Loud speech at a Peruvian tourist site triggers flight in pygmy marmosets (*Cebuella pygmaea*) and any speech reduces time spent feeding and resting, and increases alert behavior.

Short Title: Pygmy marmosets and tourist noise

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Abstract

While potentially beneficial in terms of raising awareness and conservation funding, tourist-visitation of wild primates can have negative impacts on visited groups. Tourism-generated noise is a relatively understudied facet of ecotourism research, and the effects of tourist generated noise on free-ranging, wild primates has never previously been explored. This study investigates the behavioral responses of ten groups of pygmy marmosets (*Cebuella pygmaea*) to human speech. Through the use of a manipulative playback study using recorded human speech, we show that pygmy marmosets within the Tamshiyacu-Tahuayo Reserve, Peru, are significantly less visible and often move completely out of sight after louder playbacks. Although no consistent differences were found in other behaviors with playback duration and volume, playbacks of human speech tended to increase the amount of time individuals were alert, and decrease feeding and resting behaviors, whereas these effects were not found in response to playbacks of white noise. Our results demonstrate that tourist-generated noise can alter the behavior of visited primates, and identifies the particular effect of noise volume on primate visibility. As all trials in this study took place near a marmoset group's feeding tree, moving out of sight from the visible study area is the most energetically costly behavior observed, and also has a negative effect on visitor enjoyment as it limits the time that they are able to view the target species. As this response was never observed (nor was any other consistent behavior change) in control trials where the marmosets were exposed to human presence but not to speech, this study suggests that negative tourist impacts can be reduced by encouraging tourists to refrain from speaking in the presence of visited primate groups.

Keywords: acoustic disturbance, ecotourism, flight initiation, pygmy marmoset

Research Highlights

- Wild pygmy marmosets at an ecotourism and research site moved away from, and were less visible after, playbacks of human speech.

- This effect of reduced visibility and movement away increased as playback volume increased.
- Playbacks of human speech were linked to reduced time feeding and resting, and an increase in alert behaviors by pygmy marmosets.

1. Introduction

Since its advent in the 1980s (Fennell, 2001) ecotourism has developed into an industry catering for over 8 billion visitors worldwide each year (Balmford et al., 2015) and represents a vital source of revenue for a number countries (e.g. Kirkby et al. 2010; Tumusiime & Svarstad 2011). Despite the potential conservation benefits associated with ecotourism, namely increased funding (Buckley, Morrison, & Castley, 2016) and protection (Robbins et al., 2011), a review by (Kruger, 2005) concluded that over a third of ecotourism projects are ecologically unsustainable. Ecotourism projects may be unsustainable for a number of reasons, including negative impacts on flagship species. These impacts may be apparent at the population level, such as changes in group movement (Aguilar-Melo et al., 2013; Cunha, 2010; Sibbald, Hooper, Mcleod, & Gordon, 2011) and population declines (McClung, Seddon, Massaro, & Setiawan, 2004; Watson, Bolton, & Monaghan, 2014), or at the individual level, causing behavioral (Meissner et al., 2015; Shutt et al., 2014), physiological (Behie, Pavelka, & Chapman, 2010; Zwijacz-Kozica et al., 2013) and morphological (Borg et al., 2015; Maréchal, Semple, Majolo, & Maclarnon, 2016) changes.

The negative effects of tourism on target species can arise due to a number of different factors, including the total number of tourists, their proximity and their behavior. High tourist numbers can lead to over-visitation (where sites operate at a higher capacity than is deemed sustainable) and accelerated environmental degradation (Shepard, 2002). Higher tourist numbers have been linked to elevated levels of anxiety in Barbary macaques (*Macaca sylvana*) (Maréchal et al., 2011), increased infant-directed aggression in Tibetan macaques (*Macaca thibetana*) (Huangshan, Berman, Li, & Ogawa, 2007), and decreased intra-group socialization in Mexican mantled howlers (*Alouatta palliata mexicana*) (Aguilar-Melo et al., 2013). Increased tourist proximity is directly correlated with the risk of disease transmission in great-apes (Woodford, Butynski, & Karesh, 2002). It is also linked to aggression levels (Klailova, Hodgkinson, & Lee, 2010) and elevated fecal glucocorticoid levels (Shutt et al., 2014), an indicator of physiological stress, in western lowland gorillas (*Gorilla gorilla*). Aside from the effects of tourist proximity, the interactions that take place between animals and tourists can be harmful – a possibility that many tourists don't consider (Grossberg, Treves, & Naughton-Treves, 2003). For example, tourists attempt to provoke a response from black howler monkeys (*Alouatta pigra*), it causes the female, juvenile and infant howler monkeys move higher into the canopy, while sub-adult and adult males approach the humans and/or roar (Grossberg et al., 2003).

