The effects of tourist and boat traffic on parrot geophagy in lowland Peru

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ABSTRACT

Ecotourism generates important revenue in many developing economies, but poorly regulated ecotourism can threaten the long-term viability of key biological resources. We determined the effects of tourism, boat traffic, and natural disturbances on parrot geophagy (soil consumption) across seven riverine claylicks in the lowlands of Madre de Dios, Peru. Claylick use significantly decreased when visitors did not follow good practice guidelines and tourist numbers exceeded the capacity of the observation blinds. Otherwise, tourist presence and natural disturbance did not have a significant effect. However, large macaws, particularly red-and-green macaws (*Ara chloropterus*), avoided visiting claylicks during periods of peak tourist numbers. Where parrots had multiple geophagy sites to choose from, they preferred sites further from tourist groups. The effect of boat disturbance was greatest on a narrow river with infrequent boat events. On a wider river with heavier traffic, boat disturbance had less of an effect and this effect was inversely proportional to the distance of boats from the claylick. Where visitors followed good-practice tourism guidelines, they had a low overall negative effect on parrot geophagy. We recommend that visitors respect the claylick observation guidelines to minimize anthropogenic disturbance on parrots and maintain these sites for the benefit of wildlife and humans alike.

Key words: Psittacines, psittacidae, recreation ecology, human impact, tourism

THE TOURISM AND HOSPITALITY INDUSTRIES CONTRIBUTE A SIGNIFICANT PERCENTAGE OF THE GDP IN DEVELOPING COUNTRIES: Tourism generated revenues of US$ 485 billion for emerging economies in 2013, the fourth highest grossing category after fuels, food, and clothing and textiles (World Tourism Organization 2015). Within the broad field of tourism, ecotourism distinguishes itself by generating income from nature-based attractions, channeling support to protected areas and local communities, and creating rewarding, educational experiences for tourists (Kruger 2005). In addition, tourism revenue can be an important conservation tool for threatened birds in protected areas (Steven et al. 2013), and can mitigate the risk of extinction for threatened species (Buckley et al. 2016). Ecotourism is widely recognized as more sustainable than logging, gold mining, or other extractive industries (Repetto & Gillis 1988, Groom et al. 1991), but the extent to which companies in the ecotourism industry live up to the principles of ecotourism remains to be seen (López-Espinosa 2002, Fennell & Weaver 2005).

Hiking, wildlife observation, and other non-consumptive outdoor recreation can alter the behavior, breeding success, and distribution of wild animals (Klein *et al.* 1996, Constantine *et al.* 2004, Finney *et al.* 2005, Bejder *et al.* 2006, Steven *et al.* 2011). For example, boat traffic commonly affects shoreline birds (Vermeer 1973, Galicia & Baldassarre 1997, Burger 1998, Bright *et al.* 2004). Many species show increased tolerance or habituation to tourism-related disturbance, but even habituated individuals may show hormonal changes, reduced reproductive success, or other less-obvious negative effects (Müllner *et al.* 2004, Walker *et al.* 2006, Bejder *et al.* 2009).

Rainforest conservation initiatives often highlight macaws and other colorful parrot species, especially where these birds are common, predictable, and provide visually entertaining spectacles and photographic opportunities (Munn 1998). In southeastern Peru, parrots seek out soil with high cation exchange capacity and high sodium content, usually at exposed riverbanks (Gilardi *et al.* 1999, Brightsmith & Aramburu Munoz-Najar 2004, Brightsmith *et al.* 2008b). Some of these sites, known as riverine claylicks, are important attractions for the tourism industry (Brightsmith et al. 2008a). Sites with the greatest species richness and largest numbers of individuals occur in the western Amazon basin (Lee et al. 2010). Rivers in the Amazon basin are important access routes for local people as well as tourism companies, especially where road infrastructure is limited (Killeen 2007). As a result, riverine parrot claylicks are exposed to varying volumes and types of boat traffic. Tourism boats generally want to stop to observe the birds, and local people sometimes hunt from boats (Burger & Gochfeld 2003, Hammer & Tatum-Hume 2003). Both types of boat are usually motorized; motor noise often causes macaws and parrots to abandon claylicks (Burger & Gochfeld 2003). Despite the importance of claylicks to the tourism industry and the known effects of anthropogenic disturbance, the effects of boats and tourists on parrots at claylicks have not been quantified.

In this paper we assess seven claylicks from across southeastern Peru to create a composite image of how boats, tourist foot traffic, and natural disturbances (raptors, terrestrial mammals, and other large birds) affect the spatial distribution, temporal distribution, and quantity of parrot claylick use. We hypothesize that the amount of claylick use will be inversely proportional to the intensity of disturbance around the licks. We predict that boats travelling closer to the claylick will cause greater disruption to claylick use. Finally, we explore the potential implications of these disturbances and recommend actions to reduce disturbance at these important ecological and ecotourism resource sites.

METHODS

STUDY SITES.—We conducted the study in the Madre de Dios region in southeastern Peru, along lowland Amazon rivers which form part of the approximately 160,000 km^2 Madre de Dios drainage basin (Goulding et al. 2003, Fig. 1). The region is predominantly tropical moist forest and lies between 190 and 250 m asl (Tosi 1960). We worked on two river basins – Las Piedras and Tambopata. We monitored seven claylicks: five along the main channel of the Tambopata River (Table 1) - Explorer's Inn (EI), Colpa Hermosa (Hermosa), Posada Colpita (Colpita), Colpa Colorado (TRC), Colpa Chuncho (Chuncho); one along a tributary of the Tambopta, El Gato Creek (Gato); and one along the Las Piedras River (Piedras).

DATA COLLECTION.— We conducted monitoring between June 2005 and December 2009 for most claylicks, except for Chuncho, which we monitored in 2012 only (Table 1). Observers arrived at the claylicks near dawn and initiated data collection when the first parrots landed on the claylick. The observers recorded the time, number, and species of the first birds that landed on the claylick, and subsequently counted all birds on the claylick every five min using binoculars and a spotting scope (20–60 X zoom). We calculated an index of claylick use as the sum of the number of parrots on the claylick during each count multiplied by the sampling interval (Brightsmith & Aramburu Munoz-Najar 2004). This index of 'bird-minutes' was used because quantifying and summing exact claylick use by individual birds was not feasible

(Brightsmith 2004). This index provides a suitable metric for assessing the effects of disturbance as it incorporates the total numbers of birds and the time spent on the claylick, both of which should decrease as disturbance increases. Assistants helped core staff, and were trained extensively in advance. To avoid site bias, we rotated observers among claylicks wherever possible. Although less-experienced observers could have contributed counting errors, these would have been small and not systematic.

We monitored claylick use at Hermosa, Gato, and Colpita up to 10 days per month, and at TRC up to 20 days per month (Table 1). We monitored at Piedras and EI on an *ad hoc* basis (Table 1). Monitoring effort was uneven as the remoteness of the study sites made access challenging. At all sites, we monitored during the early morning (dawn until 2–3 hours after dawn). On selected days we monitored until 17:00 h at Hermosa and at TRC, until 15:00 h at Piedras, and until 16:00 h at Chuncho. As weather influences claylick use (Brightsmith 2004), we did not monitor on rainy days. At all sites except TRC, researchers and tourists observed claylicks from blinds constructed from palm thatch and wood. These varied in proximity to the claylick, from 15 m (Colpita) to 120 m (Piedras).

