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Differential effects of human activity on Hawaiian spinner dolphins in their resting bays

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ABSTRACT

Hawaiian spinner dolphins display predictable daily behavior, using shallow bays to rest during the daytime, bays that are also frequented by humans. All previous research on the potential response of Hawaiian spinner dolphins to human activity has been conducted visually, at the surface. In this study we take a different approach by using passive acoustic monitoring to analyze dolphin behavior and assess whether human activity affects the behavior of the animals. We used days ($n = 99$) and hours ($n = 641$) when dolphins were confirmed present in visual surveys between January 9, 2011 and August 15, 2012 and metrics generated from concomitant 30-second sound recordings ($n = 9615$). Previous research found that the dolphins were predictably silent during rest and that acoustic activity matched general activity of the dolphins with higher acoustic activity before and after rest, and silence during rest. The daily pattern of dolphin whistle activity in Bay 2 and 4 (Kealakekua and Kauhako) matched what would be expected from this earlier work. However, in Bay 1 and 3 (Makako and Honaunau) there was no drop in dolphin whistle activity during rest. After assessing the relationship between time of day and dolphin acoustic activity, data on human presence were used to determine how variability in the dolphins' acoustic activity might be explained by human activity (i.e. the number of vessels, kayaks and swimmer snorkelers present). Bay 2, the bay with the most human activity, showed no relationship between dolphin whistle activity and human presence (either vessels, kayaks, or swimmer/snorkelers). Although the relationships were weak, Bay 1 displayed a positive relationship between dolphin whistle activity and the number of vessels and swimmer/snorkelers present in the bay. Bay 4 also showed a positive relationship between dolphin whistle activity and the number of swimmer snorkelers. We also documented less sound being added to the soundscape with each additional vessel in Bay 2 when compared to Bay 1, a bay with dolphin-focused activities. We hypothesize it is not the magnitude of the activity but the focus of the activity that matters and suggest that the effect of human activity on spinner dolphin acoustic behavior should be explored in future studies. These results have implications for designing future studies as well as for ongoing efforts to protect Hawaiian spinner dolphins in their resting bays.

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1. Introduction

Human disturbances to wildlife cause a wide range of effects at both the individual and population level in both terrestrial and marine wildlife (for reviews see Bejder et al. (2009), Francis and Barber (2013) and Shannon et al. (2015)). These effects are complex and context dependent (Bejder et al., 2009) and can include changes to travel (Miller et al., 2014), rest (Lusseau, 2003), calling patterns (Fristrup et al., 2003; Melcon et al., 2012; DeRuiter et al., 2013; Papale et al., 2015), foraging patterns (Williams et al., 2006; Ware et al., 2015), vigilance (Shannon et al., 2014) and habitat use (Lusseau, 2004).

Clear evidence that translates these effects to a population level consequence like a change to population growth, structure, or extinction probability (NRC, 2005) for marine mammals is difficult to find since population level effects, like a decrease in abundance (Bejder et al., 2006) or a decrease in reproductive success (Lusseau and Bejder, 2007) require long term studies that are difficult to conduct. Even capturing various short-term behavioral, acoustic, and physiological responses can be quite difficult and requires diverse techniques and methods for different types of responses. For cetaceans this is complicated by the fact that these animals live the majority of their lives underwater. Some behavioral responses of marine mammals, for example, moving away from the site of the disturbance (Bejder et al., 2006), may be able to be captured by a visual surface observer(s). Other behavioral responses, for example changing calling behavior (Holt et al., 2009), could be captured if acoustic recordings were being made underwater at the time of the disturbance. There are also physiological responses to disturbance that require very different techniques, for example, collecting fecal samples to associate decreased stress levels with a decrease in noise from shipping in North Atlantic right whales (*Eubalaena glacialis)* (Rolland et al., 2012) or collecting blow samples to monitor stress levels in beluga whales (Thompson et al., 2014). When assessing the response of an animal to disturbance it is important to note that the absence of a behavioral response does not automatically translate to an absence of a physiological response (Bejder et al., 2009) and even if a behavioral response is found, the interpretation of the response is not always straightforward (for examples see Gill et al. (2001) and Beale and Monaghan (2004)).