As negative effects on target species are linked to long-term unsustainability of ecotourism sites, it is important to reduce these negative effects. While reducing tourist numbers could create adverse economic outcomes, reducing tourist proximity and changing their behavior does not have to impact revenues. For example, following guidelines issued by the IUCN, all great-ape tracking companies claiming to implement 'best practice' must enforce a minimum approach distance of 7 meters on all their tours (Macfie & Williamson, 2010). This regulation is industry-wide and as such, protects great-apes at all 'best-practice' ecotourism sites.

One aspect of tourist-behavior that is seldom regulated is noise generation, but there is observational evidence which suggests that noise associated with ecotourism disturbs primates (e.g.. de La Torre et al. 2000; Leasor & Macgregor 2014). The frequency of threat behaviors by Tibetan macaques increases with the decibel level of the tourist viewing platform at Mt. Huangshan, China (Ruesto, Sheeran, Matheson, Li, & Wagner, 2010). Boat noise is linked to increased levels of fecal testosterone in male golden mantled howler monkeys (*Alouatta palliata palliata*) and spider monkeys (*Ateles geoffroyi ornatus*) suggesting that acoustic disturbance provokes an (energetically costly) aggressive response in these species (Vanlangendonck, Nuñez, Chaves, & Gutiérrez-Espeleta, 2015). This is supported by anecdotal observations that male howlers roar when boats pass with their motor on, but not when the motor is turned off (Vanlangendonck et al., 2015).

Decreases in tourism-related noise may enhance visitor experience either by leading to increased detection rates (Karp & Guevara, 2011) or reducing the likelihood that animals will flee from tourists (Kinnaird & Brien, 1996). Following a 60 decibel playback of human conversation, detection of rainforest birds falls by 39% (Karp & Guevara, 2011). This pattern was documented both in an intact area of protected forest and the area immediately surrounding an ecotourism lodge, indicating birds do not habituate to the noise of human conversation (Karp & Guevara, 2011). Similarly, hoatzins (*Opisthocomus hoazin*) habituate to silent approaches by canoe but continue to flee from ‘noisy’ approaches conducted with a conversational playback after 10 weeks of trials (Karp & Root, 2009).

In spite of the potentially negative effects for visited species and tourists, tourist-generated noise remains a relatively understudied aspect of the sustainable ecotourism debate. Thus far, there have been no manipulative studies investigating the effects of tourist-generated noise on wild, visited primates. Through the use of a playback experiment using recordings of human speech, this study provides the first assessment of primate behavioral responses to human speech. Specifically, we investigate whether there is a significant change in the behavior of pygmy marmosets (*Cebuella pygmaea*) following playbacks of human speech, and whether this response is stronger following louder and/or longer playbacks. We hypothesize that the following behavioral responses will be seen following playbacks of human speech: 1) pygmy marmosets will alter their behavior following playbacks, spending more time vigilant, alert and engaging in self-directed behaviors, and less time engaged in feeding, resting, social and calling behaviors; 2) individuals will move away from the playback source, either by hiding and decreasing their visibility, or by completely leaving the area. It is predicted that these effects will be stronger following louder and longer playbacks.

2 Methods

2.1 Study site

This research was carried out between March and May 2017, in the north-western tropical rainforest of the Area de Conservacion Regional Comunal de Tamshiyacu-Tahuayo (ACRCTT) (4.293519°S 73.236237°W). Designated in 1991, ACRCTT was Peru's first state reserve and covers 4,200 km^2. Hunting is strictly regulated in ACRCTT and capture of primates forbidden. Annual precipitation ranges from 2.4 to 3.0 meters per year (Myster, 2015) and the site is subject to annual monomodal flooding (Kvist & Nebel, 2001). The study area is located on the blackwater Tahuayo River and its tributaries - the water contains tannins leeched from litter leading to acidity and reduced nutrients (Myster, 2015). The study site was flooded for the duration of fieldwork.