To determine the influence of anthropogenic disturbance on parrot use of claylicks, we recorded the presence of tourist foot traffic and passing boats. We recorded the arrival time and numbers of people at six claylicks, while at EI and Piedras we used only presence/absence of tourists, as tourist numbers were recorded erratically. We recorded and classified boat types according to the type of engine: *peke peke* (a long-shaft *circa* 16 hp motor) or outboard motor (short propeller-shaft, quieter engine of 25 hp or more). Because TRC and Chuncho claylicks are on small side channels of the river and boats rarely passed in front of them, we did not record boat movements at these locations.

To determine the influence of natural disturbance on parrot use of claylicks, we recorded the presence of arboreal mammals, terrestrial mammals, raptors, and other large birds at the licks (except TRC and Chuncho). Large raptors and mammalian carnivores attack parrots at claylicks, causing birds to depart (Robinson 1994, Burger & Gochfeld 2003). Other large birds may also startle parrots on claylicks and cause them to take flight as parrots may potentially mistake large birds for raptors (Burger and Gochfeld 2003, ATKL and DJB pers. obs.). We combined raptors, mammals, and large birds into broad groups as species-level information was sparse. We recorded seven raptor species (predominantly roadside hawk, *Buteo magnirostris*, 57% of 209 records), eight species of arboreal mammals (six monkeys and two squirrels), ten terrestrial mammal species including brown agouti (*Dasyprocta variegata*, $N = 93$) and jaguar (*Panthera onca*, $N = 3$); and other large birds (predominantly three Cracidae species, 65% of 295 records). Species names follow Remsen Jr et al. (2016).

DATA ANALYSIS

EFFECTS OF DISTURBANCE ON EARLY MORNING CLAYLICK USE FOR EIGHT PARROT SPECIES.

— To determine the effects of disturbance factors on early morning claylick use, we used as our response variable the total early morning claylick use (total bird-minutes before 08:00 h) recorded at Hermosa, Piedras, Colpita, EI, and Gato for each of eight parrot species recorded on at least three of the claylicks: mealy parrot (*Amazona farinosa*), chestnut-fronted macaw (*Ara severus*), dusky-headed parakeet (*Arat-*

inga weddellii), blue-headed parrot (*Pionus menstruus*), white-eyed parakeet (*Psittacara leucophthalmus*), orange-cheeked parrot (*Pyrilia barrabandi*), yellow-crowned parrot (*Amazona ochrocephala*), and black-capped parakeet (*Pyrrhura rupicola*).

We used generalized linear mixed models (GLMM) using Markov chain Monte Carlo (MCMC) Bayesian methods implemented in the MCMCglmm R package (Hadfield 2010b), chosen over frequentist based packages due to our uneven sampling and to better account for our random effects. The predictor variables were presence or absence of tourists, total boats of each type (outboard or *peke peke*), total raptors, total arboreal mammal groups, total terrestrial mammals, and total other large birds. As seasonal patterns of claylick use are marked, we set month as well as claylick as random effects. We explored various priors, but found the best prior was nu and variance = 5 for fixed effects, and 1 for the random effects. We selected models based on minimum DIC following Hadfield (2010a). Examination of histograms showed claylick use followed a Poisson distribution and we used the appropriate family in the model. We examined trace plots for autocorrelation. In all cases we increased default burn-in (30,000) and number of iterations (130,000), as these provided acceptable trace plots based on a thinning value of 50, with final autocorrelation values for all models < 0.1.

We used a similar methodology to model effects on claylick use when the capacity of the blind at Hermosa was exceeded (15 or more people): for each parrot species we used claylick use as the dependent variable, with blind capacity exceeded or not as a factor fixed effect, and month as a random effect.

DISTURBANCE OF RED-AND-GREEN MACAWS AT HERMOSA.— To determine the effects of boats on large macaw claylick use, we monitored use of the Hermosa claylick by red-and-green macaws from 08:00 to 17:00 h, corresponding to the period of greatest use for this species. Red-and-green macaws were the only large macaw that regularly used this claylick. For each boat that passed the claylick, we recorded time, direction of travel, and engine type. We recorded the closest distance to the claylick for each boat in 50-meter bands (0–50 m from the claylick; 50–100 m etc.). We classified macaw responses to boats as follows: 0 – no reaction; 1 – increase in alarm calls; 2 – minor flush; 3 – moderate flush (up to 75% of birds take flight, but remain in the area); 4 – major flush (> 75% of the birds take flight, but remain in the area); 5 – complete flush (100% of the birds take flight and leave the area for ten minutes or more). We recorded responses separately for macaws in the trees and on the claylick. However, of the boats that passed when macaws were present, 61% (N = 3373) caused no reaction, so we conducted modeling with response as binomial (reaction 'yes' or 'no'). Here we used macaw response as the dependent variable, with boat type, boat distance from the claylick, and direction of travel as fixed effects and month as a random effect. We ran a full linear model with all two-way interactions using the lme4 package (Bates et al. 2013) and selected the best model by AIC, using the dredge function in the MuMIn package (Barton 2011) in R.

DISTURBANCE OF RED-AND-GREEN MACAWS AT PIEDRAS.— We also monitored the Piedras claylick on 115 days for reactions to boat traffic. The red-and-green macaws reacted to every boat that passed and abandoned the area (level 5 response) for 97 percent of these 152 boats. Given this uniformly strong response, modeling the influence of boat and boat travel characteristics on macaw reaction was not feasible.

DAILY TEMPORAL PATTERNS OF CLAYLICK USE BY RED-AND-GREEN MACAWS.— At Hermosa, we examined the influence of boat traffic, tourists on foot, and raptor presence on geophagy patterns by red-and-green macaws hourly (sum of bird-minutes per hour interval) from 08:00 to 17:00 h. Using date as a random effect and total claylick use by hour as the dependent variable, we modeled the influence of disturbance using total traffic for each boat type, sum of raptors, and total tourists as fixed effects using MCMCglmm, with parameters as per modeling of early morning disturbance. Due to the non-linear response of geophagy with time, we illustrate claylick use as a function of hour at Hermosa, TRC, Piedras, and Chuncho using the loess local regression approach with default settings in the dplyr package (Wickham & Francois 2014) in R.

EFFECT OF TOURIST LOCATION ON SPATIAL DISTRIBUTION OF EARLY MORNING CLAYLICK USE AT TRC.— The TRC claylick is approximately 500 m long with three main claylick sites (as per Brightsmith & Villalobos 2011) and three corresponding tourist observation points. The three observation points were 80, 105, and 150 m from the closest site used by birds. The tourism guides usually took their guests to the observation point closest to where claylick use was most intense in the preceding days. Tourist groups generally arrived before 05:30 h and were seated on folding chairs with little or no concealment from the claylick. To determine the influence of tourist location on parrot claylick use, we correlated the proportion of claylick use on each of the three sites at TRC with the number of tourists at the closest observation point (*i.e.*, proportion of birds using the right side correlated with the number of tourists at the right observation point) using Spearman's ranked correlation tests. We repeated this independently for each parrot species ($N = 13$) and each of the three observation points (left, center and right).

