University of North Carolina Asheville
Journal of Undergraduate Research
Asheville, North Carolina
May 2019

Size Structures, Distribution and Abundance of *Hemidactylus frenatus*, the Common House Gecko, and *Gehyra oceanica*, the Oceanic Gecko in two locations in the Kingdom of Tonga.

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Abstract

Among the relatively depauperate herpetofauna of the Pacific, two families of lizards, the Scincidae and the Gekkonidae, are particularly speciose.[1] The focus of this study is on the family Gekkonidae and the native species *Gehyra oceanica* and the introduced species *Hemidactylus frenatus.* Much of *Hemidactylus frenatus* and *Gehyra oceanica*'s distribution, abundance, and morphology in the Pacific Islands, and specifically in the Tongan archipelago, is undocumented. Both *Gehyra oceanica* and *Hemidactylus frenatus* occupy similar habitats, creating a competitive dynamic between native and non-native species. This study investigated differences in abundance, distribution, size structure on the islands of Tongatapu and 'Atata for *Hemidactylus frenatus* and *Gehyra oceanica*. The frequency of occurrence of both species was found to be significantly dependent on sample location. No significant difference in abundance between 'Atata and Tongatapu were found for *Hemidactylus frenatus. Hemidactylus frenatus* individuals sampled from 'Atata were significantly larger than those sampled from Tongatapu. These results, while preliminary, suggest that ecological dynamics likely exist on and among these islands, with competitive interaction possible driving idiosyncratic population differences.

1. Introduction

Natural dispersal is a mechanism by which organisms move to new locations usually on a seasonal basis. Long-distance dispersal is a process by which other mechanisms transport species beyond their normal dispersal limits. Reptiles are particularly susceptible to long-distance dispersal due to their ability to go without food or water, salt water resistant scales, and occasional commensalistic relationship with humans. Reptiles disperse and colonize islands by two main methods: natural dispersal occurs by rafting on vegetative mats or floating across bodies of water, usually between single islands, and the newly arrived reptiles are then considered native; human-mediated dispersal occurs by means of human activity such as boat or cargo transporting alien organisms across broad geographical ranges, and in this instance newly arrived reptiles are considered introduced species.[1]

In the Pacific, human-mediated dispersal is widely accepted as the main mechanism of transport of reptiles onto islands in the recent past, due primarily to the history of human inhabitants in the Pacific islands; as many species of

reptile participate in a commensalistic relationship with humans.[1] Three successions of human migration are known in the Pacific Islands, all of which are responsible for a variety of flora and fauna dispersal.[1] Once a species reaches an island, it must not only adapt to its new environment, but reproduce enough to create a viable population. Reptile adaptation to island living includes increase in body size, salt water resistant eggs, and low need for food and water for extended periods of time.

The "island rule", first coined by Foster (1964), describes the tendency for relatively small mammals to evolve larger body size, and relatively large mammals to evolve smaller body size on islands compared to mainland locations. Similar tendencies of body size trends were noted for some reptiles and believed to be driven by factors including resource limitation, predation and competition.[2] Islands generally contain fewer species than mainland locations and exhibit lower competition and predation. Due to the lack of predation, island species often lack adaptations against predation.[3] Adaptions to deter predation are energy expensive, and thus when absent, allow animals to increase in size as well foraging and mating capacity and behaviors.[3] Another key component for body size trends on islands depends on net energy that can be gained from individuals. With the diversity of predators often reduced on islands, net energy harvest for each individual is higher and allows for increased body size.[2] Insular body size is also known to depend heavily on diet; omnivorous and herbivorous reptiles tend to grow larger on islands, whereas carnivorous reptiles tend to get smaller.[3]