Only one tour operator, Amazonia Expeditions, has accommodation within the reserve. This study focusses on the areas surrounding Amazonia Expeditions' facilities on the Tahuayo River: a main lodge operating since 1995 (henceforth referred to as 'main lodge'), close to El Chino village, visited by all guests, and the Tahuayo River Amazon Research Center (henceforth referred to as 'research center') which tourists may choose to visit during longer stays. Most tourists stay for 7 nights, though there is seasonal fluctuation in total visitor numbers with a peak during July and August. Footfall and capacity are much lower at the research center.

2.2 Study species

Pygmy marmosets (*Cebuella pygmaea*) are the world's smallest monkey and are distributed across the western Amazon, inhabiting lowland evergreen forests close to rivers, usually on floodplains (Soini, 1982). Historically pygmy marmoset populations have been shown to be severely affected by live capture, noise pollution and habitat destruction (de la Torre, Yépez, & Snowdon, 2009). They are gum specialists, morphologically and behaviorally adapted for exudate feeding, but also eat fruit and insects (Jackson, 2011; Soini, 1982; Yépez, de la Torre, & Snowdon, 2005). They live in small, co-operatively breeding groups: a breeding female, her offspring from up to four successive litters, her mate and 1-2 additional adults (Soini, 1982). Home ranges are typically small (0.1-0.5 hectares) and centered around one or two feeding trees (de La Torre et al., 2000). The territoriality and specific feeding behavior of pygmy marmosets make them ideally suited to the experimental set up used in this study. Unhabituated groups can be reliably located and distinguished, ensuring appropriate rest periods can be left between playbacks of the different conditions and reducing the potential for stress from repeated playbacks to the same individuals. Sixteen marmoset groups were located in the area (Figure 1). The minimum distance between two marmoset groups was 255 meters. Three sightings of lone marmosets were documented although no feeding trees were discovered in these locations.

2.3 Experimental stimuli

Ten men and ten women were recorded speaking alone for two minutes. All participants were volunteers, and the majority Royal Holloway University of London students and faculty. Recordings were conducted using a Sennheiser ME-66 Short-Gun Microphone linked to a Marantz PMD661 Field Recorder. Background noise was removed in Audacity and tracks were randomly allocated to treatments before being cropped to the correct length in PRAAT. Six treatments were used: 60 seconds playbacks of human voices at 30db, 60db and 78db (equivalent to human's whispering, speaking and raised voices (Lane, Catania, & Stevens, 1961), 120 seconds of a human voice at 60db, 15 seconds of a human voice at 60db and a 60 second control playback of white noise at 0dB. Playbacks were conducted using a MiPro MA-303SB speaker and an Apple iPod Nano. Volume was controlled using pre-marked points on the speaker dial which generated playbacks that averaged 30db, 60db and 78db (when measured using a decibel meter at 1m) across three randomly selected playback tracks. Average ambient volume in the flooded jungle was 47.762 ± SD 0.985 decibels (42 measures across 6 locations).

2.4 Data collection

Known pygmy marmoset feeding trees were approached by boat, with the motor turned off at least 100m away. The boat was then paddled to the feeding tree until there was a good view of the feeding tree and surrounding branches. Once a marmoset was sighted, the equipment was quietly set up. There was then a five minute rest period before the experiment commenced to decrease the influence of the disruption of the boat arriving or marmoset detection of researchers.

During each experiment, a focal individual was video recorded using a Nikon D5200 SLR with a 55-300mm lens for 2 minutes prior to commencement of playback, and two minutes following the commencement of playback. Acoustic behavior was recorded using a Sennheiser ME-66 Short-Gun Microphone linked to a Marantz PMD661 Field Recorder. Recordings did not require the individual to be on the feeding tree, only that they were visible and did not disappear from view for longer than 20 seconds during the two minutes of recording prior to a playback. After each trial, a laser range finder was used to measure the distance from the speaker to the location of the marmoset at the commencement of playback. Marmosets were an average of 8.82m from the playback source (min = 4.3m, max = 13.7m).

