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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).

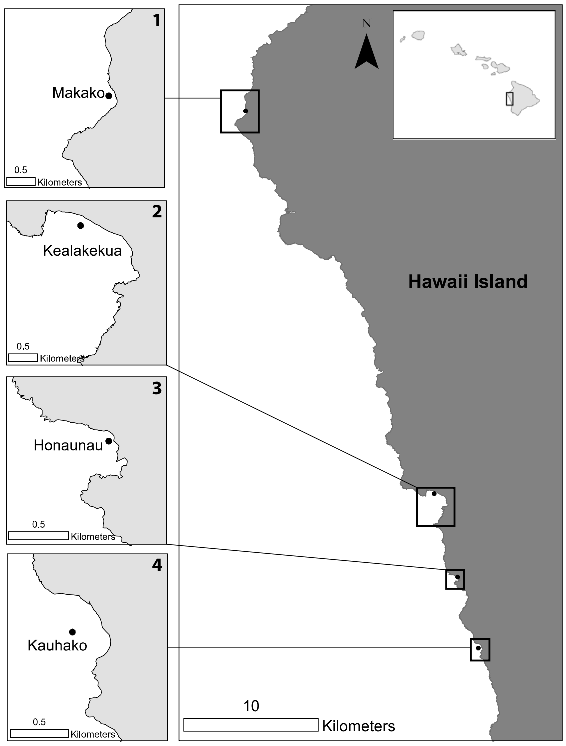

Fig. 1. Map of four study bays.

Therefore as an indication of being vigilant and active, we would expect higher acoustic activity as dolphins enter and exit the bays and a period of minimal acoustic activity at the time when dolphins are resting in the bays (10:00–14:00, Tyne et al. (2015, 2017)).

The aim of the present study was to first analyze the pattern of dolphin whistle activity throughout the day across the four bays and compare it to the findings from previous research (e.g. the dolphins are silent during rest from Norris (1991)). After examining these daily patterns in acoustic activity, given the four bays have various levels and types of human activity, we sought to determine how much of the variability in dolphin acoustic activity could be explained by human activity (i.e. number of vessels, kayaks and swimmers).

2. Methods

2.1. Study area

We conducted visual and acoustic surveys from January 9, 2011 to August 15, 2012 in four known spinner dolphin resting bays on the Kona Coast of Hawaii Island: Makako Bay, Kealakekua Bay, Honaunau Bay and Kauhako Bay hereafter referred to as Bays 1, 2, 3 and 4, respectively (Fig. 1).

2.2. Visual and acoustic data collection

Visual vessel based surveys were carried out on a monthly schedule to generate a robust estimation of dolphin abundance (see Tyne et al. (2014, 2016)) spending two days in Bay 1 and Bay 3 and four days in Bay 2 and Bay 4 each month ($n = 221$ days). Three to six project staff conducted these surveys using a 7-m outboard-powered vessel between 07:00 and 16:00, weather permitting. Information was collected during hourly vessel scans conducted at the top of each hour including whether dolphins were present or not, an estimation of the dolphin group size, the number of motorized vessels including the research vessel in the bay, the number of kayaks in the bay, the number of swimmer/snorkelers in the bay, and information about the number of any other non-motorized vessels. Due to the small size of the bays, all vessels present in the bay could be counted. This information was summarized (see Table 1) using descriptive statistics in JMP Pro 11 (JMP Pro, Version 11.SAS Institute Inc. Cary, NC, USA). For this study, we were specifically interested in those days where dolphins were present ($n = 122$ days).

Table 1
Summary of the number of hours and days per bay used in this analysis and a summary of the visual survey information including mean number (and standard deviation) of dolphins, vessels, swimmer snorkelers and kayaks per hour.