Two relatively speciose families of lizards exist in the Pacific, the Scincidae and the Gekkonidae.[1] The focus of this study is on the family Gekkonidae and the species *Gehyra oceanica* and *Hemidactylus frenatus.* Both *Gehyra oceanica* and *Hemidactylus frenatus* occupy similar habitats, creating a competitive dynamic between native and non-native species. *Hemidactylus frenatus* is considered an adult size between 60–180 mm. As an opportunist generalist predator, *Hemidactylus frenatus* consumes insect prey and is occasionally known to forage on a variety of plants. *Hemidactylus frenatus* has one of the widest distributions and invasive patterns of any lizard in the Pacific.[4] Additionally, this genus is highly associated with living in close proximity to humans. Due to *Hemidactylus frenatus*' high interaction with humans, it is subject to high rates of human-mediated dispersal. Native to Southeast Asia, *Hemidactylus frenatus* has increased its range to now include Australia, Japan, Mexico, the United States, Kenya, Madagascar, and the Pacific Islands.[5] Around the time of World War II, *Hemidactylus frenatus* reached Pacific Islands such as Hawaii, Samoa, Tonga, and Fiji, arriving on these islands as inadvertent passengers on boats or cargo.[6]

Hemidactylus frenatus is both physiologically and behaviorally equipped to invade suitable non-native habitats. *Hemidactylus frenatus* thrives in urban areas consisting of man-made structures such as walls of buildings and houses, rafters and ceilings of houses. Additionally, *Hemidactylus frenatus* is known to introduce invasive parasites, though the effects of these parasites are currently unknown; thereby posing a major threat to native biodiversity, and thus their range and expansion are critically important to document.

Gehyra oceanica is native throughout the Pacific Islands; its natural habitat includes forests, disturbed garden areas, and urban areas.[1] Arboreal and nocturnal, *Gehyra oceanica* also tends to occur on artificial habitats such as building walls, ceilings and rafters. Reaching body lengths up to 170 mm, *Gehyra oceanica* is an omnivore consuming both insect prey and plant matter. *Gehyra oceanica's* successful colonization throughout the Pacific is primarily due to its salt water resistant eggs. The genus *Gehyra's* eggs survive up to 11 days of salt water exposure and a whole day of being fully submerged in salt water.[1] Annual hurricanes in the Pacific Islands are consistent and cause huge swells of waves to wash over islands and dislodge possible rafts such as logs or vegetation. For this reason, many opportunities exist for individuals to raft each year and contribute to their natural colonization success.

From loss of biodiversity to disruption of ecosystems, non-native species cause extensive ecological damage. Affecting biodiversity through predation, competition, and introduction of parasites, invasive species sometimes even cause extinction.[5] With humans becoming increasingly mobile with boats, planes, and cars, accidental introduction of invasive species frequently occurs for human-associated species. For this reason, it is important to obtain and record data on non-native and native species. Island biogeography, dispersal, distribution, and morphological adaptions provide the framework for how species are studied. Obtaining data on distribution, abundance, and morphology of species is crucial for understanding range expansion and adaptation. However, much of *Hemidactylus frenatus* and *Gehyra oceanica*'s distribution, abundance, and size morphology in the Pacific Islands, and specifically in the Tongan Archipelago (Kingdom of Tonga) is undocumented. This study investigates differences in abundance, distribution, and size structure on the islands of Tongatapu and 'Atata for *Hemidactylus frenatus* and *Gehyra oceanica*.

2. Methods

2.1 Field Sites

Two field sites were selected within the island archipelago of Tongatapu, which forms the main southern island group in the Kingdom of Tonga. Gecko surveys were conducted on the island of ‘Atata and the town of Nuku’alofa (Figure 1). Surveys were conducted between 1 – 6 July 2018.

Figure 1. Study location, Kingdom of Tonga.

Figure 1 Map of Southern Pacific Islands in the Kingdom of Tonga, Tongatapu (A) and ‘Atata (B). Specific survey locations denoted by a red circle in the town of Nuku’alofa (C) and star on ‘Atata (B). July 2018.

Survey site 1, ‘Atata Island, consisted of three houses made out of concrete with shingled roofs. Each house was similar in building material and size. The surrounding environment was comprised of native shrub and trees. Each house contained two outside lights that were off during the survey periods. As the island is run on generators, at 2 AM all power to the island shut off completely, providing no consistent source of light. With moderate natural foliage cover, a mild corridor is created between the patches of survey site houses; allowing geckos to potentially travel between sites.