Each of the six treatments were conducted with each of 10 marmoset groups. Focal individuals were all adults but there was no way to discern whether the same individual was being recorded each time. The order of treatments was randomized for each group. Trials were conducted between 0630 and 1730, half in the morning and half in the afternoon. If no individuals were sighted, minimum time to return to return to the tree to check again was 2 hours. If individuals were sighted but no playback made, a playback trial could be attempted again after 6 hours. Following a successful trial with a playback, another trial was not attempted with the same group for a minimum of 72 hours.

2.5 Data analysis

Behavioral responses were retrospectively analyzed from the videos using CowLog 2.2 (Hänninen & Pastell, 2009). Behaviors were grouped into six types: feeding, resting, alert, moving, social (grooming, play and calling), self-grooming, scratching and vigilance (see ethogram, supplementary materials). The 'unknown' vigilance category (when vigilance could not be observed as an individual's head was out of view) was removed before calculating percentage of time allocated to the remaining vigilance categories. Time allocations for behaviors were converted to percentage of visible time in two minutes and compared before and after commencement of the playback. If an individual remained out of sight for >20 seconds they were considered ‘absent’. Individuals could also be obscured (e.g. only partially visible), and these categories where combined to classify individuals as ‘out of view’. When individuals moved completely out of sight after the playback commenced, the study area continued to be observed for up to 20 minutes until a marmoset was sighted again, and this was recorded as the ‘returned’ time. It was not possible to distinguish whether this was the same marmoset. If a marmoset was not observed within 20 minutes, the trial ended and was classified as ‘not returned’.

Pygmy marmosets have three main call types that are identifiable by ear, and used to maintain group contact. The frequency of these lie outside the auditory sensitivity of their main predators (Snowdon & Hodun, 1981). After increasing the scale peak by 0.4, spectrograms were used to view recordings in PRAAT (Boersma & Weenink, 2018) and allow visual and auditory identification of calls. Presence or absence of vocalizations before and after the start of the playback in each trial was recorded.

Data was analyzed using RStudio Version 1.0.143 (R Core Development Team, 2018). The difference in behavior between the first two minutes and last two minutes of experiments were used as the response variable. Mixed-effects linear models (LMERs) from the package lme4 (Bates, Mächler, Bolker, & Walker, 2015) were used to test for differences in time visible and percentage time allocated to different behaviors and vigilance categories before and after the playback. A binomial generalized mixed-effects linear model (GLMER) was used to investigate differences between experiments in whether the focal individuals moved completely out of sight, and for changes in calling behavior. In all analyses, group was included as a random variable. The effect of the explanatory variables playback volume (in dB, 0 dB assigned for silent playbacks of white noise), playback duration (in seconds, 0 seconds assigned for silent playbacks of white noise) and the confounding variable distance between playback and focal individual (m) were tested using the Anova function in the car package (Fox & Weisberg, 2011). Playback distance was included as a confounding variable to control for potential variations in playback amplitudes across experiments. In analysis of change in calling behavior, whether calling was recorded before the playback start (binary variable, yes/no) was also included as a confounding variable. Conditional R^2 (fixed effects) and marginal R^2 (random and fixed effects) were calculated using the r.squaredGLMM function from the MuMin package (Barton, 2018).

2.6. Ethical Statement

This research was conducted under the authority of Amazonia Expeditions Research Center, Peru, therefore no permit was required. The research adhered to the American Society of Primatologists' Principles for the Ethical Treatment of Primates and ethical approval was granted by the Royal Holloway Research Ethics Committee.

3. Results

3.1 Overview

In total 94 trials were attempted across 12 groups: 67 were successful. Trials were unsuccessful for a number of reasons: the focal individual moving out of sight before playback (N = 14) and human interference (tourist presence or boat noise, N = 6) were the main issues. Trials were also abandoned due to weather conditions (N = 3), equipment malfunctions (N = 3) and the arrival of a habituated woolly monkey (N = 1). The analyses below are based on the ten groups where a full set of six trials were conducted: six groups at the main lodge and four at the research center. For these ten groups, 60 trials were completed in 83 attempts.