Bay	# hours used in analysis (# days)	Mean (standard deviation) hourly dolphin group size	Mean (standard deviation) vessels per hour	Mean (standard deviation) hourly swimmer/ snorkelers	Mean (standard deviation) hourly kayaks
Bay 1	107 (16)	103.6 (75.8)	2.1 (1.7)	3.0 (8.9)	N/A
Bay 2	256 (33)	27.5 (34.1)	4.7 (2.8)	9.6 (12.4)	9.2 (7.5)
Bay 3	102 (15)	15.4 (18.7)	1.6 (0.9)	13.4 (11.3)	0.2 (0.6)
Bay 4	176 (35)	10.1 (14.8)	1.1 (0.3)	4.2 (4.9)	0.3 (0.8)

On those days where visual surveys were conducted and dolphins were present, we made 30-second acoustic recordings every four minutes at a sampling rate of 80 kHz (Nyquist 40 kHz) in each of the bays using four DSG-Ocean recording devices, one per bay (Loggerhead Instruments, Sarasota, FL, USA), outfitted with HTI-96-Min/3V hydrophones (sensitivity: within 1 dB of −186.6 dBV/μPa, High Tech Inc., Gulfport, MS, USA) as described in Heenehan et al. (2016).

We calculated the equivalent, unweighted ambient noise level (Leq) in the standard 1/3rd-octave frequency bands with center frequencies from 16 Hz to 20 kHz for each 30-second file recorded using custom-written scripts in MATLAB (The Mathworks Inc., Natick MA; Version 2014a). Leq is used extensively in the literature for measuring ambient noise and translates an unsteady sound level in each sound recording to a constant level with equal energy (Ware et al., 2015). The equivalent noise level (King and Davis, 2003; Griefahn et al., 2006) have both been utilized and are supported by the literature on the effects of nocturnal noise on sleep and the effects of noise on wildlife. Third octave bands are a biologically relevant and appropriate way to analyze the ambient noise since these bands relate to how marine mammals hear (Richardson et al., 1995).

For each day we calculated the hourly 90th percentile, hereafter referred to as the L10, in each of the 1/3rd octave bands between 16 Hz and 20 kHz in R (R Core Team, R Foundation for Statistical Computing, Vienna, Austria; Version 3.1.0). The L10 can be interpreted in the following manner: 10% of values are greater than the L10 (which is also the 90th percentile). This was calculated in the same manner as Hatch and Fristrup (2009). In order to calculate metrics that were directly comparable to the visual survey data collected at the beginning of each hour, as described above, instead of calculating the L10 in a typical hourly fashion, we calculated the hourly L10 in the following manner. Recordings made between 06:30 and 07:30 were attributed to the 07:00 h and used to calculate the 07:00 L10. Recordings made between 07:30 and 08:30 were attributed to the 08:00 h and used to calculate the 08:00 L10 and so on.

2.3. Daytime dolphin whistle activity

In addition to the hourly L10 and the hourly vessel scan information described above, we also completed an audit of the hourly dolphin whistle activity on days when dolphins were confirmed present during the visual surveys. We generated daily spectrograms in Raven Pro (Bioacoustics Research Program, The Cornell Lab of Ornithology, Ithaca, NY; Version 1.5) using a 1024-point DFT, 50% overlap and a 512 point (6.4 ms) Hann window. Recordings were aligned with Raven Pro's clock time axis feature to track the real date and time in the recording.

Each 30-second recording was examined and tallied as present or absent for dolphin whistles and summed by hour. This resulted in a scale ranging from 0 to 15 (no files to all files within the hour that contained dolphin whistles). There were not enough burst pulse sounds to conduct a similar analysis separately and our sampling frequency limited our recording of echolocation so we used whistles as representative of dolphin sound. This tally was calculated and combined in the same manner as the L10 (e.g. 06:30 to 07:30 attributed to the 07:00 h, 07:30 to 08:30 attributed to the 08:00 h, etc.).