Survey site 2, Nuku’alofa, the biggest town on Tongatapu, has almost no native plant cover, with most of the environment built-up and urban. The survey site consisted of six connected buildings with outside lights. Buildings were made of concrete and surface area of walls was estimated. Throughout the night, heavy use of artificial lights was constant.

2.3 Field Study

At each location, three 20-minute visual surveys were performed starting at 9 pm. Visual surveys are commonly used methods in the field of herpetology[7] and consist of actively searching all substratum at a location for a set time. On ‘Atata visual surveys were performed each night for three nights on the exterior of three houses, searching clockwise around the structure. On Tongatapu, the survey site consisted of six connected buildings, where exterior surfaces were visually searched clockwise for three nights. When a gecko was found, a photo was taken of the individual and the gecko was measured with a 200 mm caliper. Geckos were later identified for species by comparing photographs to

online resources. Gecko species were determined by assessing morphological features such as size, color, shape, and patterning. Walls of the survey sites were measured using a meter tape for covariate analysis and qualitative summation.

2.3 Data Analysis

T-tests were conducted to evaluate the difference in abundance and size of geckos sampled from the two survey locations. Chi-square tests were used to test the independence of species frequencies with regard to survey site. Size frequency summaries and t-tests were performed to investigate differences in the size structure and mean body length of geckos sampled from each site.

3. Results

Using timed searches, two species of gecko, *Hemidactylus frenatus* and *Gehyra oceanica*, were recorded in six out of six searches over three nights at both locations sampled. No significant difference in abundance between ‘Atata and Tongatapu was found for *Hemidactylus frenatus* ($T\text{-stat}_{10}$= -1.47, p= 0.17; Figure 2). In contrast, *Gehyra oceanica* was found at both survey locations, however, only one individual was found on Tongatapu and high variability was observed among surveys for this species on ‘Atata (Figure 2); statistical analysis was not performed for this species. The frequency of occurrence of both species was significantly dependent on sample location ($X^2\text{-stat}_1$=6.51, p=0.01).

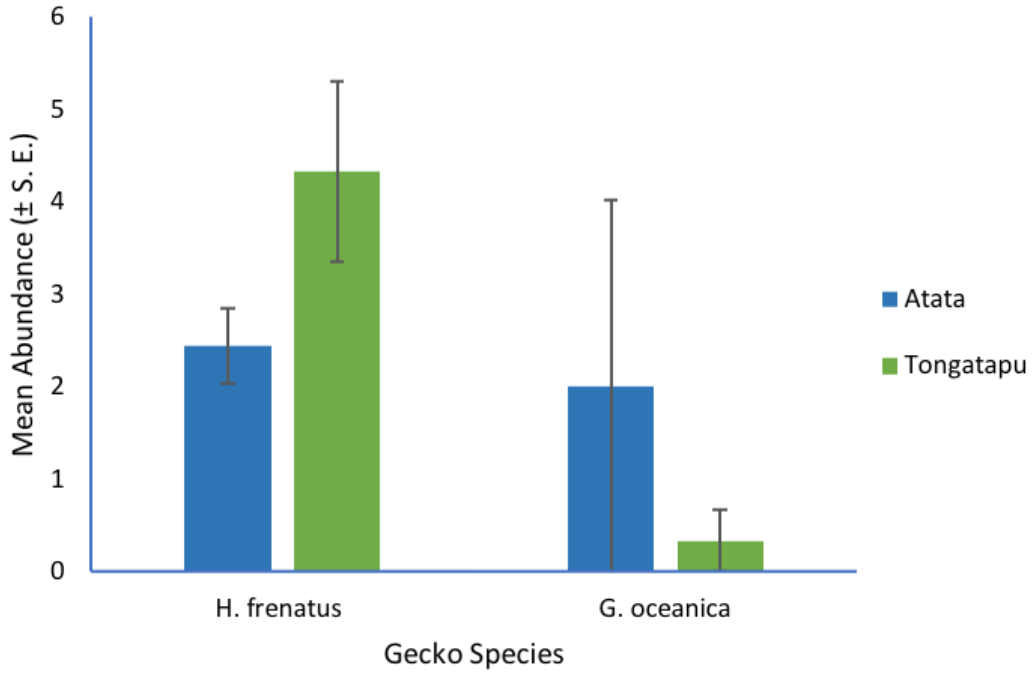

Figure 2. Gecko abundance.