3.2 Visibility and absence from view

Overall, individuals were classified as out of view for 3.18 ± SD6.05 seconds in the first two minutes of the experiment and 23.29 ± SD28.70 seconds in the last two minutes. In control experiments, there was no consistent difference in time the focal individual was in view in the final two minutes of the experiment compared to the first two minutes (Table 1). In experiments with playbacks, focal individual were in view for less time in the final two minutes of the experiment, with an average decrease in view of -27.1 (95%CI -37.1, -17.0) seconds. Individuals were less visible after playbacks at louder volumes and were predicted to spend -0.7 (95% CI -1.0, -0.3) fewer seconds in sight for each 1dB increase in volume (Figure 2, χ^2 = 15.656, $p < 0.001$), but there was no effect of playback duration or distance from the focal individual to playback source (LMER: conditional R^2 = 0.18, marginal R^2 = 0.34, Duration χ^2 = 2.353, p = 0.125; Distance χ^2 = 0.001, p = 0.976).

Focal individuals moved completely out of sight in 18/60 trials but never during control trials (Figure 3, N = 10). Average time to move out of sight following commencement of playback was 61.6 ± SD 31.4 seconds (N = 18, range = 17-112 seconds). There were differences between conditions in the probability the focal individual was visible at the end of the experiment (GLMER: conditional $R^2 = 0.51$, marginal $R^2 = 0.39$). Mirroring the results on visible time, as the volume increased, the probability that the focal individual moved completely out of sight increased (χ^2 = 6.849, P = 0.009), but there was no effect of playback duration (χ^2 = 0.353, P = 0.552) or distance between the playback source and the focal individual (χ^2 = 1.513, P = 0.219).

Individuals that moved completely out of sight returned in 9/18 trials, an average of 372.4 ± SD 231.4 seconds (N =9, range = 44 s – 782 s) after they disappeared from view. In three trials where fled individuals were deemed to have returned, more than one individual fled the area during the trial and therefore it was not possible to be certain that it was the focal individual that returned. Although three individuals from groups near the research center returned to view after fleeing, and eight individuals returned into view at the main lodge groups, there was no significant difference (Pearson's chi-squared test: $N_{\text{main lodge}} = 8$, $N_{\text{research center}} = 10$, χ^2 = 2.025, df = 1, P=0.155).

3.3 Feeding, resting and alert behaviors

During the experiments, pygmy marmosets fed an average of 30.9±SD 34.8 % of visible time. In experiments with no playback, there was no consistent difference in the amount of time the focal individual spend feeding in the final two minutes of the experiment compared to the first two minutes (Table 1). In experiments with playbacks, time spend feeding decreased by an average of -16.4 (95% CI -24.2, -8.6) percent of visible time. There was no evidence for significant effect of playback volume, duration or distance on the change in visible time spent feeding (LMER, conditional R^2 = 0.10, marginal R^2 = 0.10, Volume χ^2 = 2.104, p = 0.147; Duration χ^2 = 1.209, p = 0.272; Distance χ^2 = 0.026, p = 0.872, Table 1).

During the experiments, pygmy marmosets rested an average of 39.7±SD 35.8% of visible time. For experiments without playbacks there was no consistent difference in the amount of time the focal individual spend resting in the final two minutes of the experiment compared to the first two minutes (Table 1). In experiments with playbacks, resting decreased by -11.7 (95% CI -20.68, -2.9) % of visible time. There was weak evidence that percentage of visible time resting decreased by -0.3 (95% CI -0.6, 0.0) % for each 1dB increase in volume (χ^2 = 3.012, p = 0.083). There was no evidence for significant effect of playback duration or distance on the change in time spent resting (LMER: conditional R^2 = 0.05, marginal R^2 = 0.06, Duration χ^2 = 1.15, p = 0.28; Distance χ^2 = 0.218, p = 0.640, Table 1).

During the experiments, pygmy marmosets were alert an average of 4.9±SD 8.6% of visible time. For control treatments there was no consistent difference in the amount of time the focal individual spent alert in the final two minutes of the experiment compared to the first two minutes (Table 1). In experiments with playbacks, alert behavior increased by 3.8 (95% CI 0.6, 7.0) % of visible time. There was no evidence for effects of volume, duration, or distance in the change in time spent alert (LMER: conditional R^2 = 0.03, marginal R^2 = 0.03, Volume χ^2 = 0.070, p = 0.792; Duration χ^2 = 0.200, p = 0.070; Distance χ^2 = 1.625, p = 0.202).