RESULTS

Mixed groups of psittacines were seen on the majority of days (79% of 1636 days across all 7 claylicks monitored), making these claylicks a very reliable tourism resource. Average claylick use per early morning (before 08:00 h) varied greatly among licks, ranging from an average of 215 ± 328 (SD) bird-minutes for Colpita to 5561 ± 2164 for Chuncho. The number of parrot species ranged from 9 at Colpita to 16 at TRC (Table 2). Tourist presence at these licks before 08:00 h was highly variable, ranging from 3 percent of mornings at Piedras to 78 percent of mornings at TRC (Table 1). After 08:00 h, parrot use of the claylicks was dominated by large macaws (at six of seven licks) and small parrot species (cobalt-winged parakeet *Brotogeris cyanoptera*, Amazonian parrotlet *Nannopsittaca dachilleae,* or black-capped parakeet *Pyrrhura rupicola*). Among the large macaws, all three species (red-and-green, scarlet, and blue-and-yellow) used the TRC and Chuncho licks, but red-and-green was the only large macaw regularly recorded at EI, Gato, Hermosa, and Piedras.

EFFECTS OF DISTURBANCE ON EARLY MORNING CLAYLICK USE.— Our multivariate analysis of disturbance of early morning claylick use included five claylicks (Hermosa, Gato, Colpita, EI, and Piedras) where all six disturbance types could be documented (tourists, boat traffic, raptors, arboreal mammals, terrestrial mammals, and other large birds). We found no evidence that tourist presence at these claylicks decreased the total claylick use for any of the eight common parrot species ($P_{min} = 0.13$; Table S1). At these same five claylicks, increased outboard boat traffic was associated with decreased claylick use for two species (orange-cheeked parrot, dusky-headed parakeet).

However, increased boat traffic (both outboard and *peke peke*) was surprisingly associated with increased claylick use for yellow-crowned parrot. The presence of raptors, arboreal mammals, terrestrial mammals and other large birds at these five licks was not significantly related to claylick use for any of the eight common species (P_{min} = 0.1).

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Exceeding the capacity of the observation blind at Hermosa was associated with a significant decrease in claylick use for five of the eight species analysed (Table S2). However, this only happened on 5 percent of early mornings.

DISTURBANCE OF RED-AND-GREEN MACAWS BY BOATS AT HERMOSA.— On average, boats passed the Hermosa claylick 23 ± 7 times per day between 08:00 and 17:00 h (N = 419 full days). Boats with outboard motors (mostly used by tourist lodges) were more common than 'local transport' boats driven by *peke peke* motors (outboard: mean = 17 ± 6 per day, *peke peke*: mean = 10 ± 4; t = 20.1, $P < 0.001$, df = 772). Tourist-related boat traffic typically travelled downriver in the early morning with departing tourists, and returned upriver in the afternoon with recently arriving tourists, resulting in a bimodal daily peak in boat traffic. Boats travelling upstream were more likely to stop to observe the claylick compared to boats travelling downstream (5% of downstream traffic; 16% of upstream traffic, N = 10,319).

Overall, 39 percent of the boats passing the Hermosa claylick caused birds to fly either from the trees, the claylick, or both. Red-and-green macaws were disturbed significantly more often by boats that passed close to the claylick (Fig. 1A, Table S3). Boats traveling upstream and *peke peke* boats disturbed the macaws significantly more often than downstream boats and outboard motor boats (Fig. 1A, Table S3).

DIURNAL PATTERNS OF CLAYLICK USE BY RED-AND-GREEN MACAWS.— Although 39 percent of boats passing the Hermosa claylick disturbed the Red-and-green Macaws, increased daily boat traffic rates were not associated with significant reductions in their hourly claylick use (95% CI: 0.017 to -0.183, $P = 0.85$ for *peke peke* boats; 95% CI: 0.087 to -0.040, $P = 0.17$ for outboards, Table S4). This suggests that the macaws do not avoid the claylick during hours of peak boat traffic. The number of raptors present was also not associated with significant reductions in claylick use. However, we found a significant negative relationship between the number of tourists present and the hourly use of the Hermosa claylick by the red-and-green macaws (95% CI: -0.156 to -0.002, $P = 0.04$, Table S4). Red-and-green macaw use of the Hermosa claylick peaked in the afternoon and highest tourism use of the blind was in the early morning (Fig. 2A). This suggests that these macaws may be avoiding using the claylick during the periods of peak tourism use of the observation blind.

Further patterns of temporal use at other claylicks supports this idea that the birds may be avoiding the times of peak tourism activity: At TRC, guided tourist groups used the trail immediately above the claylick (< 20 m from geophagy sites at some points) and observed the birds perched in the trees and those visiting the claylick (DJB, pers. obs.). These groups frequently scared the birds from the trees and the claylick. This tourism traffic peaked between 09:00 h and noon while claylick use by large macaws peaked in the early afternoon (Fig. 2B). In contrast, large macaw use peaked in the late morning at Piedras and Chuncho licks where tourists on foot and boat traffic were rare and claylick use patterns likely represent natural patterns.

EFFECT OF TOURIST LOCATION ON SPATIAL DISTRIBUTION OF CLAYLICK USE AT TRC.—

Tourists at TRC visited the claylick on 85 percent of days and mean tourist group size was 10 ± 8 (N = 416 days). The birds were evenly distributed among the three main geophagy sites at this claylick with 36 percent of use occurring on the left site, 34 percent on the middle, and 30 percent on the right. Tourist distributions were less even, with 5 percent left, 54 percent middle, and 41 percent right. When tourists observed parrot activity in the early morning from the left or right sides, there were significantly fewer parrots and macaws on the side of the claylick that was occupied. When analysed at the species level, 10 of 13 species fed in significantly lower numbers at the claylick section closest to these occupied observation points (Table 3). In general, the negative correlations between tourist numbers and claylick use were stronger on the right side where the observation point was closer, except for species that rarely (<6%) used the right hand side of the claylick (orange-cheeked parrot, dusky-headed parakeet, white-eyed parakeet, and white-bellied parrot). None of the species using the middle section were noticeably affected by higher tourist group size at the middle observation point, 150 m away.