Figure 2 Mean abundance for *Hemidactylus frenatus* and *Gehyra oceanica* sampled on buildings in ‘Atata and Tongatapu, July 2018.

The body length distribution for *Hemidactylus frenatus* was not normal (Figure 4). Strong trends towards juvenile lengths (<60 mm) were found on Atata, whereas on Tongatapu, strong trends of adult body length were found (>60 mm). Body length distribution for *Gehyra oceanica* on Atata and Tongatapu was normally distributed. The data for this species was centered around adult body lengths on Atata, with only one juvenile individual found in the entire data set on Tongatapu. *Hemidactylus frenatus* individuals sampled from ‘Atata were significantly larger than those sampled from Tongatapu ($T\text{-stat}_{31}$= 7.92 p = .00). While *Gehyra oceanica’s* body length was not statically tested for sample locations, the one individual found on Tongatapu was smaller in body length than the mean and, the minimum,

body length of individuals sampled on ‘Atata. Overall, both species were greater in size on ‘Atata compared to Tongatapu (Figure 3). Both *Gehyra oceanica* and *Hemidactylus frenatus* were always found in close proximity to humans and built environments.

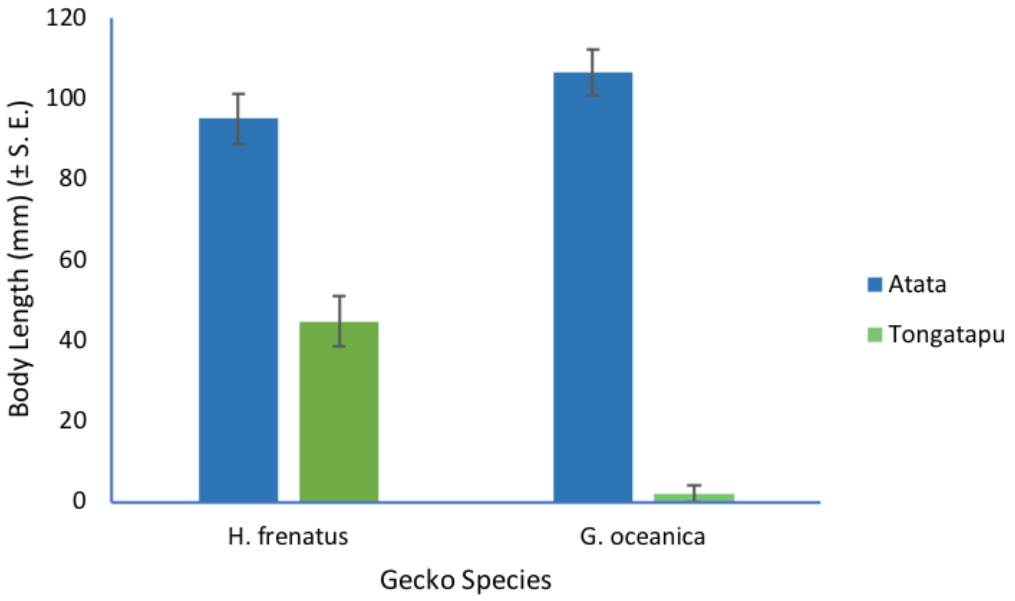

Figure 3. Mean gecko body lengths.

Figure 3: Mean body length for *Hemidactylus frenatus* and *Gehyra oceanica* sampled on ‘Atata and Tongatapu, July 2018.