3.4 Vigilance

During the experiments, pygmy marmosets spent more time directing vigilance at other objects than directing vigilance at the playback (general vigilance 67.5±SD23.9% of visible time; playback-directed vigilance 4.7±SD7.5% of visible time). There was no consistent difference before and after the playback in the amount of playback-directed or general vigilance in either control playbacks or playbacks of human voices (Table 1). There was also no evidence for significant effect of volume, duration or distance on the change in general or playback-directed vigilance (Playback directed vigilance, LMER: conditional R^2 = 0.01, marginal R^2 = 0.01, Volume χ^2 = 0.287, p = 0.592; Duration χ^2 = 0.039, p = 0.843; Distance χ^2 = 0.204, p = 0.652. General vigilance, LMER: conditional R^2 = 0.03, marginal R^2 = 0.03, Volume χ^2 = 0.022, p = 0.883; Duration χ^2 = 0.801, p = 0.371; Distance χ^2 = 0.981, p = 0.322).

3.5 Social and self-directed behaviors

Social behavior was only observed in 8 trials (all of playbacks of human speech) across 7 groups. In these 8 trials, there was no evidence for consistent changes in percentage of observed time engaged in social behavior (change of -2.4 percent of visible time, 95%CI -6.9, 2.1). Social behavior was observed across all playback experiment conditions but never observed in control experiments. Self-directed behavior was observed in 19 trials across 8 groups. Although self-directed behavior was observed across all experimental condition, it was only observed twice in control experiments. There was no evidence for consistent changes in percentage of observed time engaged in self-directed behavior in response to playbacks of human speech (change of -1.7 percent of visible time, -8.4, 6.1, n=17).

3.6 Vocalizations

In most trials (n=48) there was no change in calling behavior before and after playback: marmosets were silent both before and after playback in 37 trials, and called both before and after the playback in 11 trails. Changes in calling behavior were observed in both control (2 of 10 trials) and playback trials (10 of 50 trials, observed in all conditions). There was no evidence for a change in calling behavior with playback volume, duration or distance (GLMER: conditional R^2 = 0.15, marginal R^2 = 0.12, Volume χ^2 = 0.140, p = 0.709; Duration χ^2 = 0.054, p = 0.816; Distance χ^2 = 1.798, p = 0.180; Calling before playback [binary y/n] χ^2 = 2.589, p = 0.108).

4 Discussion

This study demonstrates a link between loud human speech and individuals leaving the visible study area. As all trials took place near a marmoset group's feeding tree, flight from the visible study area is deemed to be the most costly behavior observed. Locomotion itself can have high energetic costs (Steudel-Numbers, 2003) while movement away from the feeding tree interferes with energetic intake. Further effects of acoustic disturbance include a decrease in feeding and resting, and an increase in alert behavior after any playback of human speech. All of these behavioral changes have the potential to impact marmoset fitness.

4.1 Absence and visibility

Many animals react to human presence by displaying anti-predator behaviors such as flight initiation (Knight, 2009; Smith et al., 2017). Although primates have previously been recorded to move away from observers at tourist visited sites (Hodgkinson, Kirkby, & Milner-Gulland, 2014), this study is the first time that the role of human speech has been experimentally demonstrated to increase the likelihood of movement away from observers at a tourism site. Due to the design of this study, it was not possible to conclude individuals fled the area after playbacks, but target individuals were more likely to be absent from sight following playbacks of human speech, whereas they remained visible at the end of control trials. This difference suggests that moving out of sight is a direct response to the noise generated by the playbacks and not the presence of a boat and researchers. This is supported by the lack of evidence across all analyses for an effect of distance between the boat and the focal individuals. As well as leaving the vicinity of the playback source, individuals were less likely to be visible to the researcher following louder playbacks in comparison to control trials. Individuals obscured themselves by moving higher up the tree, around the tree or into more leafy areas. Previous research on pygmy marmosets did not find a relationship between tourist pressure and visibility(de La Torre et al., 2000), but the importance of noise, rather than simply presence, is consistent with a previous study in which hoatzins habituated to silent canoe approaches but not acoustic playbacks (Karp & Root, 2009).