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DISCUSSION

Our findings indicate that tourism and boat activities around claylicks had little or no negative effects on the total amount of time birds spent using them. However, human activities often temporarily interrupted claylick use, and birds often distanced themselves in time and space from potential anthropogenic disturbances. Boats passing in front of claylicks frequently caused birds to fly off the claylick or leave the claylick area completely (Burger & Gochfeld 2003, this study). The closer the boats were to the claylick, the greater the disturbance to the macaws. On a narrow, low-traffic river, nearly all boats that passed the claylick disturbed the birds (Piedras), whereas flush responses to boat presence were very low at a claylick on a wider, high-traffic river (Hermosa)

As found in previous studies, different types of boats elicited different responses. Burger and Gochfeld (2003; Table S3) found that the native people, who often hunt macaws, elicited a response in some cases 25 times greater than the researchers. In our study, the differences in effect magnitude between boat types were much smaller, and the likely drivers are not as clear. All tourist companies use outboard motors and many (but not all) local people use *peke peke* boats. During our time in the region (1999 to 2015) we have not heard of people shooting or trapping macaws at the claylick where boat traffic was analyzed (Hermosa), so a direct response to hunting is unlikely. However, *peke peke* motors are louder and the boats go slower, so these could contribute to the different effects of boat types.

Although boats passing near the licks disturbed the birds, boats only had minor effects on total amount of early morning use at the five claylicks analysed. Increases in the number of boats with outboard motors correlated with lower claylick use for orange-cheeked parrots and to a lesser extent dusky-headed parakeets. It is unclear why these two relatively small species were most affected, as they are rarely exploited by humans in the area. The sources of natural disturbance we measured (raptors, arboreal mammals, terrestrial mammals and other birds) had a minimal effect on overall parrot geophagy: parrots were able to accommodate their presence by moving away or feeding later. Some large raptors kill parrots at claylicks (Robinson 1994, DJB unpublished data, Burger & Gochfeld 2003) and predation risk likely structures the flocking behavior of parrots at claylicks (Brightsmith & Villalobos 2011). When large raptors attack it often results in all birds abandoning the claylick and the surrounding area (Burger & Gochfeld 2003). In our study, the presence of raptors had no significant effect on early morning claylick use. However, the great majority of the raptors recorded were species like roadside hawk, great black hawk, and black caracara which pose no real danger to any of the larger parrots and macaws and only minor threats to small parakeet species (see also Burger & Gochfeld 2003). Attacks by larger raptors such as harpy eagle (*Harpia harpyja*), crested eagle (*Morphnus guianensis*), and ornate hawk-eagles (*Spizaetus ornatus*) were not common enough for meaningful statistical analysis. Previous studies have found that large non-raptor birds can startle parrots using claylicks causing them to give 'false alarms' and scare other birds from the claylick (Burger & Gochfeld 2003). However, the birds usually return quickly to the claylick after such events (Brightsmith & Villalobos 2011). Our findings support the contention that the effects on total claylick use of such false alarm events are minor.

At the five claylicks where early morning viewing of parrot activity was conducted from blinds 15 to 120 m from the claylicks, tourists did not significantly decrease use by the common species. However, when tourists surpassed the maximum capacity of 15 persons at the blind at Hermosa (<5% of the mornings), five of the eight parrot species fed significantly less and overall claylick use averaged 51 percent less than on days with <15 guests observing the claylick. Our observations indicate that when group size surpassed 15, tourists were more likely to make loud noises, move around inside the blind, and stand outside the blind, making them much more obvious to the parrots on and around the claylick.

SPATIAL AND TEMPORAL SHIFTS IN CLAYLICK USE.— While we rarely saw overall reductions in claylick use due to anthropogenic disturbance, claylick-using parrots did shift their behavior to avoid disturbance, a common response among animals (Thiel *et al.* 2008, Crosmary *et al.* 2012). At the TRC claylick, the birds avoided sites that were within 150 m of observation points occupied by tourists. As 10 of the 11 most common species at the claylick were significantly affected, these findings probably represent a real avoidance of tourists.

Red-and-green macaws regularly use claylicks throughout the day (Burger & Gochfeld 2003, Brightsmith 2004). In areas with little tourism foot traffic, large macaw claylick use normally peaks in the late morning (Burger & Gochfeld 2003, this study). However, at the two licks with the largest numbers of tourists (TRC and Hermosa), large macaw use peaked between 12:30 and 15:00 h. We suggest that this shift represents macaws avoiding peak tourist time, in part because tourist schedules at both of these licks were very predictable. The licks have been regularly visited by the tourists following the same schedules since 1990 (TRC) and 1996 (Hermosa).

LESSONS AND IMPLICATIONS FOR TOURISM.— Currently, it is unknown what physiological or demographic effects parrots would suffer if they were deprived access to clay. Geophagy by parrots peaks in abundance and diversity in the lowlands of the western Amazon Basin where the birds most likely eat soil as a sodium supplement (Powell et al. 2009, Lee et al. 2010). Studies of soil consumption patterns by individual parrots are rare, but we observed that even when geophagy was at its highest, in adverse weather conditions sometimes lasting up to a week, parrots would not consume soil. Yet the birds invest much time and energy in visiting geophagy sites, and expose themselves to increased predation risk, suggesting that the soil plays an important role

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in their diet (Brightsmith & Villalobos 2011). Given the relatively minor anthropogenic reductions in geophagy we observed, we suspect that the ecological effects on the populations of parrots we studied were low; nevertheless, the birds may show hormonal changes, reduced reproductive success, suffer heat stress from feeding at hotter times of the day, or other less obvious negative effects.

Claylicks have no protected status under Peruvian law. Our finding of minimal reductions in claylick use due to boats and tourists is encouraging, as tourism is an important and growing industry in the region (Doan 2013, MINCETUR 2015). Visits to claylicks form an important part of the itineraries offered by many local companies, so it is in their best interests to maintain the quality of the tourism experience at these sites. However, our findings suggest that while parrots and macaws can habituate to some types of disturbance, they regularly make spatial and temporal adjustments to avoid close interactions with tourists.

Boats passing within 100 m of claylicks clearly disrupted bird activity and under some circumstances reduced overall claylick use (Burger & Gochfeld 2003, this study, DJB, ATKL pers. obs.). On narrower river systems any boat traffic is likely to cause major disturbance. As tourism boats can make up a sizable portion of the overall traffic near many claylicks, the government or the tourism industry should reduce boat traffic at peak claylick use times and set rules about maintaining minimum distances from the licks (Quillahuaman 2014).

One finding with important tourism implications is that red-and-green macaws apparently avoid the times of peak tourist presence at the licks. The ecological effects of this are likely small, but the effects on the quality of the tourism experience may be substantial, as an increasing proportion of guests see fewer and fewer birds using the sites. Practical guidelines for tour operators that are based on parrot activity patterns may ensure more sustainable parrot-watching tourism. We advocate the use of blinds with ample space to ensure capacity is not exceeded. Groups without blinds should not observe claylicks from a distance of less than approximately 150 meters. However, telescopes are needed for maximum effect at such distances, so blinds with concealed approaches are likely preferable. These can be placed as close as 30 m from a claylick (the distance of the observation blind to the claylick at Hermosa), as long as they are adequately constructed, tourist arrival or departure does not coincide with peak periods of parrot activity, tourist movement is restricted, and access trails to the blinds are concealed. Boat traffic should be scheduled so that boats do not pass the claylick at periods of peak activity and boat drivers should avoid approaching claylicks at any time.

