Best beach front real estate: microhabitat segregation of sympatric species of geckos on Mo'orea, French Polynesia

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Background

Understanding how interspecific interactions affect a species and its access to resources is of great importance in a changing environment with limited resources. Investigating the effects of interspecific interactions of sympatric gecko species in Moorea provided insight into gecko community dynamics. The aim of this study is to understand the preference of diurnal shelter as a means of effectively managing available resources in a manner that allows for the coexistence of four sympatric species of nocturnal geckos. Microhabitat preference of four species of nocturnal geckos who coexist within an overlapping niche were examined by addressing the following questions: Will different species of geckos prefer to choose different diurnal shelters when in the presence of heterospecifics? Will shelter choice by the native geckos differ in different biomes? Out of the three most common species of geckos studied, which species will have a higher prevalence of taking refuge in horizontal microhabitats as opposed to vertical microhabitats?

Methods

To quantify patterns of microhabitat selection of sympatric gekkonids, a field survey categorized into three zones that ranged from high, intermediate, and low human disturbance was conducted. In field study observed shelter preferences was categorized into either ground, plant, or vertical shelters. In addition, interaction experiments with individuals of three gecko species were conducted.

Results

The results suggested interspecific interactions may in fact have an impact on the preference of diurnal sleeping shelter choice by geckos. Comparing conspecific with heterospecific trials of *G. oceanica* and *H. frenatus*, results suggested interspecific interactions playing a significant role in shelter preference. This same comparison for *L. lugubris* revealed interspecific interactions not playing an important role in their preference for shelter. Results from field survey yielded significant trends of each of the four species preferring certain shelter types from three categories. Shelter preference of vertical shelters by *G. oceanica* was reflected both in experimental and field studies. This trend of similar shelter preference when both field and experimental studies were compared did not hold true for *H. frenatus* and *L. lugubris*. Furthermore, human disturbance did not seem to play a significant role in influencing diurnal shelter preference of gecko species.

Discussion

Using this investigative approach, gecko shelter preferences was revealed. The results from this study

suggested that although in some cases certain species held strong shelter preferences, these preferences change due to interspecific interactions. Understanding more about the severity of these interactions can help bridge the gap of understanding pertaining to the factors that shape the distributions and abundances of different gecko species who live in communities where resources are very limited.

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BEST BEACH FRONT REAL ESTATE: MICROHABITAT SEGREGATION OF SYMPATRIC SPECIES OF GECKOS ON MO'OREA, FRENCH POLYNESIA

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Abstract

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Methods

To quantify patterns of microhabitat selection of sympatric gekkonid (*Gehyra mutilata*, *Gehyra oceanica*, *Hemidactylus frenatus*, and *Lepidodactylus lugubris*) species that coexist within a mixed community assemblage, a field survey categorized into three zones that ranged from high, intermediate, and low human disturbance was conducted. In field study observed shelter preferences was categorized into either ground, plant, or vertical shelters. In addition, interaction experiments with individuals of three of the most common gecko species on Mo'orea, French Polynesia were conducted.

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The results suggested interspecific interactions may in fact have an impact on the preference of diurnal sleeping shelter choice by geckos. Comparing conspecific with heterospecific trials of *G. oceanica* and *H. frenatus*, results suggested interspecific interactions playing a significant role in shelter preference. This same comparison for *L. lugubris* revealed interspecific interactions not playing an important role in their preference for shelter. Results from field survey yielded significant trends of each of the four species preferring certain shelter types from three categories. Shelter preference of vertical shelters by *G. oceanica* was reflected both in experimental and field studies. This trend of similar shelter preference when both field and

experimental studies were compared did not hold true for *H. frenatus* and *L. lugubris*. Furthermore, human disturbance did not seem to play a significant role in influencing diurnal shelter preference of gecko species.

Discussion
Using this investigative approach, gecko shelter preferences was revealed. The results from this study suggested that although in some cases certain species held strong shelter preferences, these preferences change due to interspecific interactions. Understanding more about the severity of these interactions can help bridge the gap of understanding pertaining to the factors that shape the distributions and abundances of different gecko species who live in communities where resources are very limited.
Key Words: Gehyra oceanica; Gehyra mutilata; Lepidodactylus lugubris; Hemidactylus frenatus; gecko; invasive species; ecology; resource availability; coexistence; niche partitioning; diurnal refuge; Moorea, French Polynesia

Introduction

The availability of resources is a major structuring force within populations of organisms influencing behaviors (Raven et al., 2011). The distribution and abundance of species are dependent on availability of resources, and also the way species behave is partially dependent on how they effectively utilize resources (Pianka, 2011). Thus, by studying the mechanisms by which organisms use resources predictions about the behavior, abundance, and distributions of species can be made, assuming that the distribution of the resources is known. The need for resources drives some of the most important behaviors that animals engage in, such as finding mates, food, nesting sites, new and different habitats, and refugia (Bell, 2012). Investigating the dynamics by which organisms utilize resources can give insight into the dynamics in which they behave and how they structure their communities. Resource dimensions such as food, time, microhabitat, and macro habitat are all important trends affecting community structure (Toft, 1985). Of these factors, especially the dimension of habitats is subject to rapid modification due to human disturbances (Langkilde, O'Connor & Shine 2003). Since habitats are ever changing, determining the effect habitat has on a particular organism is of growing importance (Langkilde, O'Connor & Shine 2003). Reversely, changing biotic factors, such as interspecific competition or predation, may influence availability of shelter or microhabitat utilized by species (Downes and Shine, 1998).

There is great variability in how animals utilize habitats. For instance, animals may use different parts of the habitat for specific activities such as sleeping in one site, while hunting or reproducing in another (Shah et al., 2004). The availability of a satisfactory shelter is an important determinant of habitat suitability (Shah, et al., 2004). In many species, shelter choice is a fundamental aspect in shaping the limitations of distributions and abundance of various species (Schlesinger and Shine, 2006). Suitability for a shelter is in most cases evaluated by using structural, environmental, and social cues (Allen et al., 2015). Additionally, aspects such as predator avoidance can be considered influences that drive shelter choice (Allen et al., 2015). Because of the importance of shelter availability, understanding what shelters various species choose can give insight in a relationship between shelter availability and abundance of a particular species. In these times of rapidly changing habitats and ecosystems, understanding the mechanisms that go into shelter choice may inform us about species persistence in a changing environment.