4.2 Feeding, resting and alert behaviors

Although individuals did not appear to alter their vigilance behaviors, they did decrease the percentage of time spent feeding and resting, and become more alert when the trial included a playback of human speech. The reduction in feeding and resting may be as individuals moved on to other branches away, from the main trunk of their feeding tree (pers. ob.). This possibility is potentially collaborated by the weak evidence for a decrease in resting as playback volume increased, mirroring the decrease in visibility and movement out of sight with louder playbacks. A reduction in feeding behaviors in response to tourist presence has also been documented in other species, including western lowland gorillas (Klailova et al., 2010; Shutt et al., 2014) and red deer (*Cervus elaphus*) (Sibbald et al., 2011). This behavioral change can impact fitness impact as a reduction in time spent feeding may reduce energetic intake.

4.3 Other behaviors

We found no evidence that any of the other behaviors measured changed in response to the playbacks. The lack of evidence for a change in playback-directed vigilance is surprising, as the pygmy marmosets did respond to human speech in other ways. The distracted-prey hypothesis stipulates that, as attention is finite, anthropogenic disturbance may distract individuals and interfere with their capacity for predator detection (Chan & Blumstein, 2011). This study did not find either an increase in playback-directed vigilance, or a decrease in general vigilance, which would have been consistent with the distracted-prey hypothesis. However, these results could be confounded as focal individuals were less visible after playbacks. It was assumed that individuals allocated the same proportion of time to each behavior when out of view as when in view, but this may not be the case. When out of view, individuals will not always be able to see the playback source or researchers, altering their vigilance responses.

Contrary to predictions, there was also no significant change in time allocated to self-directed behaviors, social behaviors or calling, and these behaviors were rarely observed. Self-scratching is an indicator of anxiety (Maréchal et al., 2011) and would therefore be expected to increase if individuals are stressed by the playbacks. Previous research on the pygmy marmoset suggested that human disturbance decreased vocal behavior (de La Torre et al., 2000). However, the evidence from this study suggests that individuals might respond to human conversation by moving away, rather than changing their calling behavior or engaging in displacement behaviors such as self-scratching.

4.4 Effects on tourists

In addition to the impacts on pygmy marmosets, this study demonstrates that acoustic disturbance may be detrimental to tourist enjoyment. Tourists value guaranteed encounters and proximity (Bach & Burton, 2017) however we find that human speech (and therefore tourist speech) can cause animals to hide from view and even flee the area. Individuals moved out of sight after as little as 17 seconds of human speech, and once gone the average time to return (if they returned at all) was over 6 minutes. This has the potential to impact the tourist viewing experience as it restricts the amount of time that they can view the marmosets. When there is no acoustic disturbance, individuals remained in the area when boats were as close as 5.8 meters.

4.5 Recommendations

This study demonstrates that human speech causes changes in pygmy marmoset behavior in a way that may be detrimental to both primate welfare and tourist enjoyment. Currently, there is limited regulation in place for primate tourism. In 2010, the IUCN released best-practice guidelines for great-ape tourism (Macfie & Williamson, 2010) but these do not contain any reference to tourism-generated noise, and do not cover primate species other than the great apes. Further research is likely required before official guidelines can be put in place, as these should consider both species-specific responses and other ways which the presence of tourists may affect primates, e.g. disease transmission (Muehlenbein & Wallis, 2014). However, based on the research documented in this study we would recommend that, at least for pygmy marmosets, ecotourism operators should take steps to reduce acoustic disturbance during tours.

As tourist conversation is generated by individual tourists, educating tourists could have a strong positive effect. This approach has been shown to be successful in multiple tourism contexts. For example, informing visitors of the negative link between tourist-boat proximity and stress in Humboldt penguins (*Spheniscus humboldti*) led to visitors selecting tour options that reduced negative welfare effects (Vásquez Lavín, Gelcich, Paz Lerdón, & Montealegre Bustos, 2016). Similar results have been found for dolphin tourism (Bach & Burton, 2017; Filby, Stockin, & Scarpaci, 2015), and notably visitors are willing to accept management regulations that are detrimental to their own experience if it means safeguarding dolphin welfare (Bach & Burton, 2017). Given these previous positive results, informing tourists that talking disturbs primates and may cause them to move out of sight (especially if they speak loudly) may be enough to encourage tourists to remain quiet when viewing primates. If talking is absolutely necessary, whispering (at a volume under 30db) is less likely to cause individuals to move out of sight.

