ethology international journal of behavioural biology

Ethology

RESEARCH PAPER

The Effect of Human Presence and Human Activity on Risk Assessment and Flight Initiation Distance in Skinks

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Received: May 27, 2014
Initial acceptance: June 10, 2014
Final acceptance: June 19, 2014
(L. Ebensperger)

doi: 10.1111/eth.12281

Keywords: antipredator behavior, escape behavior, flight initiation distance, habituation, risk assessment, Squatmata

Abstract

Antipredator behavior and risk assessment of many species are affected by the presence of humans and their activities. Previous studies have largely been conducted on birds and mammals and relatively less is known about human impacts on reptiles. We used flight initiation distance (FID) as a measure of risk assessment in inland blue-tailed skinks (*Emoia impar*) and tested the direct and indirect effects of humans on risk assessment. We first examined the effects of varying levels and types of human disturbance and activity on skink FID. We found that skinks flushed at significantly longer distances in areas with the least human activity. We then tested the degree to which skinks are able to discriminate different numbers of humans by comparing FID across three different types of approaches. Skinks did not significantly differentiate between a single approacher and a single approacher coming from a group of two other people, but did flush at greater distances when approached by three people simultaneously. Although skinks are not directly harvested or harassed by humans, they have refined human discrimination abilities. Overall, skinks habituate to a variety of human activities and perceive a larger threat when the number of human approachers is greater.

Introduction

Humans may be perceived as predators by prey (Frid & Dill 2002), and thus, humans may directly and indirectly influence both risk assessment (for review: Stankowich 2008) and antipredator decisions, such as flight initiation distance (Blumstein et al. 2003; Cooper 2005). Animals may modify their estimates of the risk they associate with humans as a function of the level and type of human disturbance and harassment that they experience. Flight initiation distance (FID) is the distance between the predator and prey at the time the prey flees (Ydenberg & Dill 1986; Cooper & Frederick 2007) and is used as a quantifiable measure of risk assessment (Stankowich & Blumstein 2005). When perceived predation risk is greater, FID increases because prey prioritizes flight to escape danger (LaGory 1987; McLean & Godin 1989; Cooper 1997a,b). FID can be used to identify the presence of these human-induced effects among different prey populations. Changes in risk assessment due to varying levels of human disturbance have been well documented in both birds (Burger & Gochfeld 1998; Møller 2009; Valcarcel & Fernández-Juricic 2009) and mammals (for review: Stankowich 2008), and somewhat so in reptiles (Irschick et al. 2005; Cooper 2009; Majláth & Majláthová 2009); however, it has yet to be studied in skinks. We used FID to study the degree to which skinks modify risk assessment in response to human activity.

Humans can both indirectly and directly influence prey risk assessment. For this study, we defined human-induced indirect effects as alterations to the natural habitat, including the introduction of domesticated or feral animals, the presence of roads, the introduction of vehicular traffic, sound pollution, and the presence of humans themselves. These factors may change the way that prey behave and assess risk (Burger & Gochfeld 1998; Gill 2007; Stankowich 2008). For example, humans who engage in activities such as jogging or biking may not intend to directly interact with wildlife, but these activities nevertheless expose animals to humans (Taylor & Knight 2003; Stankowich 2008). In addition, the presence of roads and other anthropogenic habitat alterations may restrict access to resources (Gill 2007). Defining areas based on the varying levels and types of human disturbance allows comparison of FID between such sites. Changes in FID may thus reflect the influence of different types of disturbance on risk assessment (Li et al. 2011).

In addition to having indirect effects on prey risk assessment, human activity may have direct effects. Because approaching humans can sometimes be perceived as predators (Frid & Dill 2002), prey should respond to them. However, little is known about the degree to which prey responds to different numbers of approaching humans. Studies in the past have focused on whether or not birds have an increased FID (Geist et al. 2005) and short-term behavioral responses (Wheeler et al. 2009) when approached by an increasing number of humans. There has been only one study focusing on effects on FID with simultaneous approach by multiple predators in lizards (Cooper 2007). Results showed that lizards increased their FID when approached by two fast-moving predators.