An excellent system for assessing the relevance of shelter choice in the face of rapid change is formed by the sympatric gecko communities found on tropical volcanic islands, which are subject to a rapidly changing environment (Pearlman, 2014). Three of the gecko taxa in this study, *Lepidodactylus lugubris*, *Gehyra mutilata*, and *Gehyra oceanica*, are all species that are known to have the ability to disperse to remote islands such Moorea (Figure 1), French Polynesia (Pianka &Vitt, 2003). Although they are believed to have arrived as human commensals with early Polynesian settlement, natural dispersal by rafting cannot be ruled out due to the fact that geckos lay hard eggs that can withstand harsh external conditions and the ability of hatched individuals to find hiding places (Mckeown, 1996) An additional member of the Gekkonidae family in this study, which has more recently invaded Moorea, is the Asian house gecko *Hemidactylus frenatus*. This species was spread throughout the pacific islands as hitchhikers on military vessels during World War II and was first recorded in Tahiti in 1988 (Petren, Bolger & Case, 1993). The invasion of *H. frenatus* on Moorea is of significance because its competitive interactions with the resident species has been shown to displace the resident geckos that were present on Moorea (Reeder, 2005). Although there have been previous studies on the island that looked at the resource use and niche partitioning of these geckos in terms of prey availability (Pearlman, 2014), resource utilization in terms of microhabitat preference is poorly known for the populations of geckos.

The presence of invasive house geckos has altered the behavior of resident species negatively because of competitive interactions that include competition of resources (Lund, 2015), (Brown et al., 2002). However, few studies have been focused on the mechanisms that go into lizard diurnal shelters. If shelter choice is a behavior that is strongly driven by the presence of dis similar species, then shelter availability may serve as a limiting factor to gecko distributions. A consideration on shelter preferences of geckos in a mixed species community would provide insight into the role of available diurnal sleeping refuges. A more comprehensive understanding on lizard distributions in systems where suitable resources may be limited due to biotic pressures is apparent when examining sleeping shelters of geckos.

Lizard behavior is very diverse in the sense that they exhibit a broad spectrum of unique behaviors and different lizard species purposely use resources differently in order to maintain community structure (Pianka &Vitt, 2003). Lizard communities may have many layers and levels; they differentiate with respect to prey items they consume, with respect to microhabitat, and with respect to temperatures/times of activity (Pianka &Vitt, 2003). This may be explained by the need to partition habitats and fill different niches in order to be able to coexist (Pianka &Vitt, 2003). Due to the fact that *L. lugubris*, *G. mutilata*, *G. oceanica*, and *H. frenatus* overlap along many dimensions of the niche that they occupy, they are in competition with one another for resources. Looking at the dynamics in which these lizard communities on Moorea manage their resources can reveal aspects of the ecological significance of the coexisting species. Since house geckos are known to compete with the resident species of Moorea and they have the ability to displace residents, their coexistence can be explained by the ability of these geckos to utilize different resources (Pianka &Vitt, 2003). The house gecko is a competitor that recently broke down the previous structure of the original gecko community of Moorea (Lund, 2015), and shelter choice of the various gecko species may serve as an explanation for the plasticity and resilience of the resident geckos to foreign invasion.

The aim of this study is to gain a comprehensive understanding of the preference of shelter of the four gecko species that coexist on a tropical island and explore the potential importance of shelter selection in the successful coexistence of four sympatric species of nocturnal geckos with strongly overlapping niches. In this study the microhabitat preference of the four species was examined by addressing the following questions: (1) Will different gecko species prefer different shelters to rest in when in the presence of heterospecifics? I hypothesize that shelter choice will differ when in the presence of heterospecifics compared to when they are in the presence of conspecifics. (2) Will shelter choice by the native geckos differ in different biomes? I hypothesize that shelter choice will differ in areas of high human disturbance where invasive house geckos have an advantage compared to less disturbed habitats where invasive geckos are not known to occur. (3) Out of the three most common species of geckos studied, which species will have a higher prevalence to taking refuge in horizontal (terrestrial) microhabitats as opposed to vertical (arboreal) microhabitats? I hypothesize that *Lepidodactylus lugubris* will be found in lower refuges near the ground such as coconuts, the axil of leaves of low growing plants, and debris; while the larger species, such as *Gehyra mutilata* (Figure 2), and *Gehyra oceanica* (Figure 3), and *Hemidactylus frenatus* (Figure 4) will be found almost exclusively in 'arboreal' refuges such as cracks in walls, trunks of tall trees, and boards laid against vertical surfaces. Understanding which microhabitats are ideal for distinct species can aid in future conservation of these gecko species and the habitats in which they reside.

Methods

Study site

A survey was conducted and an interaction experiment with individuals of four gecko species on Mo'orea, French Polynesia (17°30'S, 149°50'W) from October 6 to November 19, 2016. Mo'orea is a volcanic island, 134 km2 in size, in the Society Islands of French Polynesia. Human settlement occurs heavily along the coast of the island as well as in flat river valleys. The island's interior areas are generally unsettled and characterized by mape (*Inocarpus fagifer*) forests.

Study organisms

The four species of sympatric geckos that were used in this study were *Hemidactylus frenatus* (house gecko), *Lepidodactylus lugubris* (mourning gecko), *Gehyra oceanica* (oceanic gecko), and *Gehyra mutilata* (stump-toed Gecko). The three latter species are geckos that are believed to have occurred on Moorea for more than a century, having either rafted or hitchhiked with early Polynesian settlers. *Hemidactylus frenatus* is believed to be a later arrival, and was not recorded on island before 1988 (Reeder, 2005). These four species of nocturnal geckos found on Mo'orea are human commensals (Reeder, 2005). With the exception of *H. frenatus* (which is exclusively found in urban areas), these geckos live in a variety of habitats that range from dense human settlements to forests. All geckos were identified by species by carefully examining toe pad and claw morphology, dorsal pattern, dorsal and ventral coloration, and tail morphology. For field study, geckos were brought out of shelter if necessary and I recorded species found and microhabitat utilized. Animals observed in the field were either released or left alone while data was recorded. For geckos that were captured and included in lab trials, they were caught by hand. Upon capture, all geckos were identified on sight and only geckos of appropriate sizes were kept in temporary holding terrarium for less than 30 minutes, before being selected for trials. All geckos were kept no longer then 12 hours and were released back at the locations of their capture. Work followed UCB Institutional Animal Care and Use Committee (IACUC Protocol # AUP-2015-05-7549), permission to work with vertebrate animals is provided by class protocol followed by the attestation.