For coastal cetaceans, there are a vast number of potential sources of human disturbance since their habitat overlaps with many different human activities and uses (for a review of threats to cetaceans see Reeves et al. (2003)). The presence of vessels is considered one source of potential disturbance and has been shown to reduce foraging activity in bottlenose dolphins (*Tursiops truncatus*) . (Pirotta et al., 2015) and killer whales (*Orcinus orca*) (Williams et al., 2006). Specifically, wildlife tourism has been associated with changes to socializing and resting behavior (Lusseau, 2003), activity budgets (Lusseau, 2004), relative abundance (Bejder et al., 2006) and reproductive success (Lusseau and Bejder, 2007) in bottlenose dolphins. Since many human activities in the ocean produce sound, anthropogenic sound is also of great concern as a potential source of disturbance in its own right (for a review see Nowacek et al. (2007)). In addition to direct responses to these sounds, it can significantly reduce communication space available to marine mammals (Clark et al., 2009).

Hawaiian spinner dolphins (*Stenella longirostris*) are targeted by a large wildlife tourism industry seeking to interact with the animals (Heenehan et al., 2014). They are an easy target due to their predictable daily behavior, using shallow bays to rest during the day with peak resting time between 10:00 and 14:00 (Tyne et al., 2015, 2017). This rest is essential to recover from intense cooperative foraging offshore (Benoit-Bird and Au, 2009a) and is unlikely to occur outside the resting bays (Tyne et al., 2015). The sandy, shallow resting bays are critical for these animals for this reason and may also afford protection from predators (Norris and Dohl, 1980; Thorne et al., 2012). The National Oceanic and Atmospheric Administration (NOAA) lists human interactions with dolphins in their resting bays as a specific area of concern for the genetically distinct (Andrews et al., 2010) Hawaii Island stock of spinner dolphins (NOAA Stock Assessment Report 2012). The most recent estimate for the number of individuals using the Kona (west) coast of Hawaii Island is between 524 and 801 individuals from Tyne et al. (2014, 2016).

All previous work on the potential response of Hawaiian spinner dolphins to the presence of human activity has relied on visual observations at the surface, with mixed results (Danil et al., 2005; Courbis, 2007; Delfour, 2007; Östman-Lind, 2008; Timmel et al., 2008; Courbis and Timmel, 2009; Östman-Lind, 2009; Tyne, 2015). Some found an increased number of aerial behaviors in response to human presence (Östman-Lind, 2009) while others did not (Courbis and Timmel, 2009). Other responses included more directional changes when people were nearby (Timmel et al., 2008) and earlier departure times from a resting bay when there were more people in the water (Danil et al., 2005). Recent work found that the spinner dolphin population on the Kona Coast of Hawaii Island was exposed to human activities more than 82% of the time but due to this high level of exposure and short time periods between exposures the effect of human presence on spinner dolphin behavior could not be tested (Tyne, 2015).

In this study, instead of relying solely on visual measures of response at the surface, we use acoustic recordings to evaluate the potential effect of human activity on Hawaiian spinner dolphin acoustic behavior in four known resting bays on the Kona Coast of Hawaii Island. Marine animals, including Hawaiian spinner dolphins, depend on sound as their key sensory modality (Lurton, 2003; Cato et al., 2005), therefore assessing potential acoustic responses is extremely relevant. In fact, in a meta-analysis of marine mammal response to disturbance, 90% of the studies that measured acoustic behavior showed an acoustic response (Gomez et al., 2016).

Hawaiian spinner dolphins use sound to navigate, find prey, coordinate foraging, and communicate (Brownlee and Norris, 1994; Lammers and Au, 2003; Lammers et al., 2003; Bazúa-Durán and Au, 2004; Lammers, 2004; Lammers et al., 2004; Benoit-Bird and Au, 2009b). Their sounds include echolocation clicks, whistles, and others broadly defined as burst-pulses initially described in Brownlee and Norris (1994). In the past, spinner dolphins were found to be acoustically silent during rest and that the amount of sound produced by the dolphins was positively related to their activity level (Norris, 1991).