The effects of humans on wildlife can be seen in areas that are not necessarily classified as urban, including those that have minimal levels of human development. Even a small research station or building can act as a source of disturbance that may influence risk assessment (Coleman et al. 2008; Carrasco & Blumstein 2012). Changes in risk assessment due to anthropogenic effects may lead to behavioral changes that resemble either habituation or sensitization (Bejder et al. 2009; Blumstein 2014). Within a wildlife refuge, birds may habituate differentially to humans due to variation in human activity among sites (Burger & Gochfeld 1998), even though animals there interact benignly with humans. This suggests that even low levels of human activity or presence can affect animal risk assessment and antipredator behavior.

The island of Moorea, French Polynesia, with a human population of 16 191 (Institut Statistique de Polynésie Française 2012), is an ideal location to study both the indirect and direct effects of humans upon prey. Moorea lacks major urban centers and, therefore, is ideal for study of behavioral changes in places with minimal human disturbance. The island is covered by natural forests, pineapple plantations, small villages, several research stations, paved and unpaved roads, and smaller hiking trails. The mix of these features creates an opportunity to study how land use influences risk assessment. Other types of disturbances found in areas with frequent use include road construction, feral chickens and jungle fowl (*Gallus domesticus* and *Gallus gallus*), and large populations of cats and dogs. As Moorea is also a popular destination for ecotourism, tourist activity may provide additional disturbance (Stephenson 1993; Burger & Gochfeld 1998; Duane 2006).

Although many studies have focused on human impacts on bird and mammal behavior (Burger & Gochfeld 1998; Blumstein et al. 2003; Mccleery 2009), much less is known about the anthropogenic effects on reptiles (but see Irschick et al. 2005; Cooper 2009; Majláth & Majláthová 2009; Cooper in press) and nothing is known about skinks. In this study, we examine whether and how the type of human presence is associated with FID of the inland blue-tailed skink, *Emoia impar*. This species is particularly suited to study indirect human effects for several reasons. *Emoia impar* are found in a variety of islands across the South Pacific (Bruna et al. 1996). In some locations, they are extremely common, which allows for ease of study, and they occur in a variety of areas with different degrees of human visitation (M. M. McGowan, P. D. Patel, J. D. Stroh, D. T. Blumstein, pers. obs.). Unlike other studies of human disturbance on reptile behavior, this gave us a suite of areas with different types of human disturbance to study. Additionally, there are well-developed methods to study FID in lizards and skinks (Cooper 2000; 2005, 2009; Cooper & Whiting 2007).

To study indirect human impacts on skink risk assessment, we categorized study sites by land-use patterns and compared the FIDs of skinks at different sites. To study direct effects of human presence, we examined possible effects of different types of human approaches on risk assessment by the skinks.

General Methods

Three observers quantified FID in blue-tailed skinks on Moorea, French Polynesia (17°32′S, 149°50′W) between Jan. 24 and Feb. 11, 2014 between 0700 and 1130 h and occasionally in the afternoon between 1300 and 1700 h. General protocols followed Cooper (2000, 2005, 2009; Cooper & Whiting 2007). In particular, on non-rainy and non-windy times of day, we identified a stationary skink, paused, approached according to the experiment type we were running, and measured its FID.

Emoia impar can be a cryptic species, sometimes confused with *Emoia cyanura,* so it was critical to correctly identify each skink that was being studied. Observers studied photographs of captured skinks and observed live skinks in the field to become familiar with species differences. While conducting an FID observation, observers focused on the brightness of tail, body coloration, and the presence of fused scales to determine that each skink was *Emoia impar* (CalPhotos 2012; Zug 2013). If the observer was unsure of the species identification, the FID was not included in the data.