Field study

Study sites were classified into three categories: high human impact (such as walls of manmade structures), low human impact such as forests, and intermediate human impact (areas with some human modification but also have varied heterogeneity of microhabitats such as mixed vegetation, rocks, and natural debris). For the urbanized manmade structures, I used the buildings and facilities in the UC Gump Station (17°29'20.12"S, 149°49'33.04"W) such as student dorms, library, and wet lab. Various shelters the geckos utilized during their hours of rest were observed. The other study zone was low human impact which are complex systems (heterogeneous habitats) locations with less human disturbance such as secondary forests. This system was identified in the forests adjacent to three pines trail (17°29.439"S, 149°49.608"W).

Additionally, systems that can vary in complexity such as suburban (intermediate) habitats were evaluated. For suburban zones the gardens around the Atitia Cultural Center (17°29'35.75"S, 149°49'36.11"W), the Lycee agriculture school (17° 31.747020' S, 149° 50.308980' W), beaches (17°29'30.41"S, 149°49'35.58"W), and mangrove beaches (17°34'17.0184"S, 149°51'56.1276"W), were surveyed. For all study zones, transects were performed into 20 minute intervals before moving to the next location. For each of the three systems surveyed a total of 3 hours and 20 minutes was allocated to each site to ensure consistent level of effort within equal time. Within each transect which species and what shelter was being utilized was recorded. In each system, structural complexity of the shelter type (ground, plant, or vertical) was recorded. In addition, photos and GPS coordinates where recorded. Transects were conducted during daylight hours to observe where these nocturnal geckos sleep.

Experimental approach

Similarly, sized individuals of *H. frenatus*, *L. lugubris* (Figure 5), *and G. oceanica* were collected near the Gump Station for use in the experimental trials. *Gehyra mutilata* was not used in the experimental portion of the study due to its low abundance. For each trial, equal densities of geckos were subjected to two treatments: three replicates of conspecific treatments and a heterospecific treatment. Equal amount of trials for each of the treatments were conducted from October 25 to November 16, 2016.

Trials were conducted as follows: geckos were caught by hand, between the times of 17:00 to 20:00. Many geckos were marked with nontoxic paint and then re captured, they then were placed in both treatments and marked individuals were recaptured and used within the maximum of 4 times per specimen. From the individual geckos that were re captured since different sleeping substrates were chosen when placed again in treatments, it was deemed unnecessary to continue to add the additional stress of re marking. In doing so, the total number of geckos stayed within the 150 gecko limit (Protocol # AUP-2015-05-7549). Once caught, geckos were held in a temporary holding terrarium for no more than 30 minutes. Captured geckos were then placed in 40 gallon tanks with six possible choices for microhabitats: 1 piece of bark laid horizontally, 1 piece of cardboard laid vertically, 1 coconut husk, 1 plant, 1 large shell, and the sides of the tanks (Figure 6). The plant that was provided in each tank was a single bromeliad where the axil of leaves could provide potential sleeping shelters for the geckos. The plants were watered regularly and mantids of appropriate sizes were provided in tanks to ensure the geckos where comfortable and had access to water and food. Gecko microhabitat choice was then observed and recorded, for 9 hours and 30 minutes, at which time geckos were released at the site of their capture. Terraria and holding tanks were rinsed with freshwater to avoid contamination.

Statistical analysis

Data were analyzed using the statistical software package R (R Core Team 2013). Chi-squared tests were performed to compare microhabitat selection by the three species of geckos that were subjected to the habitat selection trials. A Chi-Squared test was done in order to see if there was a significant difference in sleeping shelter chosen when in the presence of heterospecifics versus when in the presence of conspecifics.

Pearson's Chi-squared tests were performed from the field data to compare microhabitat selection by the four species of geckos that were observed utilizing sleeping shelters that were categorized into three categories: ground shelter, plant shelter, and vertical shelter. Also, when taking the three zones (high, intermediate, and low human disturbance) into consideration I ran a Fisher's Exact Test.

Results

Gecko shelter preference of six substrates comparing conspecific versus heterospecific treatments uncovered shelter preference (Figure 7). Significant result suggests different microhabitat preferences may be influenced by interspecific interactions between gecko species. The first Chi-squared test was run to test for independence between substrate preference taking into account all treatments which showed preferences of sleeping substrate between geckos in both conspecific versus heterospecific settings to be statistically significant, (Chi-squared test, X=265.3869 (df=25), p-value < 2.2e-16). Three more Chi-squared test for independence were performed in R in order to test the significance of sleeping substrate choice comparing choice of geckos when in the presence of conspecific geckos versus heterospecific geckos (Figure 7). In conspecific trials, *Gehyra oceanica* was approximately three times more likely to choose shell than in heterospecific trials, (Chi-squared test, X=16.4854 (df=5), p=0.005587). In heterospecific trials, *Hemidactylus frenatus* was approximately four times less likely to choose shell than conspecific trials, (Chi-squared test, X= 15.3938, (df=5), p=0.008806). Furthermore, *Lepidodactylus lugubris* (Figure 8) had a high prevalence of choosing plant as a sleeping substrate, this preference not affected by presence of heterospecifics (Chi-squared test, X=4.7792 (df=5), p=0.4498).

In the field, the four species geckos segregated their microhabitats with higher prevalence of certain species in a particular shelter type (Figure 9). Unequal preferences for a certain shelter was observed to be species specific and varied across species (Chi-squared test, X-squared=39.7273 (df = 6), p-value = 5.153e-07). Unlike the other three gecko species *G. mutilata* was seldom seen on any non-ground shelters. (Pearson's Chi-squared test, Chi-squared= 17.7143, df = 2, p-value = 0.0001424. In the present study a high affinity for vertical shelters was exhibited by *G. oceanica* (Pearson's Chi-squared test, Chi-squared= 49.6364, df = 2, p-value = 1.666e-11). Also, *H. frenatus* appeared to have similar trends of about equal prevalence in ground and vertical shelters, with a slightly higher frequency in ground shelter (Pearson's Chi-squared test, Chi-squared= 8.3125, df = 2, p-value = 0.01567. Lastly, *L. lugubris* had the highest frequency of any of the other gecko species to be found on plants even though they were observed in much higher frequencies on the other two shelter types (Pearson's Chi-squared test, Chi-squared= 10.093, df = 2, p-value = 0.006432.

