Determining Boldness Syndrome in Gold Dust Day Geckos

A Senior Honors Project Proposal

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with Honors

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Abstract

Gold dust day geckos, *Phelsuma laticauda*, originated in Northern Madagascar and have been a widely successful invasive species in many parts of the world including on the island of O'ahu, Hawai'i (Goldberg & Kraus, 2011). Over the past few years, there has been an increasing number of literature citing boldness syndrome, the within-individual consistency of boldness across multiple contexts, in many invasive species (Brown et al., 2005; Myles-Gonzalez et al., 2015; Pintor et al., 2008; Screen, 2022; Short & Petren, 2008). This study aims to determine the presence of boldness syndrome in *P. laticauda* in order to understand how behavioral strategies influence the successful dispersal of invasive species. In this study, boldness will be defined as the tendency for an individual to take risks and expose themselves to potential threats (Nordberg et al., 2021; Sakai, 2018). Two behavioral assays will be performed on a population of ~30 geckos in two 10 m x 10 m seminatural outdoor enclosures to measure (1) the shortest distance a human can approach before the individual leaves and (2) the time an individual spends before exploring a novel food, respectively. An intraclass correlation coefficient (ICC) analysis will be used to measure the within-individual consistency of the sample population. The results from this study can be used to compare behavior with other urban invaders as well as help fill in the gaps in the limited amount of published literature about *P. laticauda* in general.

Hypothesis

It is hypothesized that the *P. laticauda* population will display evidence of a boldness syndrome, specifically within-individual boldness consistency, under the contexts of a predator threat and exploratory behavior by generating a non-zero intraclass correlation coefficient.

Specific Aims

The objectives of this research are to: (1) assess whether a *P. laticauda* population on O'ahu has a consistent variation in boldness across different contexts through two behavioral assays and (2) understand the results by comparing the group's behavioral strategy with the results from a similar study on brown anole, *Anolis sagrei*, another widespread urban invader.

Significance

This proposed project will be one of the first studies to assess boldness syndrome in *P. laticauda* which will potentially provide insight into how behavior can contribute significantly to the successful spread of urban invaders. In addition, the methodology of this study will replicate a previous study on *A. sagrei* on O'ahu, providing an opportunity to compare the two invasive species' behavioral strategies. This study will also contribute to the relatively small but growing number of scientific literature on this species.

Background Information and Literature Review

Behavioral Syndrome Introduction

A behavioral syndrome occurs in a population where either a single behavioral trait or a suite of behavioral traits are repeatable and consistently correlated across many contexts (Screen, 2022; Sih et al., 2004). One individual may be consistently shyer than most while some may be consistently bolder than most. These consistent within-individual variations can be classified into behavioral types such as aggressive and unaggressive. A 2005 study examined a population of water striders where a positive link between aggressiveness and activity levels of individuals was observed (Sih & Watters, 2005). Individuals were separated into groups according to their behavioral type. The study concluded that while aggressive and active males found success in foraging, they were relatively unsuccessful when compared to unaggressive males in finding mates. In fact, the presence of hyperaggressive males was key in driving away female individuals. The existence of this phenomenon is interesting because while many think of behavior as flexible, a behavioral syndrome restrains the ability of individuals to adjust according to specific conditions.

If behavioral syndromes can lead to suboptimal outcomes, why do they still persist? Behavioral traits in a behavioral syndrome evolve together (Sih et al., 2004). As such, the nature of behavioral syndromes requires all behaviors to be judged together across many contexts including different life stages. A common misconception about behavioral syndromes is that an individual's behavioral type is permanent. Different stages in a life history pose different selective pressures on individuals. This can result in a switch in behavioral type later on in life. Consider an organism where small juveniles are particularly defenseless to predators. This selective pressure may force them to be bolder and forage more in order to grow faster in size and escape this selection (Sakai, 2018). More experience with predator attacks as individuals age may also discourage boldness. Alternatively, the bolder individuals may not have persisted to adulthood or if they did, they did not live for long. The opposite may be true for other organisms. Since the need to survive and grow is especially important during the early stages, juveniles may be shyer if their strategy is to remain hidden from predators and other potential threats (Brown et al., 2005). On the other hand, adults may be bolder in many contexts because their priority is to reproduce.

If changing behavioral types over ontogeny is still within the definition of a behavioral syndrome, how does this differ from learning? The key is to test for consistency of the target traits across different contexts. Learned behavior will change according to the most appropriate response in a given situation, whereas fixed behavior will remain unchanged irrelevant of the conditions posed.

Boldness in Invaders

In certain conditions and organisms, the advantages of limited behavioral plasticity may outweigh and even mitigate its disadvantages (Sih et al., 2004). In an environment where the environmental conditions, predation presence, and resources are relatively predictable, there is no pressure to change. In these cases, and even in hypervariable conditions, being adaptable will require more resources considering that higher learning capability demands proportionally higher trade-offs (Snell-Rood et al., 2011). The energy that may have been reserved for reproduction, for instance, is instead allocated to grow and maintain neural tissues (Laughlin et al., 1998), to explore the constantly changing conditions, and develop appropriate responses and skills (Gurven et al., 2006).