Experiment 1: Do Skinks Modify Risk Assessment as a Function of Human Use?

The aim of this experiment was to determine whether risk assessment by skinks could be influenced by various types and amounts of human development and presence. We refer to this as indirect human influence.

Methods

We slowly walked through skink habitat looking for skinks. When a skink was initially sighted, the observer moved to the appropriate starting distance (between 2 and 6 m), waited 5 s, and directly approached the skink while maintaining eye contact (Blumstein et al. in press; *sensu* Cooper 1997a, 2005, 2009; Cooper & Whiting 2007). Observers minimized noise by remaining silent while approaching the focal skink and walking quietly. Because FID in lizards may increase significantly when approach velocity increases (Cooper & Whiting 2007), observers approached at 0.5 m/s (average ± SD = 0.53 ± 0.08 m/s, $n = 40$; there were no significant observer differences in velocity: p = 0.535). Observers noted the distance between the focal subject and the observer where they began their experimental approach (starting distance), the distance from the observer where the skink first responded to their approach by moving their head or body (alert distance), and the skink's FID. Observer noted their locations by dropping a flag as each of these responses occurred; all recordings were performed after the flush. Following the skink's escape, we measured these distances (in cm) as starting distance (Cooper 2005), alert distance (Cooper & Blumstein in press), and FID (the distance between the skink at time of flush and the observer's position; Cooper & Blumstein in press). FID generally increases as alert distance increases, but in some cases, alert distance and flight initiation distance were the same if the skink's first response to the approaching observer was to flee (Cooper & Blumstein 2014).

Because cover can affect risk assessment (Cooper 2006), we excluded from analysis all skinks that were under cover. Because wind can affect perceived temperature by the lizard (Grand & Dunham 1988; Bulova 1994) and because the motion noise created by wind may alter lizard antipredator behavior (Peters et al. 2007), we estimated wind velocity using the Beaufort scale. We excluded from analysis any readings taken when Beaufort wind exceeded 2. Body temperature is another factor that can influence lizard FID but a previous meta-analysis showed no consistent effect (Stankowich & Blumstein 2005). In addition, substrate temperature has been shown to be negatively correlated with FID (Braun et al. 2010). While we were unable to record skink body temperature or substrate temperature, all experiments were conducted on sunny days when skinks were active. We collected data when skinks were active: This includes periods of time in the morning and afternoon. However, there were no difference in either the alert distances or the FIDs for skinks approached in the AM or PM (AD: $t = 0.029$, df = 85, p = 0.977; FID: $t = 0.030$, df = 85, p = 0.813), so we did not include time of day in subsequent models. Because body size influences risk assessment by an individual skink (Cooper in press), the observer estimated the skink's size (to the closest cm). We calibrated our estimates of skink size using card stock skink models of varying sizes (average proportion error ± SD = 0.072 ± 0.096, n = 25). Group size may affect risk assessment (Stankowich & Blumstein 2005; Blumstein et al. in press), so the number of conspecifics within a 1 m radius was also noted. The intensity of the blue color on the tail was also recorded on a 1–3 scale because color attracts the attention of predators and may be positively correlated with exposure to risk and antipredator behavior (Hawlena 2009). To ensure color recording was identical between observers, we initially recorded these colors together until all observers were in agreement as to how to score an individual. Given that autotomy can affect predation risk assessment in lizards (Cooper & Frederick 2010), we observed only intact skinks.

We used the above methods to quantify FID at four sites characterized by different levels of disturbance. Because skinks were found in brushy areas, from the skinks' perspective, all sites could be said to have similar amounts of cover, eliminating any possible sources of differences between sites due to the focal skink's distance to refuge. We assume that because there were many skinks in each area and because we did not resample a particular area, each approach was unique. At each site, we recorded the number of people, cars, trucks, motorcycles/quadrunner all terrain vehicles, and bicycles that passed through the area. We also recorded the presence of resident dogs, resident cats, chickens, and nearby buildings. These were used to quantify the level and types of disturbance present in each study site.