Gecko shelter type preference did not differ when observing gecko prevalence on the three diurnal shelter types when the three different zones: high human disturbance, intermediate human disturbance, and low human disturbance was compared (Fisher's Exact Test, p-value of 0.7199). The frequency of certain species on a particular sleeping shelter did not differ with respect to zones, inferring human disturbance has very little to do with influencing gecko shelter preference (Figure 10).

Discussion

The results of this study demonstrated while some species of gecko show strong preference for specific types of shelter, these preferences can be changed in interspecific interactions. *Gehyra oceanica* and *H. frenatus* when placed in a mixed species assemblage, significantly choose different microhabitats to sleep when compared to their preference when other species were absent. Thus, suggesting that interspecific interactions plays a significant role in what sleeping shelters are available to these geckos. The only group that did not seem to change preference even when placed in a heterospecific community was *L. lugubris*, which suggests that their preferences for sleeping shelters are more concrete and less flexible. This study provided a better understanding of gecko community dynamics by showing that interspecific interaction can influence gecko behavior.

Gehyra oceanica and *Hemidactylus frenatus* in conspecific trials both equally preferred cardboard and large shell as a suitable sleeping; however, when placed in a heterospecific setting their use of the shell became significantly less frequent. This suggests that the preference of shell is no longer a viable resource when *G. oceanica* and *H. frenatus* are present in a mixed species community. These geckos no longer utilize the shell as a resource which may be causing them to use more of the other sleeping substrates that were provided to avoid further interactions. The mechanisms behind why the shell drops from being a viable resource is not very clear. It may infer that a negative interaction between these two species may be present and that this repels them from further utilizing the shell in these conditions. In experimental trials and during field observations, *H. frenatus* was much more vocal when compared to other gecko species; having the highest call, which may disrupt *G. oceanica* ability to utilize this sleeping substrate when *H. frenatus* is present. *Hemidactylus frenatus* may also not feel compelled to vocalize as frequently when in the presence of *G. oceanica* which also may distort their view of the shell as a suitable diurnal refuge in a mixed community. Furthermore, because *G. oceanica* and *H. frenatus* both exhibited similar patterns of diurnal refuge preference in conspecific compared with heterospecific settings, we can infer that they share similar biological and ecological morphologies (such as large body size) that drive these decisions. The same factors that may be driving these similar patterns that are shared by *G. oceanica* and *H. frenatus* may serve as an explanation behind the mechanism of why these preferences are being exhibited. The factor may be due to similar body morphology or may be due to similar traits that both these species possess. Future studies that focus more on body size and its relation to thermal preferences may provide insight into the importance of gecko morphologies and may suggest an alternative explanation for shelter preference.

The sleeping shelter choice pattern of some species did not differ between conspecific and heterospecific trials. *Lepidodactylus lugubris* did not show a significant difference in patterns of diurnal shelters when comparing conspecific and heterospecific settings. They generally followed the same pattern of almost exclusively preferring plants as a diurnal sleeping shelter no matter which setting they were placed in suggesting that they utilized this particular resource because they specialize in occupying this microhabitat. This phenomenon may be explained by the fact that unlike the other two species used in this study, *L. lugubris* is the only unisexual species. The fact that *L. lugubris* are asexual may reflect the model that asexual geckos are less genetically diverse to their sexual counterparts (Hanley, Case & Bolger, 1994). Less genetic diversity may diminish their plasticity to a changing environment making their niche breadth not as flexible. The resources they currently use may be the limitations of the available resources they see as suitable, rendering them dependent on these specific resources (such as plants) even in a fluctuating environment. In support of this prediction, previous models state that interactions between species are formed by the extent and source of their genetic diversity (Hanley, Case & Bolger, 1994). In addition, models have predicted that sexual populations wider niche breadth enables them to better utilize fluctuating resources (Hanley, Case & Bolger, 1994). Furthermore, because of the fact that *L. lugubris* are parthenogenetic they may not have the same ability to adapt to variability of resources when compared to their sexual counterparts.

Although the precise explanation for why gecko preference is affected when in the presence of heterospecifics was not determined, my results support the hypothesis that in the presence of heterospecifics shelter choice preference was different then when compared to preference when geckos were in a conspecific setting. The data supports the conclusion that gecko behavior was influenced by interspecific interactions which caused the resources that were able to be utilized by geckos to become either unattainable or non-preferred resources depending on the presence of particular species. In support of this conclusion, a previous study had shown interspecific interactions between sympatric gecko species to cause geckos to significantly alter their behavior as a response to the presence of another species (Brown et al., 2002). Although this previous study did show the significance of the effects exploitative competition on sympatric gecko populations, they mainly focused on competition for food between only two species *H. frenatus* and *L. lugubris*, and diurnal shelter choice was not extensively studied. The study at present showed that in an experimental setting that shelter preference for G. *oceanica* and *H. frenatus* was altered when in the presence of heterospecifics, providing a more comprehensive understanding of dynamics of gecko communities that consists of mixed species assemblages.

The results of my field data suggested that in the wild certain species favored certain shelter types, when shelter types were categorized into three shelter types: ground, plant, and vertical. *Gehyra mutilata* favored ground shelters to an overwhelming degree, and observed higher abundance in forests. This is of interest because previous studies of *G. mutilata* on other pacific islands found them exclusively on buildings (Crombie & Steadman, 1986). On Mo'orea, *G. mutilata* being less abundant on urban structures may be due to negative interactions with invasive *H. frenatus* that compete with them in urban areas, restricting them to ground cover and forest habitats. In support of this conclusion, previous observations in the Hawaiian Islands observed *G. mutilata* being displaced by *H. frenatus* in urban areas (Mckeown, 1996). More extensive studies that focus on the direct interactions between these two geckos may provide additional insight into their relationship with one another. Furthermore, *G. oceanica* preferred vertical shelters over all others, which was also reflected in the experimental trials. Although *G. oceanica* preference for vertical shelters was reflected both in experimental and field trials, *H. frenatus* showed a preference for vertical shelters in an experimental setting; however, this was not mirrored in nature. In nature *H. frenatus* preferred ground shelters over vertical shelters. This may be a sampling biased due to difficulty to look into cracks on walls compared to lifting ground cover, which may have caused me to overlook some geckos that were hidden deep within the structures of the buildings. Or it may suggest that in nature which is almost exclusively a heterospecific community, these geckos are not provided opportunity to choose their preferred shelter. This conclusion may also be applied to *L. lugubris* where in an experimental setting had an extremely high preference for plant shelter; however, in nature plant shelter was rarely utilized by this species.