Our findings indicate that tourism can and does affect birds using claylicks. The Peruvian government has taken the first steps towards creating claylick use guidelines (Quillahuaman 2014). However, these have not been implemented or enforced as of 2016, and will only be applicable to licks within the system of national protected areas. Therefore, tourism companies, researchers, and governments should work together to create and implement guidelines for claylick observation throughout the region to ensure the long-term sustainability of claylicks and the high-quality tourism experiences they provide. Ultimately, responsible tourism around claylicks will require a strong, well-implemented management plan and continued education of locals, tourists, and the tourist industry.

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References

BARTON, K. 2011. MuMIn: Multi-model inference. R package version 1.12.1. Vienna, Austria: R Foundation for Statistical Computing. See http://CRAN. R-project. org/package= MuMIn.

BATES, D., M. MAECHLER, B. BOLKER, AND S. WALKER. 2013. lme4: Linear mixed-effects models using Eigen and S4. R package version 1.

BEJDER, L., A. SAMUELS, H. WHITEHEAD, H. FINN, AND S. ALLEN. 2009. Impact assessment research: use and misuse of habituation, sensitisation and tolerance in describing wildlife responses to anthropogenic stimuli. Marine Ecology Progress Series 395: 177-185.

BEJDER, L., A. SAMUELS, H. WHITEHEAD, AND N. GALES. 2006. Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. Anim Behav 72: 1149-1158.

BRIGHT, A., G. R. REYNOLDS, J. INNES, AND J. R. WAAS. 2004. Correlations between human-made structures, boat-pass frequency and the number of New Zealand dabchicks (*Poliocephalus rufopectus*) of the Rotorua Lakes, New Zealand. N Z J Ecol 28: 137-142.

BRIGHTSMITH, D. J. 2004. Effects of weather on parrot geophagy in Tambopata, Peru. Wilson Bull 116: 134-145.

BRIGHTSMITH, D. J., AND R. ARAMBURU MUNOZ-NAJAR. 2004. Avian geophagy and soil characteristics in southeastern Peru. Biotropica 36: 534-543.

BRIGHTSMITH, D. J., A. STRONZA, AND K. HOLLE. 2008a. Ecotourism, conservation biology, and volunteer tourism: A mutually beneficial triumvirate. Biol Conserv 141: 2832-2842.

BRIGHTSMITH, D. J., J. TAYLOR, AND T. D. PHILLIPS. 2008b. The Roles of Soil Characteristics and Toxin Adsorption in Avian Geophagy. Biotropica 40: 766-774.

BRIGHTSMITH, D. J., AND E. M. VILLALOBOS. 2011. Parrot behavior at a Peruvian clay lick. The Wilson Journal of Ornithology 123: 595-602.

BUCKLEY, R. C., C. MORRISON, AND J. G. CASTLEY. 2016. Net Effects of Ecotourism on Threatened Species Survival. PloS one 11: e0147988.

BURGER, J. 1998. Effects of motorboats and personal watercraft on flight behaviour over a colony of common terns. The Condor 100: 528-534.

BURGER, J., AND M. GOCHFELD. 2003. Parrot behaviour at a Rio Manu (Peru) clay lick: temporal patterns, associations, and antipredator responses. Acta Ethol 6: 23 - 34.

CONSTANTINE, R., D. H. BRUNTON, AND T. DENNIS. 2004. Dolphin-watching tour boats change dolphin (*Tursiops truncatus*) behavior. Biol Conserv 117: 299–307.

CROSMARY, W.-G., M. VALEIX, H. FRITZ, H. MADZIKANDA, AND S. D. CÔTÉ. 2012. African ungulates and their drinking problems: hunting and predation risks constrain access to water. Anim Behav 83: 145-153.

DOAN, T. M. 2013. Sustainable Ecotourism in Amazonia: Evaluation of Six Sites in Southeastern Peru. International Journal of Tourism Research 15: 261-271.

FENNELL, D., AND D. WEAVER. 2005. The ecotourism concept and tourism–conservation symbiosis. Journal of Sustainable Tourism 13.

FINNEY, S. K., J. W. PEARCE-HIGGINS, AND D. W. YALDEN. 2005. The effect of recreational disturbance on an upland breeding bird, the golden plover *Pluvaialis apricaria*. Biol Conserv 121: 53–63.

GALICIA, E., AND G. A. BALDASSARRE. 1997. Effects of Motorized Tourboats on the Behavior of Nonbreeding American Flamingos in Yucatan, Mexico. Conserv Biol 11: 1159.

GILARDI, J. D., S. S. DUFFEY, C. A. MUNN, AND L. A. TELL. 1999. Biochemical functions of geophagy in parrots: Detoxification of dietary toxins and cytoprotective effects. Journal of Chemical Ecology 25: 897-922.

GOULDING, M., C. CAÑAS, R. BARTHEM, B. FORSBERG, AND H. ORTEGA. 2003. Amazon headwaters. Amazon Conservation Association, Lima, Peru.

GROOM, M., R. PODOLSKY, AND C. A. MUNN. 1991. Tourism as a sustained use of wildlife: a case study of Madre de Dios, Southeastern Peru. *In* J. Robinson and K. Redford (Eds.). Neotropical wildlife use and conservation., pp. 393-412. University of Chicago Press, Chicago.

HADFIELD, J. 2010a. MCMCglmm: Markov chain Monte Carlo methods for Generalised Linear Mixed Models. Tutorial for MCMCglmm package in R: 1-25.

HADFIELD, J. D. 2010b. MCMC methods for multi-response generalized linear mixed models: the MCMCglmm R package. Journal of Statistical Software 33: 1-22.

HAMMER, M., AND E. TATUM-HUME. 2003. Surveying monkeys, macaws and other animals of the Peru Amazon. Biosphere Expeditions, Suffolk, United Kingdom.

KILLEEN, T. J. 2007. A Perfect Storm in the Amazon Wilderness: Development and Conservation in the Context of the Initiative for the Integration of the Regional Infrastructure of South America (IIRSA). Advances in Applied Biodiversity Science, p. 102. Center for Applied Biodiversity Science, Arlington.

KLEIN, M. L., S. R. HUMPHREY, AND H. F. PERCIVAL. 1996. Effects of ecotourism on distribution of waterbirds in a wildlife refuge. Conserv Biol 9: 1454–1465.

KRUGER, O. 2005. The role of ecotourism in conservation: panacea or Pandora's box? Biodivers Conserv 14: 579-600.

LEE, A. T. K., S. KUMAR, D. J. BRIGHTSMITH, AND S. J. MARSDEN. 2010. Parrot claylick distribution in South America: Do patterns of 'where' help answer the question 'why'? Ecography 33: 503-513.

LÓPEZ-ESPINOSA, R. 2002. Evaluating ecotourism in natural protected areas of La Paz Bay, Baja California Sur, Mexico: ecotourism or nature-based tourism? . Biodiversity and Conservation Biology 11: 1539-1550.