One of our four sites was the UC Berkeley Richard Gump research station (17°29.526′S, 149°49.655′W), located on the coast of Cook's Bay in northern Moorea. Three observers, working independently, conducted skink FID experiments for 7 h each (i.e., 21 observer hours) over the course of 2 d, while one monitored human disturbance. The station has frequent foot traffic from researchers walking from their living quarters to the laboratory and study sites. This area has resident dogs, cats, and chickens; all of which are potential skink predators. However, vehicles were relatively uncommon and moved at slow speeds into the parking lot and on the driveway to the living quarters (average ± SD = 0.57 ± 0.271 vehicles/h).

The second study area was along an unpaved cross-island road (17°31.423′S, 149°49.899′W), with modest, but periodic vehicular traffic each day (average ± SD = 10.14 ± 1.907 vehicles/h). However, this area had no resident dogs or cats, and feral chickens/jungle fowl were detected on only one of three tested days. Foot traffic was light and only consisted of people passing along the road without stopping (average ± SD = 0.86 ± 0.345 people/h). The three observers visited this site for a total of 7 h over 3 d.

The third study area was in and around a small dump (17°29.196′S, 149°49.904′W) found at the end of a dirt road that was off the main island road. During our 4-h working at the dump, chickens/fowl were sighted, and vehicles drove in so that drivers could drop off trash and foliage cuttings (average ± SD = 0.86 ± 0.466 vehicles/h). The presence of a dump in itself is a direct result of human manipulation of natural forest habitat. The skinks observed that they were located on human-deposited piles of debris, which provided cover and insects associated with garbage and vegetation clippings.

The fourth study area was a relatively pristine, overgrown footpath that was inaccessible by vehicles (17°31.329′S, 149°49.799′W). During our time at this location, no dogs, cats, or feral chickens/jungle fowl were sighted. However, fowl could sometimes be heard in the distance. Several pieces of trash and a single set of footprints were evidence of infrequent foot traffic, but no other humans were observed on the path for the 8 h, spread over 4 d we were at this site.

Our final data set contained 87 unique experimental approaches: 14 at the dump, 33 at the research station, 11 at the pristine trail, and 29 on the unpaved cross-island road. We assume that because there were many skinks in each area, and because we did not resample the exact same locations, that these were unique approaches. We fitted a general linear model in SPSS v. 21 (IBM, Armonk, NY, USA) to explain variation in FID by main effects. We also calculated linear contrasts of the alert distance (AD) × FID interactions using Stata v. 13.1 (StataCorp, College Station, TX, USA). Our independent variables included alert distance, site (4 different locations in which skinks were observed), skink size (visually estimated in cm from snout to tip of tail), tail color (degree of blue color vibrancy on tail of skink; 1 = faded blue, 2 = blue, 3 = brighter blue), number of conspecifics within 1 m (number of other skinks observed within 1 meter of subject skink), wind (wind intensity measured according to Beaufort scale calibrations), and the interaction between site and alert distance. Estimated marginal means were used to make pairwise comparisons between sites. We tested for homogeneity of variance and visually examined the distribution of our FID data; transformations were not required. We estimated type III sums of squares, report adjusted R^2 values, interpreted p-values < 0.05 as significant, and used partial eta square values as a measure of effect size. While the sum of eta square (which ranges from 0–1) values for each term in a model sum to 1.0, partial eta square values may exceed 1.0 because it reports the variance explained by a variable after controlling for other variables. Nonetheless, the rough magnitude of values can be similarly interpreted (i.e., small effect ca. 0.02, medium effect ca. 0.13, large effect 0.26). We checked for any observer effects by adding observer to our initial model; the term was not significant (p = 0.397) and was thus removed.