This study did not test whether pygmy marmosets were able to habituate to acoustic disturbance. A study investigating whether habituation can ameliorate the behavioral changes reported here would provide useful recommendations for the pattern of visits which would reduce disturbance at a population level. If pygmy marmosets do habituate to acoustic disturbance then guides can minimize disturbance and maximize the tourist experience by taking tourists to frequently-visited groups. In contrast, if habituation is not observed, spreading tourist visits over multiple groups would mean each group is disturbed less frequently.

In conclusion, the behavioral changes documented in this study highlight the need for tour operators and tourists to consider the impact noise may have on visited species. In particular, human speech, and particularly loud speech, changes pygmy marmoset behavior in ways which are undesirable for both primate welfare and visiting tourists. Fortunately however, as these responses were not observed in control trials, this study suggests this effect can be reduced by encouraging tourists to refrain from speaking in the presence of visited primate groups.

5. Acknowledgements

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Table 1: Change in behavior after playbacks, and slope estimates for the effect of playback volume, duration and distance on changes in behavior. Means and estimates where the 95% confidence interval (95% CI) does not include zero are shown in bold.

Behavior	Change and 95% CI after control playbacks (n=10)	Change and 95% CI after playbacks of human voice (n=50)	Volume (slope estimate and 95% CI from LMER)	Duration (slope estimate and 95% CI from LMER)	Distance (slope estimate and 95% CI from LMER)
Out of view (seconds)	0.7 (-7.9,6.4)	**-27.1 (-37.1,-17.0)**	**-0.7 (-1.0, -0.3)**	0.2 (-0.1,0.4)	-0.1 (-4.2,4.0)
Feeding (% of visible time)	0.18 (-16.6,16.9)	**-16.4 (-24.2,-8.6)**	-0.2 (-0.5,0.1)	-0.1 (-0.3,0.1)	0.3 (-3.0,3.5)
Resting (% of visible time)	-0.8 (-12.1,10.5)	**-11.7 (-20.6,-2.9)**	-0.3 (-0.6, 0.0)	0.1 (-0.1,0.3)	0.8 (-2.4,4.0)
Alert (% of visible time)	4.3 (-2.2,10.9)	**3.8 (0.6,7.0)**	0.0 (-0.1,0.1)	0.0 (-0.1,1.1)	-0.9 (-2.2,0.5)
General vigilance (% of visible time)	-1.9 (-14.7,10.9)	3.2 (-3.0,9.3)	0.0 (-0.3, 0.2),	0.1 (-0.1,0.2)	-1.4 (-4.0,1.3)
Playback-directed	-0.3 (-3.7,3.0)	1.3 (-0.9,3.6)	0.0 (-0.1,0.1)	0.0 (-0.1, 0.1)	-0.2 (-0.7,1.2)

vigilance (% of visible time)					

Figure legends

Figure 1: Locations of pygmy marmoset groups close to tourist facilities within the Tamshiyacu-Tahuayo Reserve. Circles represent groups of pygmy marmosets, confirmed by sighting of marmosets on a feeding tree. The northern star shows Amazonia Expeditions' Main lodge, the southern star is the Amazon Research Center (ARC). Map produced in QGIS 2.18.12, with rivers digitalized from Google Satellite images © 2017.

Figure 2: Change in visibility of individual pygmy marmosets in the last two minutes of experiments compared to the first two minutes, measured in seconds. Experimental conditions were either silent playbacks of white noise (0dB) or playbacks of human speech at 30, 60 or 78dB, corresponding to human whispering, talking or a raised voice. Playbacks at 30 and 78dB were 60 seconds long, playbacks at 60dB varied between 15 and 120 seconds.

Figure 3: Status of individual pygmy marmosets at the end of the 4 minute experiment. Playback conditions consisted of a silent control and pre-recorded human speech played back at 30db, 60db and 78db. Bar width is proportional to sample size.