MINCETUR. 2015. Estadisticas. Available at: http://www.mincetur.gob.pe/newweb/Default.aspx?tabid=3459, Downloaded on 13 Jan 2016. .

MÜLLNER, A., K. E. LINSENMAIR, AND M. WIKELSKI. 2004. Exposure to ecotourism reduces survival and affects stress response in hoatzin chicks (*Opisthocomus hoazin*). Biological Conservation 118: 549-558.

MUNN, C. A. 1998. Adding value to nature through macaw-oriented ecotourism. Journal of the American Veterinary Medical Association 212: 1246-1249.

POWELL, L. L., T. U. POWELL, G. V. POWELL, AND D. J. BRIGHTSMITH. 2009. Parrots take it with a grain of salt: available sodium content may drive collpa (clay lick) selection in southeastern Peru. Biotropica 41: 279-282.

QUILLAHUAMAN, N. 2014. Estudio de Límites Aceptables de Cambio para las collpas Chuncho y Colorado en la Reserva Nacional Tambopata, Rainforest Alliance y AIDER. Puerto Maldonado, Perú.

REMSEN JR, J., J. I. ARETA, C. D. CADENA, S. CLARAMUNT, A. JARAMILLO, J. F. PACHECO, J. PÉREZ-EMÁN, M. B. ROBBINS, F. G. STILES, D. F. STOTZ, AND K. J. ZIMMER. 2016. A classification of the bird species of South America. American Ornithologists' Union. http://www.museum.lsu.edu/~Remsen/SACCBaseline.html.

REPETTO, R., AND M. GILLIS. 1988. Public policies and the misuse of forest resources. Cambridge University Press, Cambridge.

ROBINSON, S. K. 1994. Habitat selection and foraging ecology of raptors in Amazonian Peru. Biotropica 26: 443-458.

STEVEN, R., J. G. CASTLEY, AND R. BUCKLEY. 2013. Tourism revenue as a conservation tool for threatened birds in protected areas. PLoS One 8: e62598.

STEVEN, R., C. PICKERING, AND J. G. CASTLEY. 2011. A review of the impacts of nature based recreation on birds. Journal of environmental management 92: 2287-2294.

THIEL, D., S. JENNI- EIERMANN, V. BRAUNISCH, R. PALME, AND L. JENNI. 2008. Ski tourism affects habitat use and evokes a physiological stress response in capercaillie *Tetrao urogallus*: a new methodological approach. Journal of Applied Ecology 45: 845-853.

TOSI, J. A. 1960. Zonas de vida natural en el Perú. Memoria explicativa sobre el mapa ecológico del Perú. Instituto Interamericano de las Ciencias Agricolas de la Organización de los Estados Americanos, Lima, Peru.

VERMEER, K. 1973. Some aspects of the nesting requirements of Common Loons in Alberta. Wilson Bull 85: 429-435.

WALKER, B. G., P. D. BOERSMA, AND J. C. WINGFIELD. 2006. Habituation of adult Magellanic penguins to human visitation as expressed through behavior and corticosterone secretion. Conserv Biol 20: 146-154.

WICKHAM, H., AND R. FRANCOIS. 2014. dplyr: A grammar of data manipulation. URL http://CRAN. R-project. org/package= dplyr. R package version 0.4.1.

WORLD TOURISM ORGANIZATION 2015. UNWTO Annual Report 2014, UNWTO, Madrid.

Table 1: Summary of start and end monitoring periods for each claylick, with N days = total monitoring days; boats = sum of boats recorded; Tourist Present: percentage of N days on which tourists were recorded; Total Tourists = sum of tourist numbers (if known); Raptor = percentage of N days when raptors were recorded.

Claylick	Start	End	N days	Boats	Tourists Present	Total Tourists	Raptor
Colpita	10/12/2005	11/07/2009	261	NA	23%	257	10%
EI	03/08/2006	27/06/2009	231	633	17%	No data	6%
Gato	21/09/2007	08/07/2009	125	4	66%	667	31%
Hermosa	07/01/2006	09/12/2009	419	11619	72%	5423	48%
Piedras	01/06/2005	17/12/2008	115	261	3%	No data	42%
TRC	04/01/2006	31/12/2007	473	NA	79%	4226	No data
Chuncho	09/12/2012	21/12/2012	12	NA	33%	19	No data

Table 2: Early morning use of seven claylicks by parrots in southeastern Peru. Species are ordered by relative abundance across all licks combined. All data were collected between first light and 08h00. Numbers represent the mean bird-minutes recorded per morning (including mornings with observations but no bird use). "Average all species" gives the estimated mean total bird-minutes of claylick use per morning for all parrot species combined during the monitoring period.

	Claylick use (mean bird-minutes per early morning)						
Parrot Species	Chuncho	Colpita	EI	Gato	Hermosa	Piedras	TRC
Mealy parrot (Amazona farinosa)	2201	133	215	91	51	78	868
Chestnut-fronted macaw (Ara severus)	1135	1	46	1	35	0	266
Dusky-headed parakeet (Aratinga weddellii)	347	17	215	163	218	49	145
Scarlet macaw (Ara macao)	1000	0	0	2	1	0	35
Blue-headed parrot (Pionus menstruus)	148	10	51	7	119	229	461
White-eyed parakeet (Psittacara leucophthalmus)	0	6	11	0	1	1	516
Red-and-green macaw (Ara chloropterus)	452	0	2	0	10	20	9

Orange-cheeked parrot (Pyrilia barrabandi)	205	33	11	47	28	3	129
Red-bellied macaw (Orthopsittaca manilatus)	0	0	0	0	0	0	452
Yellow-crowned parrot (Amazona ochrocephala)	13	2	18	0	81	13	76
Blue-and-yellow macaw (Ara ara-rauna)	62	0	0	0	0	0	113
White-bellied parrot (Pionites leu-cogaster)	0	0	1	0	0	0	36
Blue-headed macaw (Primolius couloni)	0	0	0	0	0	0	26
Black-capped parakeet (Pyrrhura rupicola)	0	9	0	7	7	0	0
Cobalt-winged parakeet (Bro-togeris cyanoptera)	0	4	0	11	2	0	1
Amazonian parrotlet (Nannopsit-taca dachilleae)	0	0	0	0	0	0	0.02
Average all species	5563	215	570	329	553	393	313 3
Number of mornings monitored	12	160	213	89	348	61	467

Table 3: Effect of tourist number on parrot use of different sections of the claylick at TRC. Correlation analyses were conducted between daily tourist numbers and the proportion of the total amount of claylick use that was observed at each section. Left, middle, and right observation points were 100, 150, and 80 m from the claylick respectively. Values for *P* where the correlation is significant at the 0.05 level (2-tailed) are indicated in bold. *N* = 416 days. Species are ranked by claylick use, which is mean of total daily bird-minutes ± standard deviation.