2.4. Data integration and analysis

We combined the three data sources explained above: the hourly L10 metric, the hourly vessel scan information and the hourly scale of dolphin whistle activity, removing the first hour of data when there was incomplete coverage. We analyzed these data using JMP Pro 11 to establish the pattern of dolphin whistle activity throughout the day. In other words we wanted to see how much variability could be explained by time of day, given the well-documented behavior of the animals. Then we sought to establish how much variability in dolphin acoustic activity could be explained by human activity in the bays. To do this we established what frequency band(s) track the number of vessels and dolphin acoustic activity best, and investigated the relationship between dolphin acoustic activity and the number of vessels, kayaks and swimmer/snorkelers present.

In order to establish the 1/3rd-octave frequency band that tracks vessel activity the best, we conducted multiple linear regressions of the hourly L10 in 1/3rd-octave bands and the hourly number of vessels present in the bay, using the latter as a proxy for noise. Similarly, to establish the band that tracks dolphin acoustic activity the best, we conducted multiple linear regressions of the hourly L10 in 1/3rd-octave bands and the hourly scale of dolphin whistle activity. We conducted these analyses in each bay individually. Multiple linear regressions and multivariate pairwise correlations were also used to explore the potential effects of the human activities by comparing the presence of vessels, swimmer/snorkelers and kayaks on the dolphin whistle activity.

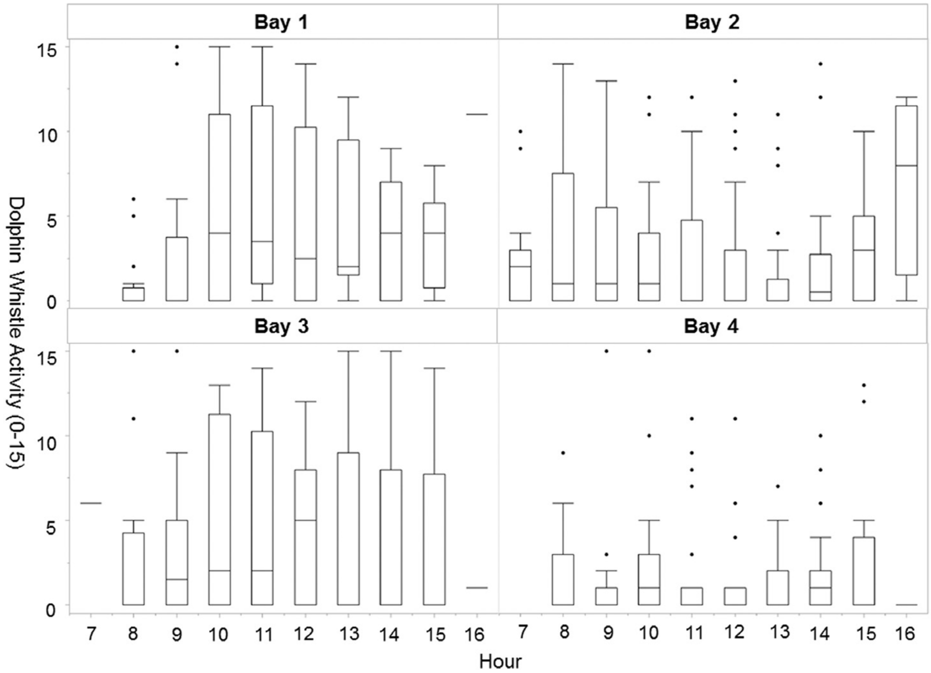

Fig. 2. Outlier boxplot of the scale of spinner dolphin whistle activity throughout the day from 07:00 to 16:00 in each of the four bays. The boxplot represents the median, 75th and 25th quantiles as well as any outliers (dots).

3. Results

Acoustic recordings overlapped with visual surveys when dolphins were present on 99 of the 122 days spanning 641 h (Table 1). The number of days used for this analysis ranged from a minimum of 15 (Bay 3) to a maximum of 35 days (Bay 4). The number of hours used in each of the bays ranged from a minimum of 102 (Bay 3) to a maximum of 256 h (Bay 2). The variability in available days and hours between bays was mostly due to the number of days spent in the bays for visual surveys but also variable arrival and departure times due to weather, and occasional failure or servicing of the acoustic recorder.