Results

Our model was statistically significant ($p < 0.001$) and explained 28.7% of the variation in FID (Fig. 1a). The FID of skinks differed significantly among sites ($p = 0.010$; partial eta squared = 0.140). There was a significant and positive effect of the main effect of alert distance ($p < 0.001$; partial eta squared = 0.257; $B = -0.001$; Fig. 1) and a significant interaction between site and alert distance ($p = 0.001$; partial eta squared = 0.197). All other covariates were not significantly related to FID ($p_{size} = 0.892$, partial eta squared = 0.000, $B = -0.368$; $p_{conspecifics} = 0.478$, partial eta squared = 0.007, $B = 2.306$; $p_{wind} = 0.673$, partial eta squared = 0.002, $B = 3.103$; $p_{\mathrm{tailcolor}} = 0.718$, partial eta squared = 0.002, $B = -2.328$). The estimated marginal mean FID was 144.8 cm at the dump, 152.3 cm at the research station, 190.6 cm at the pristine trail, and 152.6 cm on the unpaved cross-island road. Pairwise comparisons showed a significant difference between the pristine trail and all other sites (dump $p = 0.025$, research station $p = 0.034$, unpaved cross-island road $p = 0.038$).

The linear contrast revealed significant differences in the AD × FID relationship between the pristine trail and all other sites (research station $p = 0.038$, dump $p = 0.012$, unpaved road $p < 0.001$). The difference between the unpaved road and the research station was significant ($p = 0.003$). All other comparisons between sites were not significant.

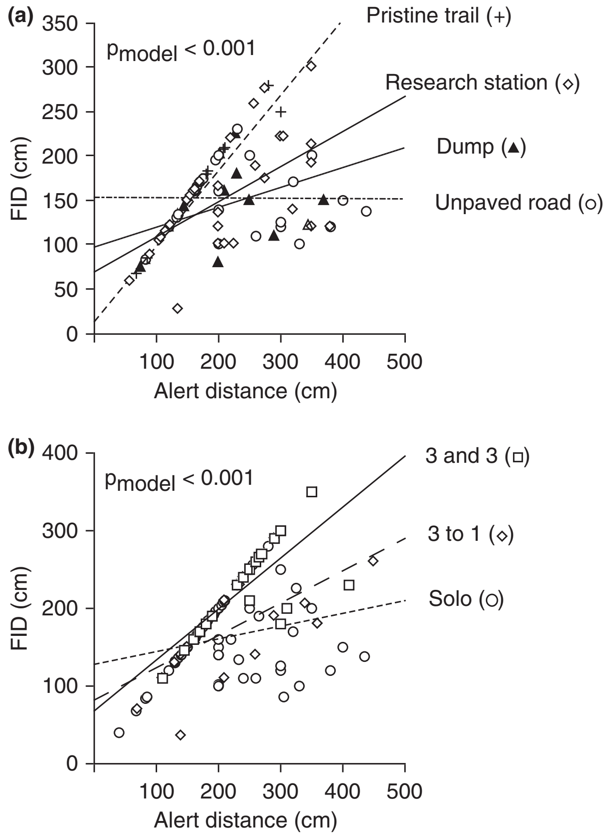

Fig. 1: (a) The relationship between alert distance (*x*-axis) and flight initiation distance (*y*-axis) as a function of study site. Pairwise comparisons showed a significant difference between the pristine trail and all other sites. (b) The relationship between alert distance (*x*-axis) and flight initiation distance (*y*-axis) as a function of the number of approaching humans. Pairwise comparisons showed that skinks flushed at greater distances when three people approached them.

Experiment 2: Do Skinks Assess the Risk of Different Numbers of Approaching Humans?