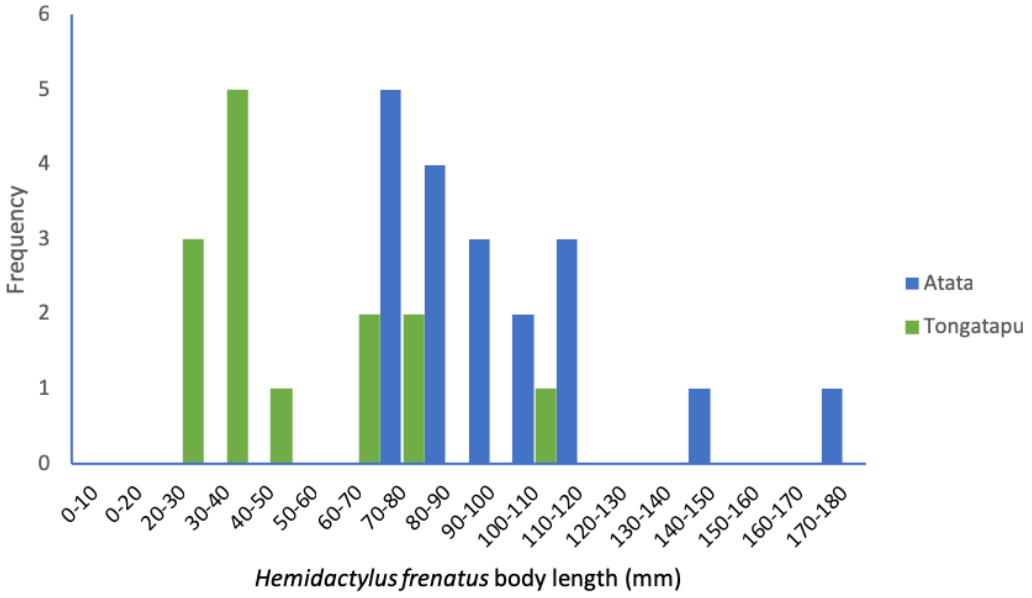

Figure 4. *Hemidactylus* body length distributions.

Figure 4 Body length (mm) distribution for *Hemidactylus frenatus* sampled on ‘Atata and Tongatapu. July 2018.

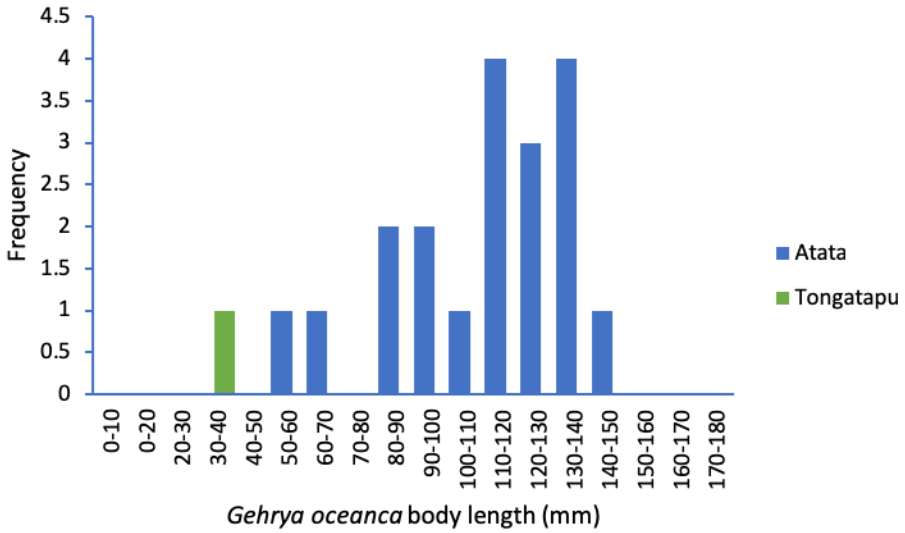

Figure 5. *Gehyra* body length distributions.