The largest dolphin groups were found in Bay 1 (Table 1). The greatest number of vessels per hour was found in Bay 2. The mean number of swimmer/snorkelers in the four bays ranged from a minimum of 3 in Bay 1 to a maximum of 13.4 in Bay 3. Kayak numbers were highest in Bay 2, were never present in Bay 1 and were uncommon in Bays 3 and 4.

3.1. Daytime dolphin whistle activity

In Bay 2 and Bay 4, dolphin whistle activity showed the expected pattern with the highest activity in the early morning and late afternoon hours and the lowest activity at 13:00–14:00 in Bay 2 and 11:00–12:00 in Bay 4 (Fig. 2). Overall, Bay 2 had higher whistle activity than Bay 4. In Bay 1 and Bay 3, dolphin whistle activity was highest in the late morning and early afternoon hours and lowest in the early morning hours.

3.2. Relationship between human presence and dolphin acoustic activity

After establishing the pattern of dolphin acoustic activity throughout the day we sought to determine the variability in dolphin acoustic activity that might be explained by human activity.

First, we sought determine the variability in dolphin activity that could be explained by human activity using the number of vessels, swimmer/snorkelers and kayaks present in the bays and the scale of dolphin whistle activity. In Bay 2 and Bay 3 there was no relationship between the number of vessels, swimmer/snorkelers or kayakers and the dolphin whistle activity. In Bay 1, there was a positive correlation between the number of vessels ($R2 = 0.25$) as well as the number of swimmers/snorkelers ($R2 = 0.16$) and dolphin whistle activity (Fig. 3). Bay 4 showed an even weaker positive relationship between swimmers/snorkelers and dolphin whistle activity.

We then sought a second way to approach this analysis, using the 1/3rd-octave bands that track vessel noise and dolphin sound to assess the relationship between vessel presence and dolphin behavior.