		Left side of claylick		Middle		Right side	
	Claylick use	r_s	*P*	r_s	*p*	r_s	*P*
Mealy parrot	649 ±1373	-0.06	0.259	0.05	0.323	-0.11	0.021
White-eyed parakeet	612 ±1752	-0.206	0.01	0.09	0.068	-0.05	0.305
Red-bellied macaw	375 ±657	-0.12	0.017	0	0.963	-0.14	0.005
Blue-headed parrot	312 ±536	0	0.988	0.03	0.492	-0.15	0.002
Chestnut-fronted macaw	247 ±390	-0.12	0.017	0.02	0.648	-0.14	0.005
Dusky-headed parakeet	185 ±268	-0.054	0.274	0.05	0.336	-0.042	0.392
White-bellied parrot	102 ±204	-0.14	0.004	0.08	0.101	-0.05	0.36
Orange-cheeked parrot	100 ±177	-0.135	0.006	-0.01	0.836	-0.083	0.091

Blue-and-yellow macaw	92 ±147	-0.02	0.701	0.02	0.71	-0.11	0.027
Yellow-crowned parrot	74 ±106	-0.11	0.024	0.07	0.151	-0.11	0.024
Scarlet macaw	21 ±56	-0.05	0.269	-0.03	0.589	-0.1	0.039
Blue-headed macaw	11 ±29	-0.09	0.072	0.05	0.345	-0.01	0.867
Red-and-green macaw	5 ±30	-0.01	0.912	-0.02	0.716	-0.06	0.259

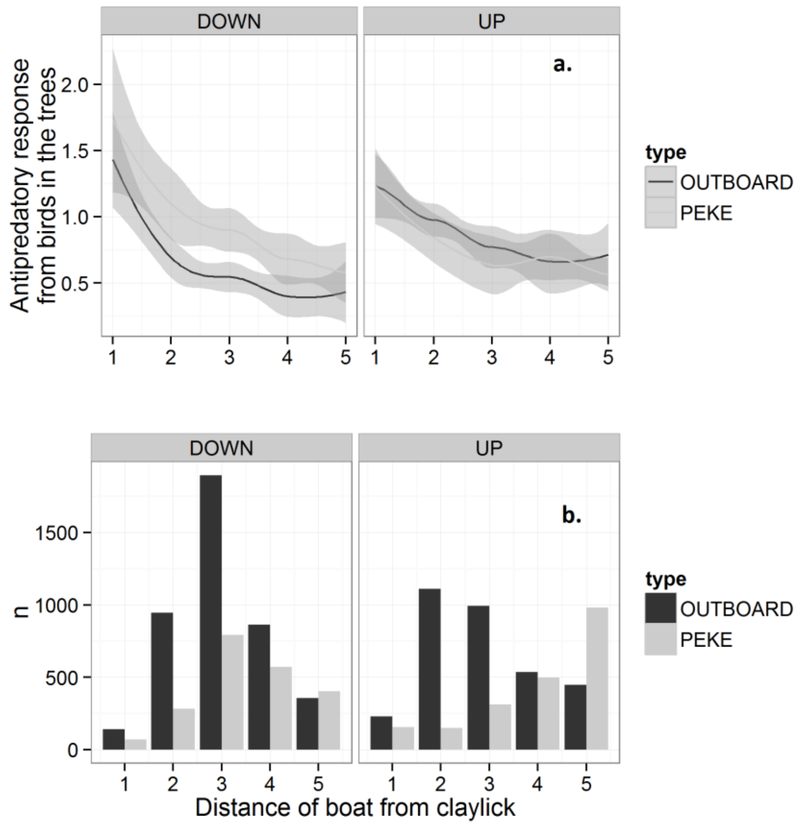

Figure 1a: Response of red-and-green macaws to passing boat traffic as a function of boat engine type, direction of travel (down-river or up-river), and proximity to the claylick: 1 = within 50 m of the claylick, 5 = up to 250 m from the claylick. 1b: Bar charts represent total boat traffic for the 430 days of observation. Response is shown for macaws in trees. Birds on the claylick followed a similar pattern, but with smaller sample size.

Commented [4]: The grey line for PEKE" is very hard to see.

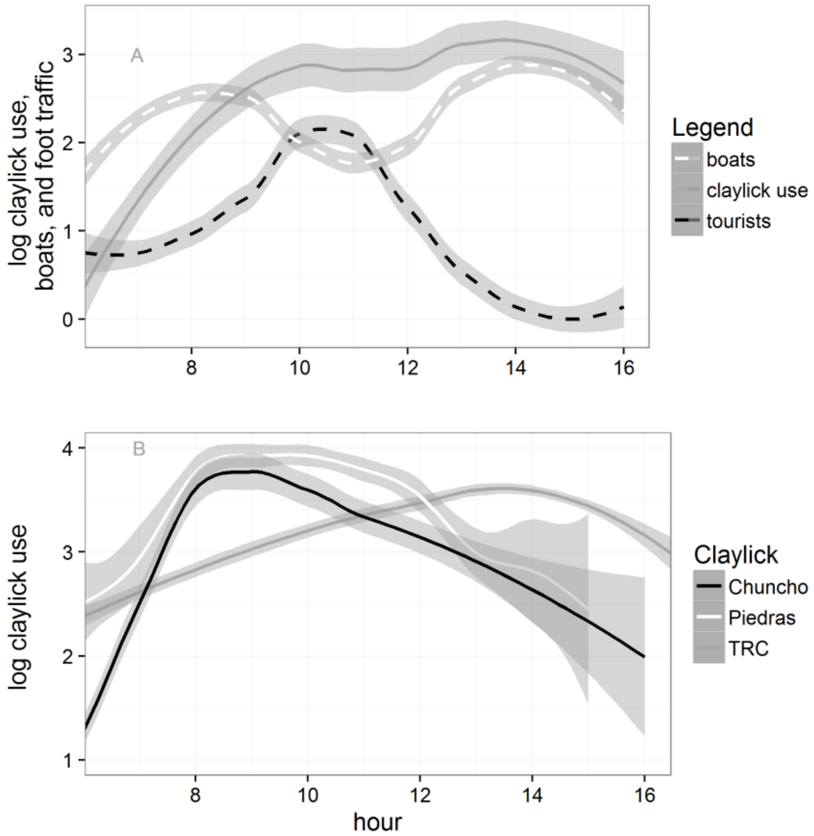

Figure 2A: Red-and-green macaw claylick use at Hermosa as a function of time (hour). Line is a loess smoother of the log of mean claylick use+1 modelled as a function of hour with shading representing 95% confidence interval. Mean tourist foot traffic is plotted as black, and mean of all boat traffic as white. Figure 2B: comparative claylick use by red-and-green macaws at Piedras, Chuncho, and TRC claylicks.