The aim of this experiment was to determine whether skinks differentiated between numbers of approaching humans (direct human influences). We measured FID using the same methods as Experiment 1, but expanded them to include three treatments: solitary human approaches, a single approacher initially standing between two others, and grouped human approaches (three people walking side by side). We chose these three types of approaches based on previous literature that suggested lizards (Cooper 2007) and birds (Geist et al. 2005) can discern differences between threat level of one to two approachers and we wished to expand on the types of approaches previously used. In the treatment with a solitary approach, the three observers searched for skinks at locations > 15 m away from one another to avoid interference.

Methods

Our data in this experiment consisted of 80 observations; 27 solitary, 27 approaches by a single observer initially with two other observers, and 26 approaches by three persons. These data were collected along the cross-island unpaved road and the pristine trail. We would have liked to collect more data, but were limited by an extended storm that cut short our fieldwork. Thus, we added data from Experiment 1 collected at the same two sites, which increased our number of solitary approaches from 27 to 67. Using these combined data, we fitted a GLM in SPSS (IBM) and again used Stata to estimate linear contrasts.

Results

After accounting for variation explained by the same factors and covariates used in Experiment 1, there was a significant effect of treatment ($p = 0.042$, partial eta squared = 0.056). The model was significant ($p < 0.001$) and explained 45.8% of the variation in FID (Fig. 1b). There was a significant and positive effect of alert distance on FID ($p < 0.001$, partial eta squared = 0.347, $B = 0.189$), and the interaction between alert distance and treatment was significant ($p = 0.001$, partial eta squared = 0.120). All other covariates were not significantly related to FID ($p_{\mathrm{size}} = 0.395$, partial eta squared = 0.007, $B = -1.892$; $p_{\mathrm{conspecifics}} = 1.000$, partial eta squared = 0.000, $B = 0.144$; $p_{\mathrm{wind}} = 0.630$, partial eta squared = 0.002, $B = -3.201$; $p_{\mathrm{tailcolor}} = 0.886$, partial eta squared = 0.000, $B = -1.074$). A post hoc pairwise comparison of treatments showed that solitary approaches significantly differed from three-person approaches ($p = 0.001$). FID also differed significantly between solitary approach coming from a group including two other observers and three-person approaches ($p = 0.005$). However, FIDs for solitary approaches and solitary approaches from a group of two other observers did not differ significantly from each other ($p = 0.804$). The estimated marginal means for treatments were 164.4 cm (solitary approach), 167.0 cm (solitary approach from group of two other observers), and 202.9 cm (three-person approaches).

The linear contrast analysis showed significant difference between the solitary approach and both other treatments: three-person approach ($p < 0.001$), solitary approach from group of two other observers ($p = 0.025$). The FIDs for three-person approach and solitary approach from a group including two others did not differ significantly ($p = 0.078$).

Discussion

Blue-tailed skinks reacted to human approaches differently as a function of overall land use, and their response was sensitive to variation in the number of humans approaching. Skinks had longer FIDs in more pristine areas. Site had a medium-sized effect on skink FID when calculated as a main effect and as an interaction between AD and site. Skinks also had longer FIDs when approached by three observers than when approached by a single observer. The effect size of this treatment was small when examined as a main effect, but medium when quantified as the interaction between AD and treatment. Thus, a species of skink that is not overtly harassed by humans, and may be somewhat of a human commensal, responded to variation in human presence and land-use differences and the effect size of these effects was small to moderate.

Although Moorea is a small (134 km^2), relatively undeveloped island, minor human impact and development was sufficient to influence skink risk assessment. Habituation-like behavioral responses to humans are consistent with results found for many birds (Ikuta & Blumstein 2003; Scales et al. 2011) and mammals (Coleman et al. 2008; Parker & Nilon 2008; Li et al. 2011) as well as some lizards (Cooper 2005, 2009). Interestingly, the FIDs at the research station, dump, and unpaved cross-island road were not significantly different from each other despite being characterized by different kinds of human disturbance. Comparing three different human-disturbed locations to a pristine location allows us to draw the conclusion that skinks exhibit habituation-like processes to a variety of types of human disturbance and only behave substantially differently in areas with essentially no human activity.