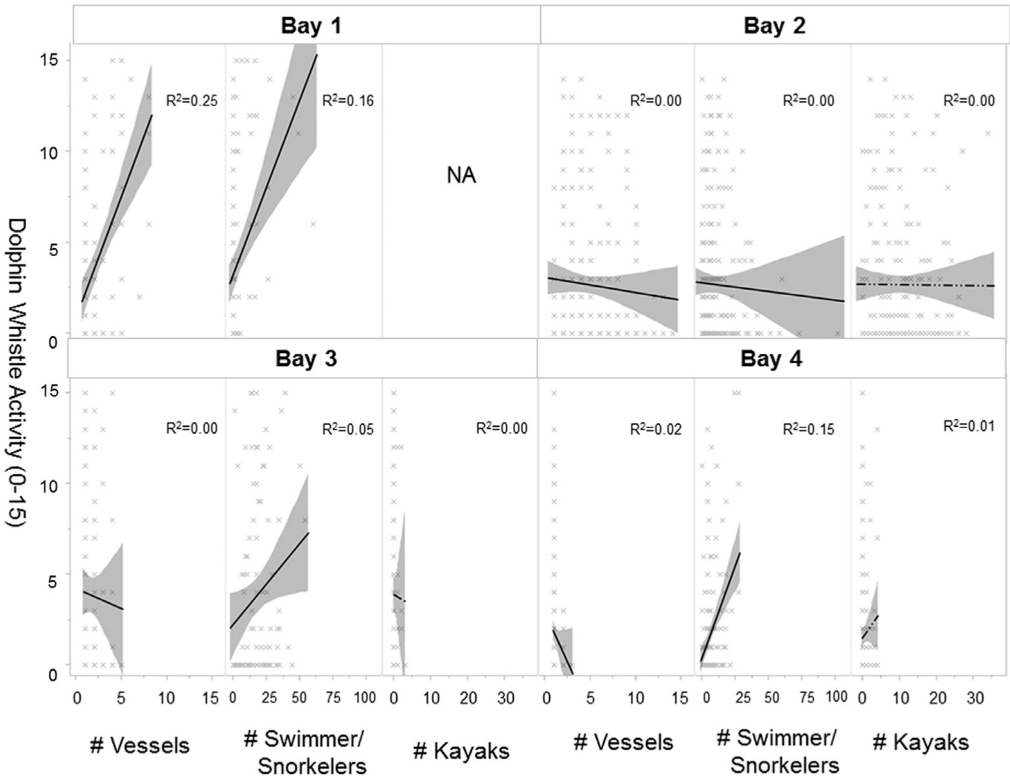

Fig. 3. Assessing the potential relationship between human activities (the hourly numbers of vessels, swimmer/snorkelers and kayaks) and dolphin whistle activity in all four bays. Lines of best fit with confidence of prediction and the R^2 values are presented for each possible correlation.

Table 2
Analysis supporting the establishment of the 1/3rd-octave bands that track vessel and dolphin whistle activity best. For each bay individually, the 1/3rd-octave band or bands with the strongest correlation between the hourly L10 and the hourly number of vessels to establish the vessel band and the hourly dolphin whistle activity to establish the dolphin band. The corresponding R2 value is also provided. Highlighted in bold is the band or bands (and the corresponding R2 value) for the highest R2 value overall for each. Bay 1 had the highest R2 value overall for each of the three categories.

	# Vessels		Dolphin whistle activity	
	1/3rd-octave band(s) with the strongest relationship (Hz)	R^2	1/3rd-octave band(s) with the strongest relationship (kHz)	R^2
Bay 1	400 & 500	.26	12.5	.28
Bay 2	500	.15	16 & 20	.02
Bay 3	125	.05	10	.22
Bay 4	200	.01	12.5	.20

In this study, we observed that the 1/3rd-octave bands best reflecting the number of vessels varied substantially across each bay. However, the strongest relationship observed was in Bay 1 (R2 = 0.26) in both the 400 and 500 Hz 1/3rd-octave bands (Table 2). Bay 2 was similar to Bay 1 (500 Hz R2 = 0.15), with Bay 3 and 4 tracking vessel numbers best in the 125 Hz and 200 Hz 1/3rd-octave bands respectively but with very low R2 values.

The 1/3rd-octave band L10 that best represented dolphin whistle activity ranged between 10 kHz in Bay 3 to 12.5 kHz in Bays 1 and 4 (Table 2). Individually, the strongest relationship was in Bay 1 in the 12.5 kHz 1/3rd-octave band (R2 = 0.28). Bay 2 did not show a strong relationship with any band.

Ultimately, we used the 1/3rd octave band L10 that showed the highest level of correlation in each case. This meant that we used the 400 and 500 Hz 1/3rd-octave bands to represent vessel acoustic activity and the 12.5 kHz 1/3rd-octave band to represent dolphin acoustic activity for the next set of analyses.

In this second approach to analyzing the relationship between human activity, in this case vessels, and dolphin behavior we focused on Bays 1 and 2 seeing as the other two bays had too little vessel activity for a valid comparison (Table 1) and examined the 400 and 500 Hz 1/3rd-octave L10 band for vessels and the 12.5 kHz 1/3rd-octave L10 band for dolphins (Fig. 4).