Conclusion

This study has shown that when looking at gecko diurnal shelter preference, the choices of several species may change in response to external influences such as interspecific interactions. The coexistence of these sympatric species of nocturnal geckos may be explained by the effectiveness of each species to utilize the available resources that are provided. In the presence of heterospecifics the resources that are available to the geckos may differ as a result of competition or a mechanism of avoidance. In some instances, patterns of shelter choice preferences in nature seemed to reflect preferences observed in the laboratory setting. This reflection suggests that further laboratory tests may be beneficial into understanding what specific mechanisms influence and shape the distributions and abundances of these sympatric gecko species. Gaining more insight into the gecko dynamics may provide beneficial insight into distributions of geckos in communities in response to interspecific interactions that shape gecko behavior. Knowing how a gecko behaves in response to interspecific interactions is not of just importance to Mo'orean ecosystem but may also aid in the conservation of other island ecosystems who are constantly experiencing rapid change. More extensive studies that show a link between patterns out in nature compared to lab trials may provide insight into which specific factors go into shaping diurnal shelter preference by geckos.

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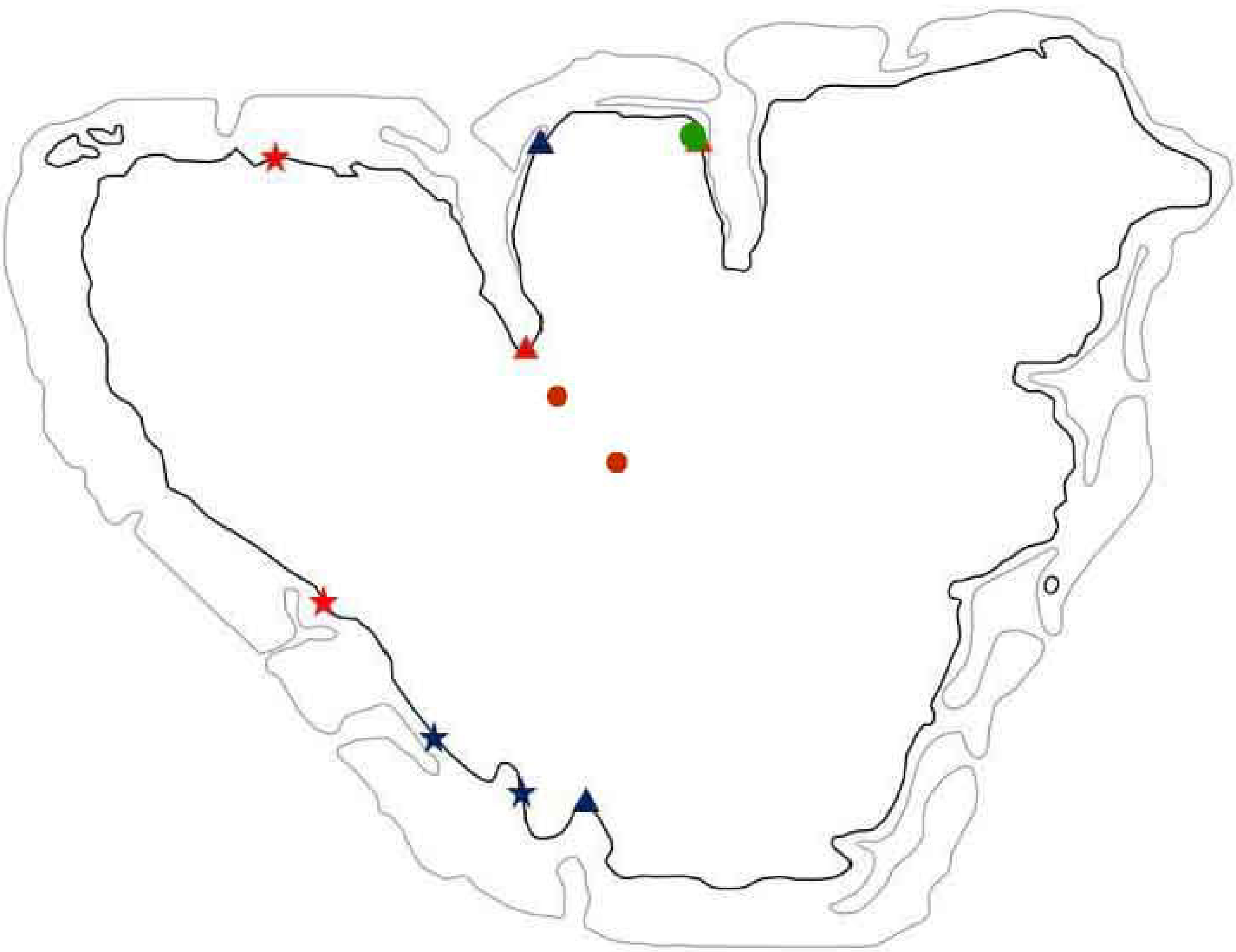

494
495 Figure 1. Map of the island of Moorea, French Polynesia with coordinate points included where
496 gecko experiments and surveys were conducted. Green coordinate represents area around Gump
497 Station. Red circles represent field sites in Opunohu Valley, which included rural and forest
498 sites. Stars and triangles represent mangrove beach sites, which some of which were
499 incorporated at some of the intermediate zone sites.

Figure 2. *Gehyra mutilata* (stump-toed gecko) easily identified by very delicate skin, slightly transparent skin containing lightly colored spots that fade when gecko is active at night, adhesive toe pads, and adults attaining a SVL: 42-50 mm. Juvenile stump-toed geckos are a dark purple color with yellow spots. Most commonly found on ground cover in forest, suburban, and rural habitats where *H. frenatus* were not prevalent. Photo taken by author, Ferris E. Zughaiyir

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Figure 3. *Gehyra oceanica* (oceanic gecko) most easily identified by it large size of 59-84 mm, beige to bright yellow belly, large adhesive toe pads, and light colored eyes. Juvenile oceanic geckos may be identified by having dark bands and ventrally orange colored tails. As a defense mechanism these geckos will rip off amounts of their skin to avoid predation. Most commonly found on vertical surfaces, in urban areas these are represented as building walls, while in forests these are represented as trunks of trees. Photo taken by author, Ferris E. Zughaiyir