Identifying a threshold response was not possible in previous studies that have focused only on two sites. However, escape models (Cooper in press) predict threshold responses, in that animals should flee only when the benefits of fleeing exceed the costs of remaining. Thus, what these results have shown us is that skinks classify a variety of human activities similarly in that they seemingly have habituated to a variety of different human activities and land-use patterns. This results in similar cost/benefit assessments as interpreted by our measurements of AD and FID. It is only the true pristine area that skinks behave differently and flush at greater distances.

Examination of Fig. 1a suggests an FID threshold of approx. 150 cm at the unpaved tourist road that is quite different from the linear relationship between AD and FID found at the pristine trail. Thus, context (in this case disturbance type) may play an important role in whether animals flush early and avoid the rush (Blumstein 2010). In the pristine area, skinks were much more likely to flush early to avoid the rush, which further suggests they are not habituated to humans. The conclusion that FID is inversely related to human exposure is similar to results of past studies that compared amount of human exposure to FID (Burger & Gochfeld 1990). However, the conclusions drawn regarding differences between types of disturbance in different locations are novel. Most previous studies of reptiles have contrasted behavior at disturbed versus undisturbed sites (Labra & Leonard 1999; Diego-Rasilla 2003; Suarez-Dominguez et al. 2011) rather than at a variety of sites that differed in their disturbance as we did.

While both comparisons of main effects and interactions were largely similar in Experiment 1, there were some differences in Experiment 2. Indeed, comparisons of the relationship between AD and FID in Experiment 2 suggest that skink discriminative abilities could be even more sophisticated. Blue-tailed skinks appeared to discriminate between a solitary approach and a solitary approach leaving two other observers behind. This expands upon the findings of Cooper (2007), in which skinks only had a significant change in FID when approached by two fast-moving predators, and no change when the two predators moved at a slow pace.

Humans are not active predators of *Emoia impar*, yet human presence influenced skink risk assessment. A similar phenomenon has been documented with the displacement of birds in response to dog walking (Banks & Bryant 2007). Such results have broad implications for other non-targeted species. Risk assessment is a costly behavior (Cooper & Blumstein 2014, in press; Cooper in press), especially if prey repeatedly respond to false threats. Habituation allows prey to reduce energy expenditures and focus their time on fitness-enhancing activities.

Most studies on habituation, sensitization, and risk allocation are focused on species that are hunted or actively disturbed by humans (Burger & Gochfeld 1990; Stankowich 2008). Our results suggest there is a need to study more non-targeted species because they also may display similar behavioral changes due to varied frequency of disturbance. Although risk allocation is expected to exist in species that are eaten by a predator, this process seems to hold true in situations where the prey are never or very infrequently attacked. A general hypothesis is that habituation should be expected in many species exposed to human disturbance, regardless of the nature of the interaction, and/or whether humans are actively harassing them. Situations where non-hunted prey sensitizes to increased human disturbance (e.g., Blumstein 2014) are all the more intriguing. Developing better models of the conditions under which species habituate and/or sensitize are urgently needed in our increasingly populated and urbanizing world. These models, at their essence, are behavioral and behavioral biologists have much to contribute to conservation biology (Blumstein & Fernández-Juricic 2010).

Acknowledgements

We thank the UCLA Department of Ecology and Evolutionary Biology, the Office of Instructional Development, and the Holmes O. Miller Endowment for financial support, Frank and Hinano Murphy, and the staff at the Richard B. Gump South Pacific Research Station for their hospitality and support, William Cooper provided guidance on flushing skinks and astute comments on a previous draft, Robert Fisher, Emilio M. Bruna and Christopher C. Austin helped with skink identification, and Nicole Munoz and Phil Endler helped with statistical analyses. We thank two anonymous reviewers for constructive comments on previous versions. DTB is supported by the NSF.

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