For Bay 1, the lines of best fit for the number of vessels and the vessel L10s displayed a positive slope (approximately 1.3 for both bands with R2 = 0.26) indicating more sound recorded, approximately 1.3 dB more, with each additional vessel (Fig. 4). In Bay 2, the lines of best fit for the number of vessels and the vessel L10s also displayed a positive slope (approximately 0.5

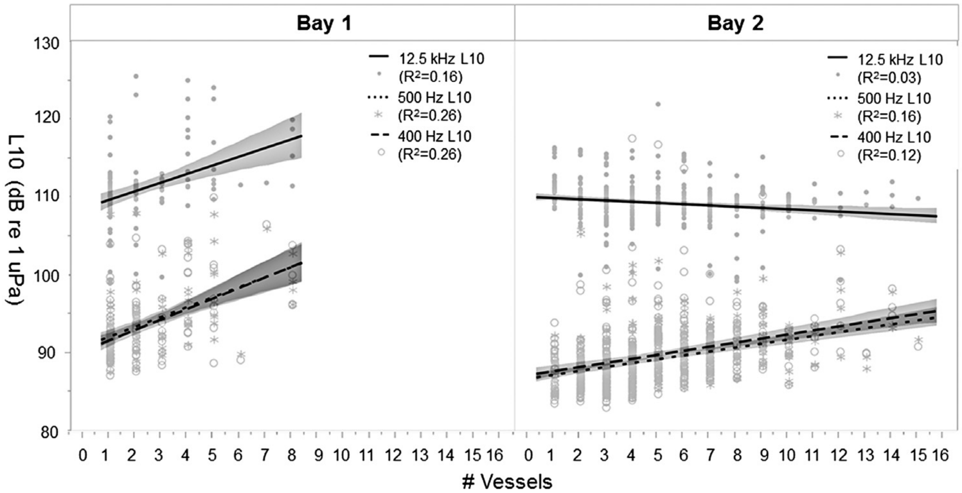

Fig. 4. Bay 1 and Bay 2 relationship between the number of vessels and the 1/3rd-octave bands found to track vessel (400 and 500 Hz 1/3rd-octave bands) and dolphin activity (12.5 kHz 1/3rd-octave band) best. Lines of best fit with confidence of prediction and the R^2 are presented for each line. This figure combines the results from Table 2 and Fig. 3.

for both bands with $R2 = 0.16$ and $R2 = 0.12$) indicating more sound recorded with more vessels present, approximately 0.5 dB per vessel. Each individual vessel created more sound in Bay 1 compared with individual vessels in Bay 2. Therefore, even though there were more vessels present in Bay 2 (max = 15 vessels) compared with Bay 1 (max = 8 vessels), the latter produced considerably louder sound.

In Bay 1, the line of best fit for the relationship between the number of vessels and the dolphin L10 displayed a positive slope (0.96 with $R2 = 0.16$) showing a positive correlation between dolphin acoustic activity and the number of vessels present which aligns with the relationship between whistle activity and vessels (Fig. 3).

In contrast, in Bay 2, the line of best fit for the relationship between the number of vessels and the dolphin L10 displayed a negative slope (−0.13) with a low R2 value ($R2 = 0.03$) suggesting that vessel presence was not directly related to dolphin acoustic activity in the bay (Fig. 4) which also aligns with the lack of relationship between whistle activity and vessels (Fig. 3).

4. Discussion

It is known that wildlife responses to human disturbance can take many forms (for reviews see Bejder et al. (2009), Francis and Barber (2013) and Shannon et al. (2015)). In all previous work on the potential response of Hawaiian spinner dolphins to human presence and wildlife tourism, data were collected visually at the surface (Danil et al., 2005; Courbis, 2007; Delfour, 2007; Östman-Lind, 2008; Timmel et al., 2008; Courbis and Timmel, 2009; Östman-Lind, 2009; Tyne, 2015). These results, showed varied responses from increased aerial behaviors (Östman-Lind, 2009), variation in directional changes (Timmel et al., 2008), and earlier departure times (Danil et al., 2005) to no visual response (Courbis and Timmel, 2009). In contrast, in this study we assessed the potential acoustic response of Hawaiian spinner dolphins to the presence of human activities in four well studied resting bays (Norris et al., 1994; Östman-Lind, 2008; Timmel et al., 2008; Courbis and Timmel, 2009; Östman-Lind, 2009; Tyne et al., 2014, 2015). Given the importance of sound and these bays for these dolphins, assessing the potential acoustic response to human presence in these areas is crucial.