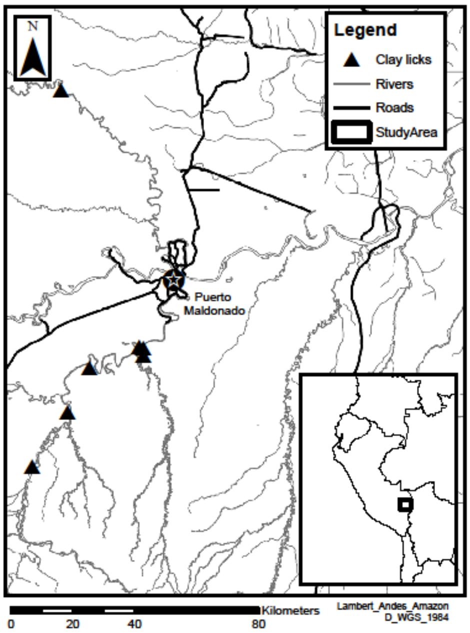

Figure SI 1: A map of the study area of southeastern Peru, indicating major rivers, the principal town of Puerto Maldonado, and riverine claylicks.

Table S1: Model summary for the influence of disturbance on total early morning claylick use by eight common parrot species across five claylicks (Colpita, Hermosa, EI, Gato, Piedras). Natural disturbance sources (raptors, arboreal mammals, terrestrial mammals, other large birds) were not significant for any species ($p > 0.1$ for all natural effects). post.mean: posterior mean; l/u.95.CI: lower to upper 95% confidence intervals; eff.samp: effective sample size; p = pMCMC, with values <0.05 highlighted in bold.

Species Effect	post.mean	l.95.CI	u.95.CI	eff.samp	p
Black-capped parakeet					
Outboard	-0.219	-0.769	0.328	431	0.438
Peke peke	-0.497	-1.502	0.432	330	0.294
Tourists	-0.039	-0.236	0.163	463	0.68
Blue-headed parrot					
Outboard	-0.04	-0.169	0.102	1074	0.54
Peke peke	-0.2	-0.432	0.067	875	0.104
Tourists	-0.017	-0.076	0.04	830	0.558
Chestnut-fronted macaw					
Outboard	-0.158	-0.376	0.052	818	0.128
Peke peke	-0.047	-0.444	0.348	675	0.826
Tourists	-0.033	-0.131	0.047	780	0.46
Dusky-headed parakeet					
Outboard	**-0.158**	**-0.329**	**-0.018**	**1000**	**0.046**

Peke peke	-0.108	-0.414	0.177	808	0.512
Tourists	0.048	-0.015	0.116	1000	0.16
Mealy Parrot					
outboard	0.067	-0.179	0.282	821	0.578
Peke peke	-0.184	-0.564	0.219	798	0.374
Tourists	0.038	-0.064	0.125	769	0.45
Orange-cheeked Parrot					
outboard	**-0.339**	**-0.525**	**-0.152**	**709**	**0.002**
Peke peke	0.062	-0.316	0.406	906	0.754
Tourists	-0.016	-0.104	0.066	849	0.704
White-eyed Parakeet					
outboard	-0.341	-0.919	0.189	350	0.236
Peke peke	0.557	-0.428	1.78	316	0.326
Tourists	-0.348	-0.856	0.076	81	0.132
Yellow-crowned Parrot					

outboard	**0.491**	**0.172**	**0.831**	**394**
				0.002
Peke peke	**0.531**	**-0.028**	**1.027**	**716**
				0.048
Tourists	-0.008	-0.147	0.116	623
				0.886

Table S2: Effect on total early morning claylick use of exceeding blind capacity at the Hermosa claylick for eight common parrot species. “Exceeded” indicates tourist numbers were 15 or greater (*N*=22 days), while <15 indicates tourist numbers were lower than 15 (*N* = 408 days). Claylick use at Hermosa (mean birdminutes ± standard deviation) for each species is indicated. 95.CI = 95% confidence intervals; eff.samp = effective sample size; p < 0.05 highlighted in bold; Claylick use (bird-minutes) as daily mean and standard deviation (sd) are provided.

	Model output					Claylick use	
Species	post.mean	l-95% CI	u-95% CI	eff.samp	p	Mean	sd
Black-capped parakeet							
Exceeded	**-13.52**	-22.28	-6.67	190.5	**0.001**	0.5	2.1
<15	3.13	-3.83	9.99	312.6	0.422	6.4	34.1
Blue-headed parrot							
Exceeded	0.76	-1.21	2.72	931.3	0.443	67.5	110.6
<15	1.35	-0.32	2.80	787.8	0.088	97.9	137.3

Dusky-headed parakeet							
Exceeded	-0.90	-3.11	1.61	1108.0	0.448	114.5	214.8
<15	0.46	-1.53	2.37	1289.7	0.644	179.6	288.6
Orange-cheeked parrot							
Exceeded	-0.05	-2.83	2.59	770.0	0.987	13.0	41.5
<15	0.87	-1.48	3.35	896.1	0.507	23.3	51.4
Mealy parrot							
Exceeded	**-4.08**	-7.03	-1.23	702.0	**0.005**	10.7	31.6
<15	1.17	-1.49	3.83	922.5	0.408	43.2	176.8
Chestnut-fronted macaw							
Exceeded	**-4.96**	-7.90	-1.66	411.4	**0.001**	21.1	44.0
<15	3.20	0.62	5.92	492.8	0.013	29.1	53.7
Yellow-crowned parrot							
Exceeded	**-5.36**	-8.72	-1.92	749.5	**0.001**	38.6	52.6
<15	-0.49	-3.35	2.83	1264.0	0.752	66.9	104.8
White-eyed parakeet							

Exceeded	**-146.48**	-230.37	-44.24	2.0	**0.001**	0.0	0.0
<15	128.79	29.51	219.03	1.9	**0.001**	0.7	7.6

Table S3. Best model output of boat distance (distance bands), type, and direction of travel on red-and-green macaw flush responses for macaws perched in trees at the Hermosa claylick (Trees); and on the claylick surface (Claylick). dAIC of best model from full model with tree response: 5; dAIC of best model from full model with clay-lick response: 3.

Trees	**Estimate**	**Se**	**z value**	**Pr(>|z|)**
(Intercept)	-0.143	0.188	-0.760	0.447
Direction UP	0.498	0.098	5.067	0.000
Distance	-0.219	0.035	-6.222	0.000
Type PEKE	0.637	0.111	5.742	0.000
DirectionUP:typePEKE	-0.611	0.152	-4.018	0.000

Claylick	**Estimate**	**Se**	**z value**	**Pr(>|z|)**
(Intercept)	0.613	0.373	1.645	0.100
Direction UP	-0.421	0.379	-1.109	0.267
Distance	-0.501	0.106	-4.744	0.000
Type PEKE	0.538	0.217	2.478	0.013
DirectionUP:Distance	0.285	0.126	2.262	0.024

DirectionUP:typePEKE	-0.685	0.303	-2.258	0.024

Table S4: Model output of effects of tourists and boat traffic on hourly red-and-green macaw claylick use of the Hermosa claylick. DIC = 9265. Headers as in Table S2.

	post.mean	l-95% CI	u-95% CI	eff.samp	pMCMC
(Intercept)	-3.353	-3.855	-2.938	282	0.001
Foot traffic	-0.076	-0.156	-0.002	796	**0.040**
Peke peke	0.017	-0.183	0.221	1000	0.854
Outboard	0.087	-0.040	0.216	896	0.168
Raptors	0.496	-0.652	1.484	1000	0.374