Figure 5 Body length (mm) distribution for *Gehyra oceanica* sampled on ‘Atata and Tongatapu. July 2018.

4. Discussion

Two gecko species, *Hemidactylus frenatus* and *Gehyra oceanica*, were found on the islands of Tongatapu and ‘Atata. *Hemidactylus frenatus* exhibited no significant difference in abundance between the two survey locations. Due to the colonizing nature of *Hemidactylus frenatus*, a significant difference in abundance was expected, however, these results were likely due to small sample size (n=3). *Hemidactylus frenatus* is non-native to the islands of Tongatapu and Atata. The presence of *Hemidactylus frenatus* on Tongatapu and ‘Atata highlights the invasion potential of this non-native species in the Pacific Islands. In this study, *Hemidactylus frenatus* was always found in close proximity to human environments, with no individuals found in natural foliage environments. Due to the commensalistic relationship with humans, it is likely this species is in fact transported through human mediated dispersal as the literature suggests. Although no significant difference in abundance was found between the two gecko species in this study, *Gehyra oceanica* is less abundant overall and expected to be competing with *Hemidactylus frenatus* for resources.

The significant dependence of species on location is conceivably due to lack of predation and competition on the island of ‘Atata. Resource limitation such as food and space imposed by predators can cause a decrease in population size.[2] The survey location on Tongatapu, Nuku’alofa, is home to a variety of dogs, cats, birds, and human predators that influence species occurrence. In contrast, ‘Atata, contains very few dogs, humans, and cats; and thus may enhance the gecko species occurrence. Body length data for *Hemidactylus frenatus* indicates a population of juveniles on Tongatapu and adults on ‘Atata. Lack of predation on ‘Atata increases the likelihood that species can grow from juveniles to adults. Additionally, life history habitat partitioning could influence the detection of juveniles in this study as sample locations and habitats were limited. *Hemidactylus frenatus* was found to have significantly larger body size on ‘Atata than Tongatapu. Meiri (2007) contends scarcity of predation on islands allows for small species to evolve larger. With a scarcity of predation from dogs, humans, and cats on ‘Atata, *Hemidactylus frenatus* exhibiting larger body length is consistent with the literature. Body length data for *Gehyra oceanica* indicates a normal distribution of adult populations on ‘Atata. Only one individual in the species *Gehyra oceanica* was found on the Tongatapu survey location and was smaller in body length than the mean and minimum length of individuals found on ‘Atata. The size distribution of this species could be due to competition with *Hemidactylus frenatus*, which is outcompeting *Gehyra oceanica* for food and space resources. However, additional sample locations and habitats need to be assessed to support these findings as habitat partitioning for juveniles and adults was not taken into account. The collection of this data was limited to two sample sites and do not provide a full representation of the whole islands dynamics.

Hemidactylus frenatus is the only other gecko found in this survey area and is known to be behaviorally and physically dominant to other native Pacific Island geckos, moving faster and further to capture insects.[6] If an individual

cannot get enough net energy, body size and frequency of that population can suffer.[2] *Hemidactylus frenatus* is non-native to the Kingdom of Tonga and is likely out-competing the native *Gehyra oceanica*. Lack of juvenile geckos of either species could indicate less available breeding adults in future populations. To further support abundance results on these gecko species, larger survey areas of Tongatapu and Atata with larger sample sizes would be beneficial for documenting species abundance differences between the islands. Additionally, including other islands survey locations in the Tongan Archipelago would provide a larger understanding of range expansion, competition dynamics and size structures of *Hemidactylus frenatus* and *Gehyra oceanica* in the Pacific.

5. Acknowledgments

Endless gratitude to Dr. S. Goldstien for her guidance, knowledge, and continual assistance. Earth Systems crew, thank you helping collect data. Tremendous gratitude to Dr. G. Reynolds for fostering my love of science and herpetology. Thank you, Dr. S. Hampton, for data analysis assistance. Lastly, eternal gratitude to K. Marten, R. Nunn, and Dr. J. Marten for the boundless support.

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