Figure 1. *Phelsuma laticauda* on a banana plant in central Saint-Denis, Réunion (Caro, 2007).

Invasive species such as *P. laticauda* (Figure 1) and *A. sagrei* are exposed to different novel environments and are therefore may be expected to demonstrate flexibility in order to meet the demands of these new conditions.

However, there is evidence of boldness syndrome among *A. sagrei* populations in the context of a simulated and actual predator threat (Lapiedra et al., 2017; Screen, 2022). Studies have shown that variations in behavioral traits were favorable within this invasive species. In particular, Lapiedra et. al (2017) concluded in their study that novel environments favored bolder individuals when encountering familiar threats and more cautious individuals for unfamiliar ones. This is another example of how fixed behavioral types can be used as an adaptive strategy for a population.

Comparing P. laticauda and A. sagrei

The same boldness in *A. sagrei* is also observed in other invasive species such as mourning geckos, *Lepidodactylus lugubris* (Short & Petren, 2008), signal crayfish, *Brachyraphis episcopi* (Pintor, et al., 2008), and gobies, *Neogobius melanostomus* (Myles-Gonzalez et al., 2015). Thus, it is reasonable to hypothesize that *P. laticauda* individuals in this study will also demonstrate a mostly bold behavioral type. However, comparing *A. sagrei* and *P. laticauda* shows more differences than similarities.

A 2022 study on the life histories of Hawai'i invasive lizards assessed differences between *Anolis carolinensis, A. sagrei*, and *P. laticauda* (Alascio, 2022). The life history of an organism is the collection of traits of a species critical to its growth, reproduction, and survival. Successful invasive species, including *A. sagrei*, are typically associated with fast life histories.

The results of the one-year study exhibited a slower life history for *P. laticauda* compared to *A. sagrei*. The *A. sagrei* females reached sexual maturity at only three months and had the highest probability of reaching sexual maturity. Despite the low survival rate, the species' fast growth rate and the characteristics mentioned previously allowed for a much faster generation time and population growth. While both *A. sagrei* and *P. laticauda* are on a faster life history in regards to reptiles, *P. laticauda* has a comparatively slow life history with one year to reach sexual maturity, leading to a significantly lower growth rate. Despite this, *P. laticauda* had the highest survival rate as well as the lowest proportion of injuries—indicating that they may have used risk-averse strategies.

Currently, these two species are among the most successful and widely distributed invasive lizards in Hawai'i (Wright et al., 2021). With all these contradictions, both species reached a similar population size after a year's worth of observation which suggested that both species were just as successful as the other at increasing and maintaining their population even with their opposing life histories (Alascio, 2022). This raises the question as to how *P. laticauda* can be an equally successful invader as *A. sagrei*. While a boldness syndrome in *P. laticauda* will help support the growing observations of invasive species being aggressive exploiters of resources, it is also equally fascinating if no evidence of boldness is observed. This would indicate that this species used an alternative behavioral strategy that is just as effective in dispersing and colonizing as aggression.

Methodology/Research Design

Data Collection and Analysis

All data will be collected between June to July 2023 at the Waimanalo Research Station. Over the first three to five days, the day geckos in two selected 10 m x 10 m outdoor enclosures will be collected to be sexed, measured for the linear distance between their snout and their cloaca (snout-vent length), identified with their unique back pattern, and briefly screened for any physical damage. One observation day will begin with one trial per resighted individual for the flight initiation distance assay (see below), switching plots once the maximum number of resighted individuals have been assessed within two hours. Once the two plots have undergone the flight initiation distance assay, I will proceed with the same general protocol for the latency to novel food assay (see below).

Once an individual is located, the back pattern of the individual will be captured using a DSLR camera with a telephoto lens for identification. I will wear the same color of clothing and have a standardized speed of approach for all trials (Putman et al., 2017). The linear distance between myself and the individual's previous location will be recorded for the flight initiation distance. Shorter distances will be interpreted as exhibiting bolder behavior. For each individual, a minimum rest period of one hour between each assay will be employed. For the latency to novel food assay, a perforated petri dish containing a slice of fruit will be placed within 1 meter of the individual's line of sight while a camera tripod and a GoPro camera situated 3 meters away will be used to record. There will be a 30-minute cut-off for each assay where individuals who exceed this will have 30 minutes recorded as their maximum time. If time permits, more trial replications will be attempted for the resighted individuals after the two plots have completed one round of each assay.

In order to standardize the values from two different metrics (distance and time), each value will be rescaled by subtracting it from the mean and dividing it by the standard deviation (Screen, 2022). An ICC analysis will be employed using the psych package in the statistical program R to determine behavioral consistency within each individual in both behavioral assays (Revelle, 2023). The responses will be scaled from zero to one for each assay where similar response values for the two assays will be interpreted as consistent behavior. For the purposes of this research, the consistently lower response values will be indicative of bolder behavior. The correlation coefficient represents the total population variation based on within-individual variation. Essentially, a coefficient of zero represents no consistency of responses among the assays, whereas the maximum coefficient of one represents an identical response for all assays. While a high correlation coefficient indicates a significant consistency in many fields, a low non-zero value (p-value <0.05) is considered sufficient, albeit weak, evidence of consistency in behavioral ecology (Screen, 2022).