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Figure 4. *Hemidactylus frenatus* (Asian house gecko) easily identified by uniform brown to beige color, long skinny adhesive toes, dorsal spikes protruding from tail, and total SVL of 48-58 mm. House geckos are highly vocal, making loud chirping sounds thorough out day and night. Strong human commensal being found on and around urban areas. Often seen gathering at lights during the night catching insects attracted to the light. Highly invasive gecko having been recently accidently spread by humans to tropical regions worldwide. Photo taken by author, Ferris E. Zughaiyir

Figure 5. *Lepidodactylus lugubris* (mourning gecko) identified by attaining a total SVL of 34-44 mm, beige color with dark eye strip, spotting and patterning that depending on which clone may be represented as broken spots or a zig zag patter. Mourning geckos are parthenogenetic which means they are an all-female species of geckos that reproduce asexually. This motive of reproduction makes them great at colonizing remote islands such as Mo'orea because of the fact that it only takes one individual to form a new population. Habitat generalist being found in both urban and forest environments, the only species that was abundant in all habitats on Mo'orea. Photo taken by author, Ferris E. Zughaiyir

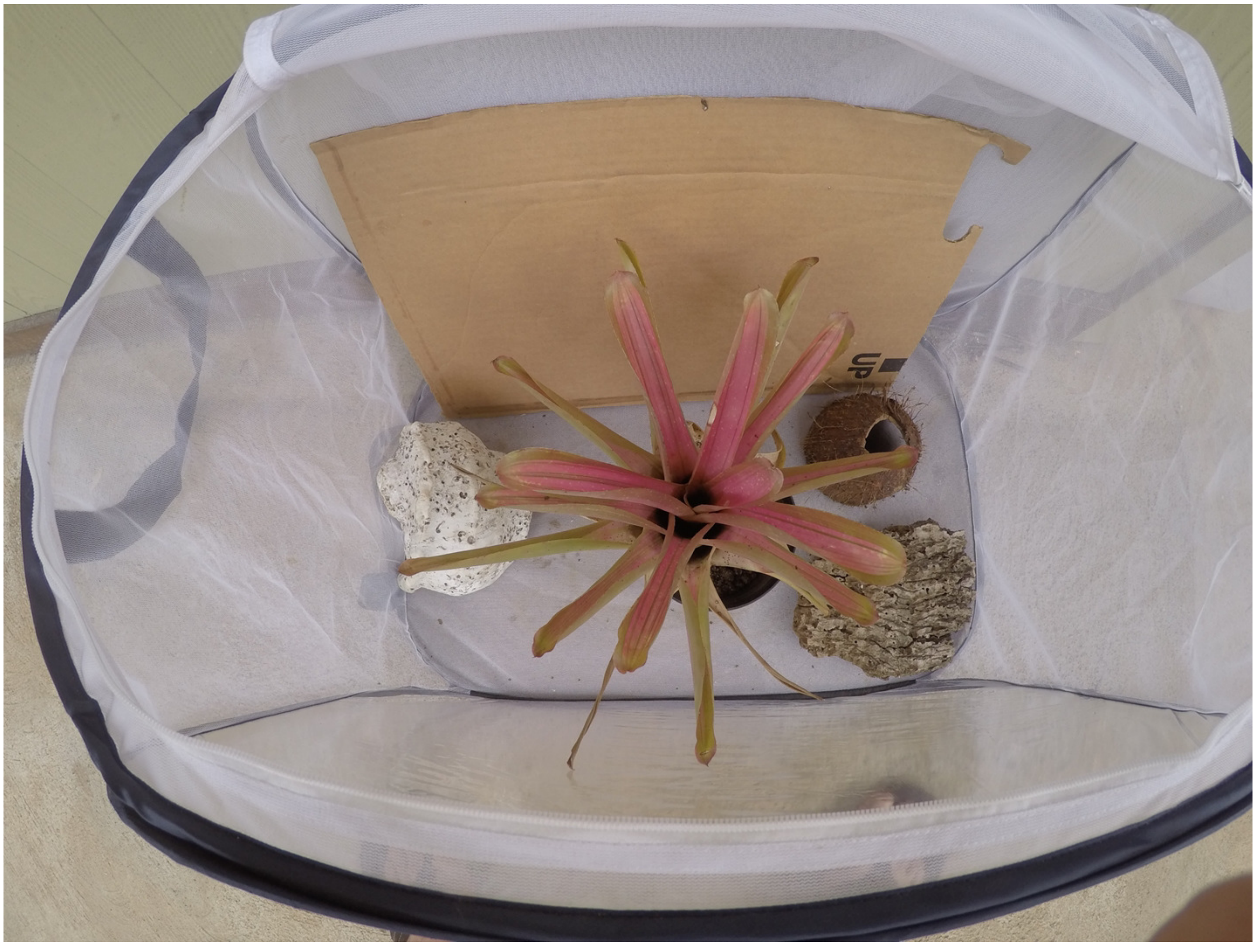

Figure 6. Experimental setup that housed three species of geckos: *Gehyra oceanica*, *Hemidactylus frenatus*, and *Lepidodactylus lugubris* that were studied. Once captured geckos were then placed in tanks with six possible choices for sleeping shelters: 1 piece of bark laid horizontally, 1 piece of cardboard laid vertically, 1 coconut husk, 1 plant, 1 large shell, and the sides of the tanks. Two treatments: three conspecific replicates and a heterospecific treatment. For each treatment equal numbers of geckos used. Gecko microhabitat choice was then observed and recorded, for 9 hours and 30 minutes, at which time geckos were released at the site of their capture. Photo taken by author, Ferris E. Zughaiyir