Our analysis of dolphin whistle activity throughout the day matched what we expected to observe based on earlier work (Norris, 1991; Brownlee and Norris, 1994) in two bays, Bays 2 and 4 (Fig. 2). Brownlee and Norris (1994) showed that the dolphins were acoustically silent during rest and that the acoustic activity reflected the behavioral state of the animals with more sound indicating more active or awake states and no sound indicating rest. Therefore we expected to see a period of minimal acoustic activity at the time when spinner dolphins are known to rest in the bay (10:00–14:00, Tyne et al. (2015)) and periods of maximum acoustic activity on either ends of this resting period. The decrease in dolphin whistle activity in Bays 2 and 4 during the middle of the day aligns with reported dolphin resting time in Tyne et al. (2015, 2017). Norris (1991) described brief interruptions to the silence when human activities got close to the animals. We hypothesize that the outliers during peak resting time in Bays 2 and 4 (Fig. 2) may reflect brief interruptions to rest like Norris described. We also propose that the higher levels of human activity in Bay 2 compared to Bay 4 could be the reason for the overall higher whistle activity in Bay 2.

In contrast, the other two bays, Bay 1 and Bay 3, did not have a decrease in acoustic activity during spinner dolphin resting time. Bay 3 had relatively low levels of anthropogenic activity, only small groups of dolphins and little dolphin presence with dolphins there less than 40% of days monitored (Heenehan et al., 2016) suggesting that dolphin usage of Bay 3 may be too low to draw any meaningful conclusions (Table 1). In previous work, Bay 1 has been cited as the "very core of the most frequently used resting areas'' (Östman, 1994) with large groups of dolphins reported using this area (Norris and Dohl, 1980; Norris, 1991; Östman, 1994). Bay 1 is home to the largest groups of dolphins of all bays (Table 1) and the dolphins are present approximately 90% of days monitored (Heenehan et al., 2016). Using visual observations, Tyne (2015) showed that in Bay 1 the dolphins spent 72.6% of their time resting. Interestingly, there is some evidence that suggests that rest is shallower in Bay 1 compared to other areas and that dolphins seem more alert in Bay 1 (Norris and Dohl, 1980; Norris, 1991). Tyne (2015) suggests that this is still the case in Bay 1. The lack of ''acoustically silent rest'' observed in Bay 1 in this study supports the theory that the dolphins are in a more vigilant state in Bay 1. Based on calculations of detection range in Heenehan et al. (2016), we are confident that we had good coverage for detecting whistles produced by the dolphins within the bays.

In Bays 2 and 4, time of day and the dolphins' well documented predictable daily behavior could explain the patterns we saw in dolphin whistle activity. However, two bays did not display the expected pattern. Therefore we sought to look at the variability in dolphin acoustic activity that might be explained by human activities. Comparisons of the number of vessels, swimmer/snorkelers and kayaks in each bay showed that the highest levels of vessel and kayak activity occurred in Bay 2 and the highest swimmer/snorkeler activity in Bay 2 and Bay 3. However, we did not find a relationship between any of these human activities and dolphin whistle activity in either bay (Table 2 and Fig. 3). In Bay 1 and Bay 4, two bays with less overall activity, we did find a weak relationship between vessels and swimmer/snorkelers and dolphin whistle activity. We suggest that these differential responses to human activities in the four bays could be due to the type of tourism that occurs in each bay and the human behavior that ensues from these differences.

