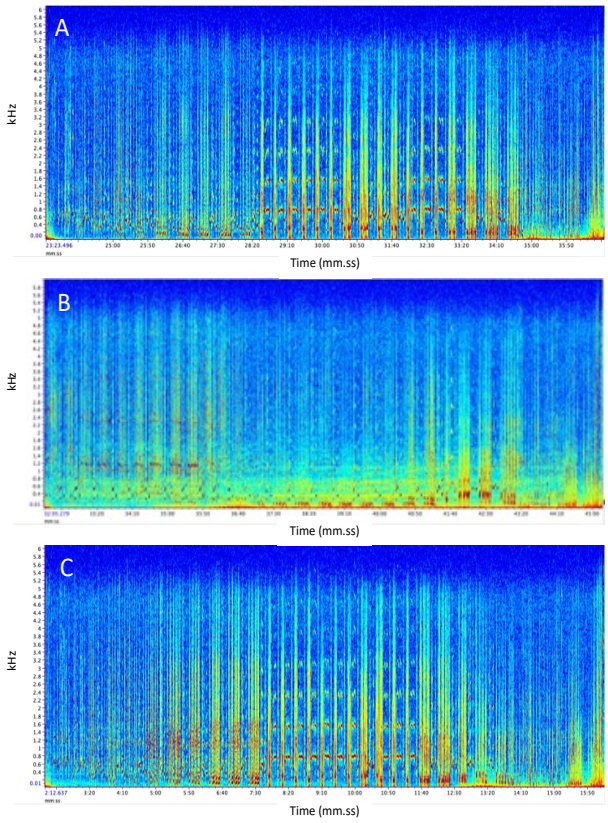

Figure 4. Spectrograms of representative song cycles produced by the tagged whale before (A), during (B) and following (C) the passage of the tug and barge.

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