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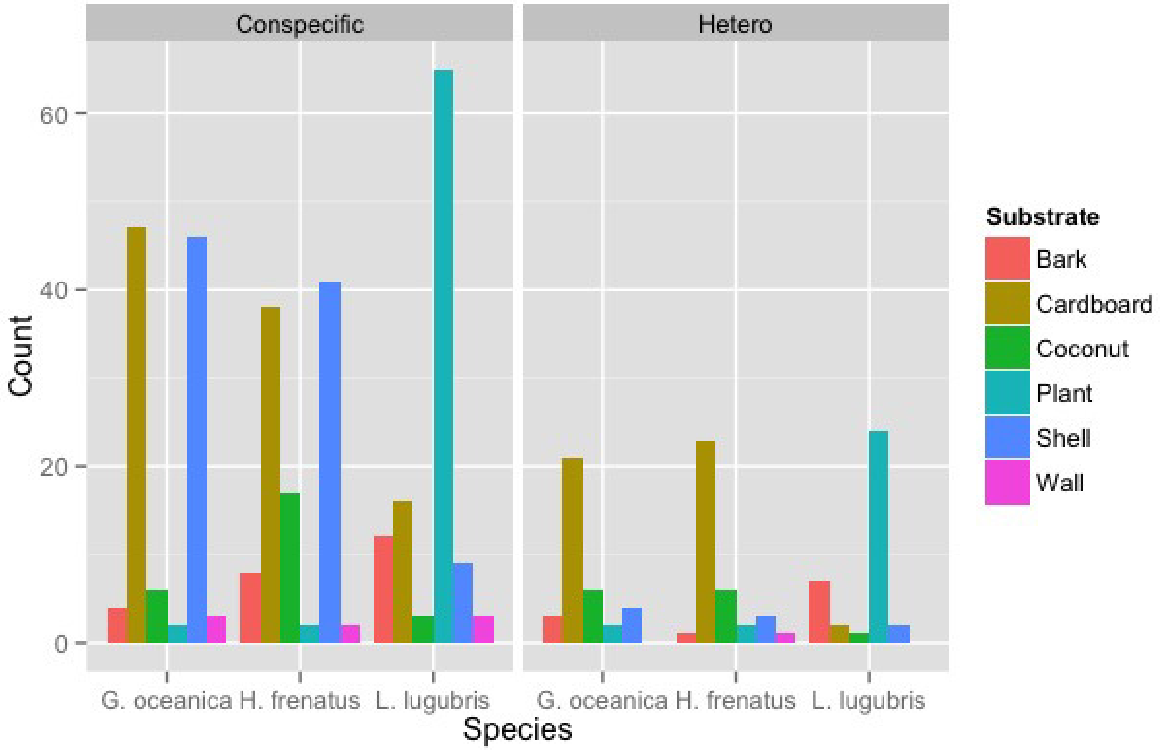

Figure 7. Graph depicting gecko counts on the six different substrates that were provided in the experimental trials. Shelter preference in conspecific trials was compared with shelter preference in heterospecific trials.

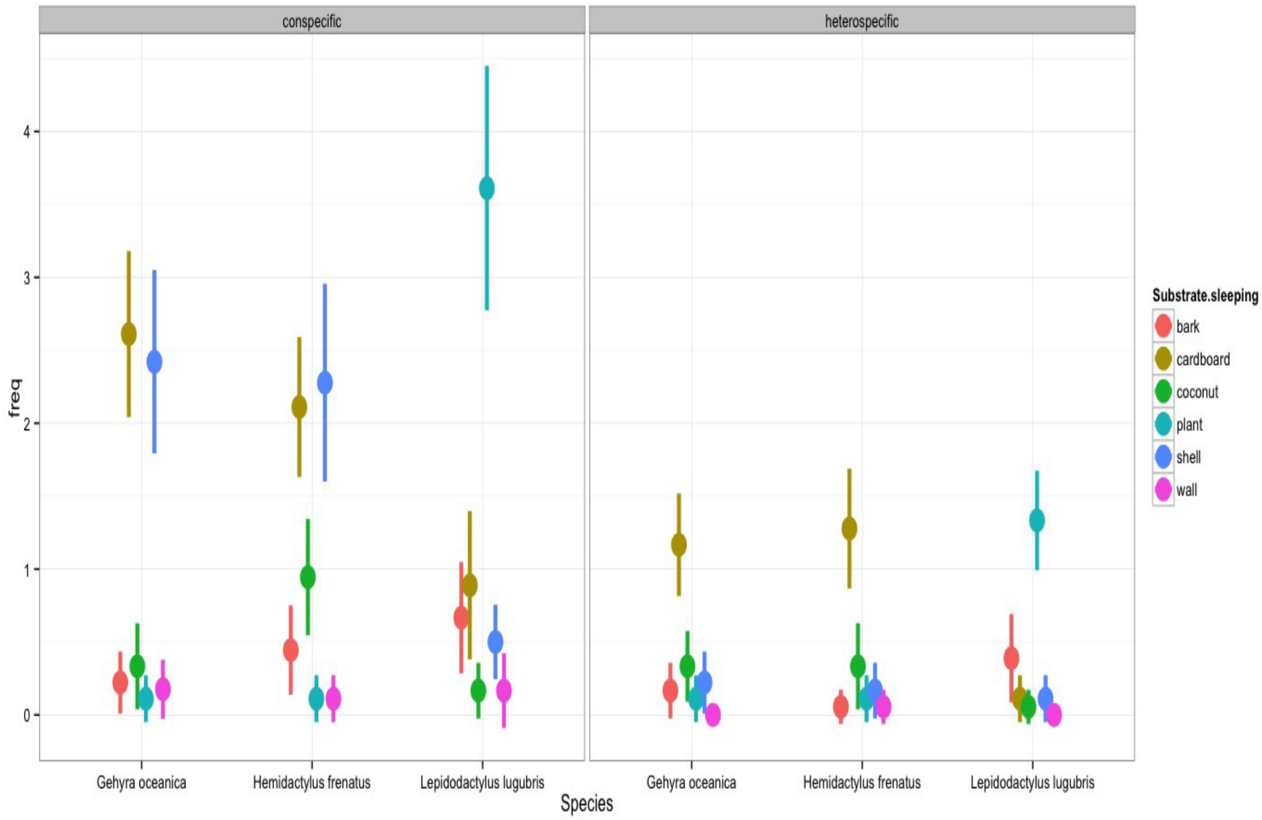

Figure 8. Mean of frequency of geckos' preference of the 6 substrate choices when comparing the three sympatric gecko species used both in conspecific and heterospecific treatments. This graph suggests as the frequency of geckos preferring a particular substrate increases, the margin of error increases.