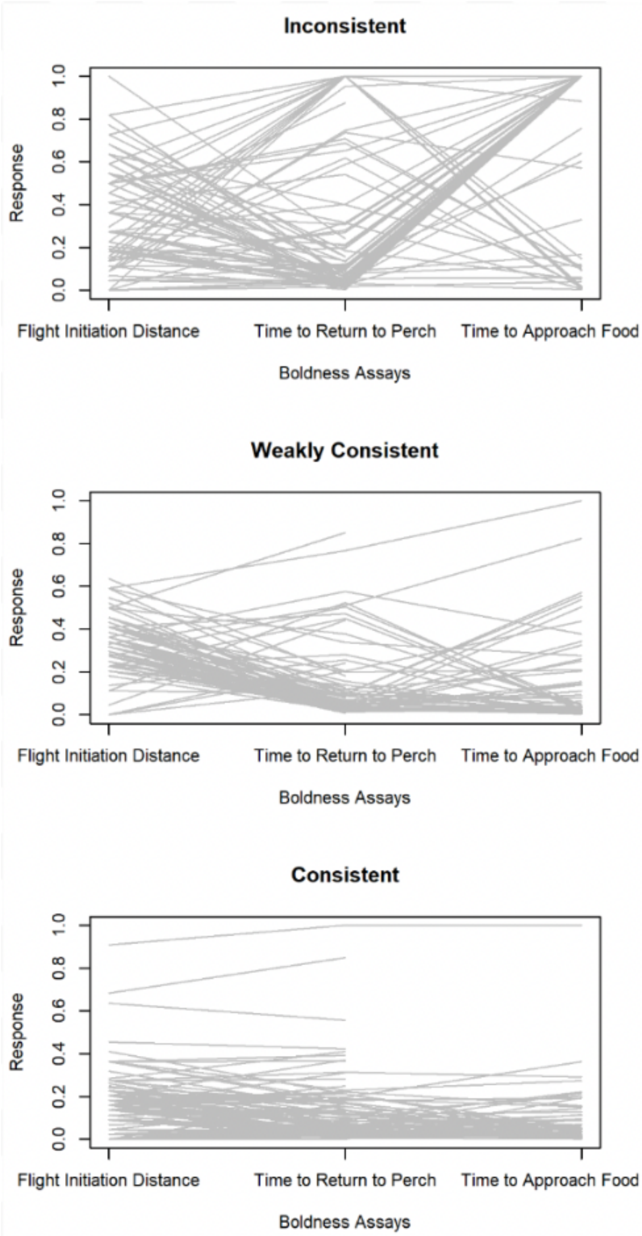

Figure 2. The results from the ICC analysis of *A. sagrei* individuals across three boldness assays classified into inconsistent, weakly consistent, and consistent reaction norms (Screen, 2022).

Figure 2 exhibits three different reaction norms that can be expected from this research. The inconsistent reaction graph exhibits individual response values that are widely different across each assay. On the other extreme, the consistent reaction graph exhibits almost identical response values in all assays. The weakly consistent reaction shows a moderate number of consistent and inconsistent response values among individuals. For this research, a zero correlation coefficient will demonstrate an inconsistent reaction for the majority of *P. laticauda* individuals, signifying no evidence of boldness syndrome found in the population. Conversely, a non-zero correlation coefficient will be the minimum requirement for evidence of a boldness syndrome. In a population with a behavioral syndrome, clusters of consistent response values correspond to different behavioral types. The consistent reaction graph in Figure 2 shows the population mainly belongs to a consistently bold behavioral type as the single cluster present is on the lower end of the scaled response axis. In some cases, a population that also has a consistently shy behavioral type will generate a cluster located higher in the response axis.

Lab Trainings Completed/Ethics Approval

The student has completed the Investigators Staff and Students CITI Program course offered by the University of Hawai'i at Manoa. Additionally, Dr. Amber Wright's laboratory has been certified by the Institutional Animal Care and Use Committee (IACUC Protocol no. 15-2050) for handling and observation of lizards in the enclosures.

Role of the Researcher

The student will be responsible for collecting and marking the individuals, conducting the behavioral assays, identifying the individuals, collecting data, and analyzing the results under the guidance of Dr. Wright's laboratory.

Resources and Materials

All materials and resources are available and provided by Dr. Wright's laboratory.

Timetable

Conduct Research	June - July 2023
Data Analysis	August - November 2023
Outline Thesis	December 20, 2023
Write ½ of Thesis	January 20, 2024
First Thesis Draft	February 20, 2024
Submit to Mentor and Committee Member	March 20, 2024
Upload Personal Statement and Resume	March 20, 2024
Final Honors Project Submission	April 15, 2024
Undergraduate Showcase	May 5, 2024
Graduation	May 2024

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