Bay 2 and Bay 3 are both popular coral reef snorkeling destinations and people visit these bays for purposes other than interacting with the dolphins. In Bay 2, Heenehan et al. (2014) showed that there was no significant difference in vessels, swimmer/snorkelers or kayaks when dolphins were present versus when they were absent indicating the activity in this bay is not dolphin-centric or not focused on the dolphins. This supports our conclusion that although the activity levels may be high, tourism that is not dolphin-centric may be less disruptive for the dolphins in the bay. Bay 2 is also a relatively large bay, perhaps affording the dolphins the opportunity to avoid the activity and stay within the protection of the bay.

Bay 1 and Bay 4, are both places where activity in the bay translates to direct interaction with the dolphins. Heenehan et al. (2014) showed that the activities in Bay 1 are dolphin-centric or dolphin focused with significantly more human activity occurring when dolphins are present. In Bay 1, we found a positive correlation between the number of vessels and dolphin whistle activity. We also found a positive correlation between the number of swimmer/snorkelers and dolphin whistle activity which was to be expected since the swimmer/snorkelers are brought in by the vessels, therefore this relationship is highly correlated. There is no opportunity to swim out from shore and kayaks were never observed in Bay 1. Therefore, all of the interaction between humans and dolphins stems from vessels and swimmer/ snorkelers getting in the water off those vessels. The strongest relationship found between any human activity and dolphin acoustic activity was between the number of vessels and dolphin whistle activity in Bay 1. In Bay 4, the bulk of the interaction between humans and dolphins stems from people swimming out from the shore of the beach park to interact with the dolphins. Therefore, not surprisingly, we found no relationship between the number of vessels and dolphin whistle activity. We did find a weak positive relationship between dolphin whistle activity and the number of swimmer/snorkelers in the bay. This could suggest that activity in the bays that specifically targets the dolphins and is dolphin-centric, thus resulting in close interaction with animals elicits a response.

Interestingly, our vessel noise comparison between Bay 1 and Bay 2 differed in unexpected ways (Fig. 4). In Bay 1, each additional vessel added 1.3 dB to the underwater soundscape of the bay. While in Bay 2, the bay with the most vessel activity (Table 1), each additional vessel added only 0.5 dB. In addition, Bay 1 achieved higher levels of sound with a lower number of vessels. We propose that this result is likely due to the behavior of the vessels in the bay and the dolphin-centric nature of the vessel activities in Bay 1 compared with the non-dolphin-centric activities in Bay 2. In Bay 1, the vessels follow the dolphins and move to keep swimmers close to the animals whereby producing increased levels of sound. Vessel behavior in Bay 2 is generally more focused on direct transits in and out of the bay with minimal movement within the bay. The vessels enter the bay, drop snorkelers near the reef, move out from the reef and wait with their engine off until it is time to retrieve the snorkelers and then return to the harbor.

Timmel et al. (2008) suggested that response of the spinner dolphins depended on the magnitude of presence (i.e. the number of people or vessels in the water) not ''their specific activity''. If this were the case, we would have expected to see the greatest response in Bay 2, the bay with the most activity. However, we found no evidence of an acoustic response in this bay and instead found a weak but positive response in Bay 1. We propose that this may be due to the behavior of the vessels, as described above, and perhaps the noise produced by those vessels. Noise from vessels instead of the presence of vessels was the ''likeliest mechanism'' for disturbing killer whale behavior for Williams et al. (2006). Although the relationships we found were weak, we suggest this is an important area for future research and that studies designed to specifically address the relationship between human activity and dolphin acoustic activity are warranted.

The level of human impact on the dolphins in these bays has been of concern for more than a decade (NOAA, 2006) with dolphins exposed to human activities approximately 82% of the time in their resting bays with very little time between disturbances (Tyne, 2015). Bejder et al. (2006) showed population level consequences for a population of bottlenose dolphins exposed to significantly less human activity and suggested that such long term consequences on a population could go unnoticed for decades. Therefore, Bejder et al. (2006) suggested, taking an ''adaptive and precautionary approach'' to protecting marine mammals from the effects of human interaction and disturbance. The results of this study demonstrate that a similar adaptive and precautionary approach should be taken in this case.

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