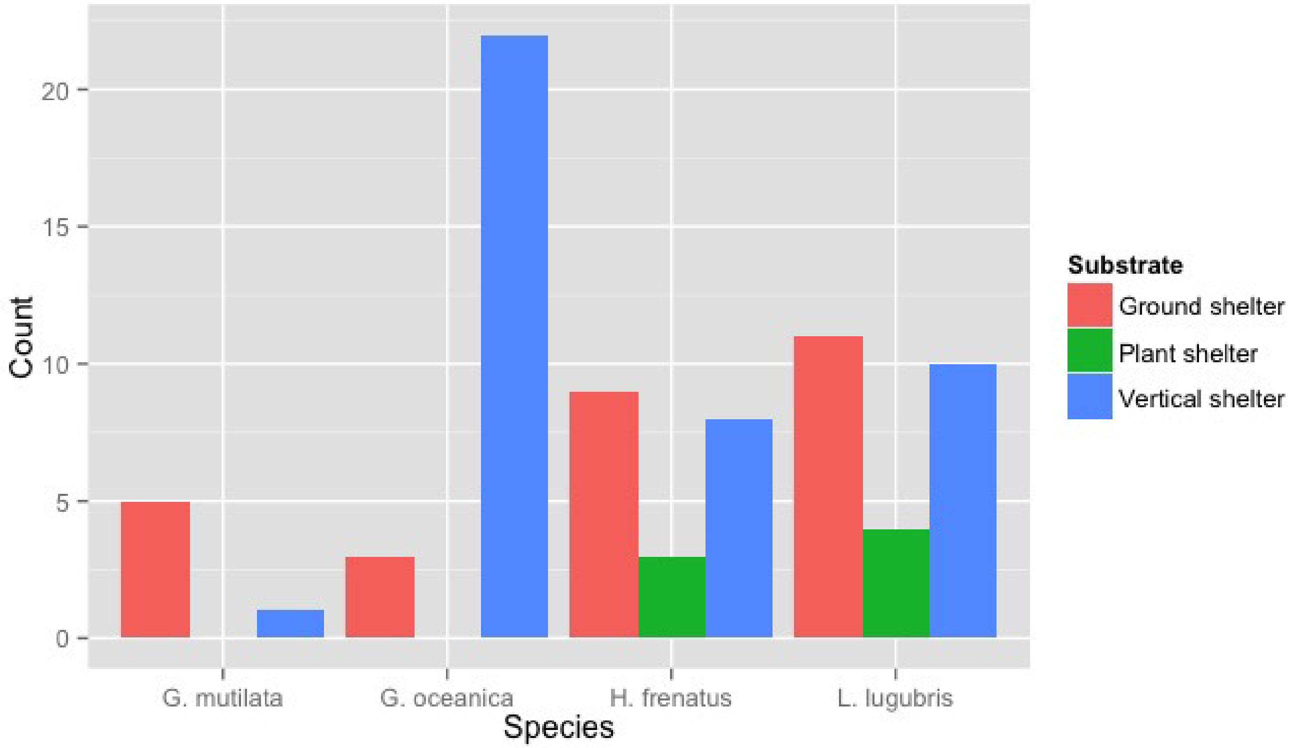

Figure 9. Graph showing amount of the four sympatric geckos found on one of the three shelter types: ground, plant, and vertical shelters. All this data is from individuals found out in nature in various zones not taking into account levels of human disturbance.

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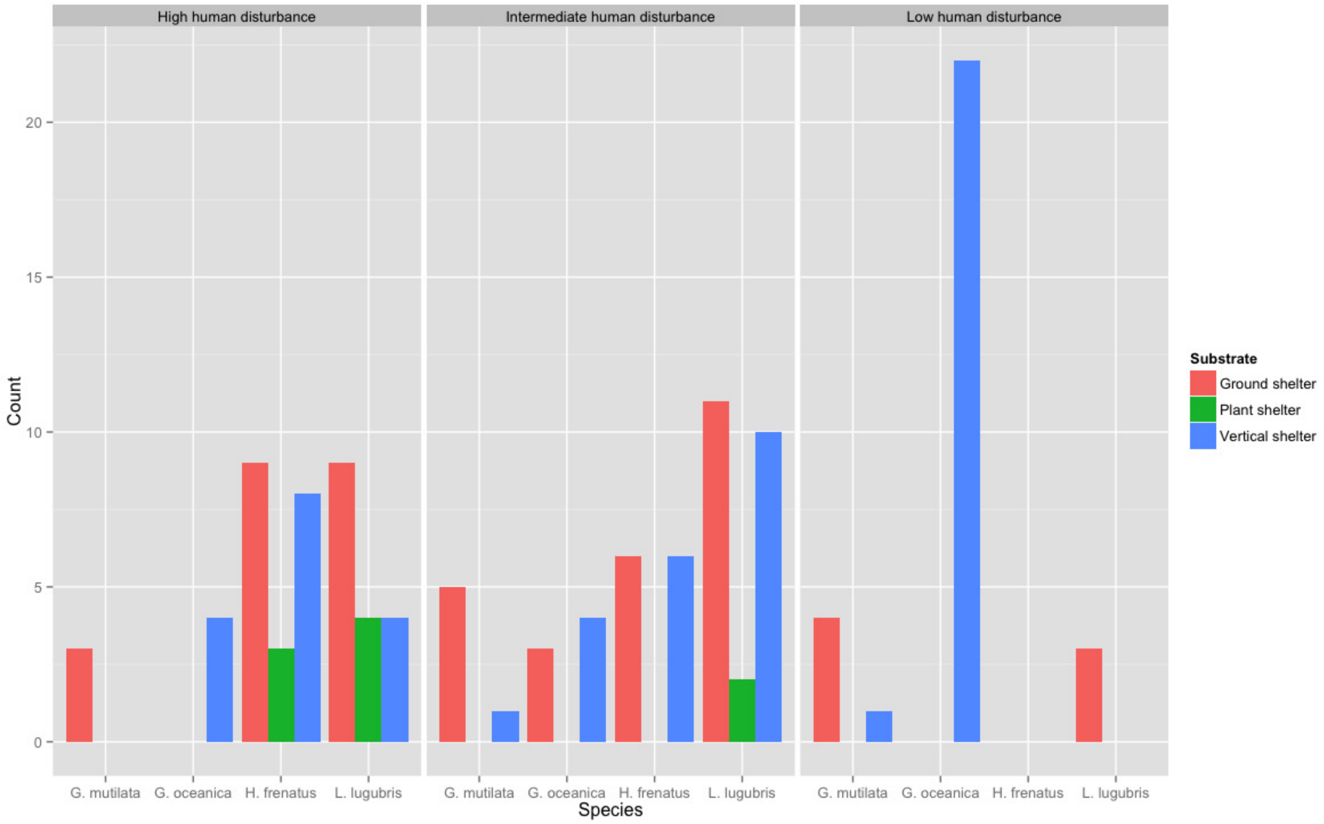

Figure 10. Graph showing amount of the four sympatric geckos found on one of the three shelter types: ground, plant, and vertical shelters. All this data is from individuals found out in nature in various zones taking into account human disturbance ranging from low (forests) to high (man-made structures).