CONTEXT-DEPENDENT SOCIAL BEHAVIOR IN GOLD DUST DAY GECKOS

*(*PHELSUMA *LATICAUDA*)

THESIS SUBMITTED FOR PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE

IN

GLOBAL ENVIRONMENTAL SCIENCE

MAY 2023

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We certify that we have read this thesis and that, in our opinion, it is satisfactory in scope and quality as a thesis for the degree of Bachelor of Science in Global Environmental Science.

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Acknowledgements

I would most importantly like to thank my advisor, Amber Wright, for her guidance, dedication, and kindness throughout the entire process of my thesis requirement. Without her guidance and support, this project would not have been possible. Thank you for helping introduce and navigate me in the world of research. I am at a loss for words to describe how appreciative I am of your unwavering support and am honored to have you as a role model as a woman in science.

I would like to give a special thank you to Stevie Kennedy-Gold, without her work on her own research, the videos used in my research may not have been available. I truly enjoyed your video commentary as it helped guide me to see many things, I may have missed at first glance.

I would like to thank all my advisors in the Global Environmental Science program who helped guide me and answered all my many questions over the years. A special thank you to Lentina for sending reminders of deadlines, answering questions, helping to make sure everyone has access to the resources needed to get the most out of their education opportunity, and checking in on me personally to see if there was anything I needed to help support my education personally.

I especially want to thank my mom, Amy, for supporting me and encouraging me to go halfway across the United States and Pacific Ocean to pursue my dream field. Thank you for always believing I could do anything, listening to me constantly talk about my classes, and when I thought, I would have to put everything on pause encouraging me to push through. Thank you to my cousin Katie for listening to me talk about the geckos, all my classes and making me laugh when I started to question my sanity with my workload. I appreciate both of you more than you will ever know.

Abstract

Non-avian reptiles can exhibit complex social behaviors, but they are vastly understudied relative to birds and mammals. Social behaviors relay information between individuals about each other and are important for mating, territory, predator altering, and the individual's overall fitness. The gold dust day gecko was introduced to the Hawaiian Islands in the 1970's. Little is known about their reproductive/social behavior, in their native or introduced range, and how this may affect their ability to thrive as an invasive species. Their introduction provides an opportunity to study their social behaviors. I used focal observations of lizards in experimental enclosures to develop an ethogram and determine whether the types and frequencies of behaviors varies during intraspecific pairwise interactions depending on the sexes of the interactors. Out of an initial set of 141 videos focused on a single lizard, the most common interaction observed was between females and males (n = 24 of videos), while only 4 included male-male interactions (M-M) and only 1 was of a female-female interaction. Despite having few observations, I consistently observed that in M-M interactions one individual was the aggressor, and this did not depend on the size of the individuals interacting. Most F-M and all M-M interactions occurred during the summer. In F-M interactions I identified behaviors that were exhibited more by one sex. Males performed bodyglide, parallel stance, head bob, and stalked more while females did tailwag and moved more. The fact that behavioral frequencies differ among the sexes when interacting suggests that these behaviors may play an important role in courtship. Future studies that address the potential role for these behaviors in individual identification or assessment of individual quality are warranted, and additional effort is needed to observe M-M and F-F interactions.

Keywords: BORIS, day gecko, ethogram, interactions, Phelsuma *Laticauda*, social behavior, t-test

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1.0 INTRODUCTION

Studying animal behavior is important as it can allow insights into individual fitness, manage invasive species, and conserve endangered species. This is because behavior is relevant to managing populations of conservation concern as well as introduced ones. The definition of a behavior has variation among ethologists, for this study the definition of behavior is "externally visible activity of an animal, in which a coordinated pattern of sensory, motor and associated neural activity responds to changing external or internal conditions" (Beck et al, 1991). Understanding social behaviors in same species interactions helps to explain variation in individual fitness. Fitness perception is vital for an individual's survival and continuation as it determines access to food sources, territory, dominance, and mating privileges. Animals with greater fitness provide stronger genes to pass onto the next generation, driving population increase and expansion into new territories (Marshall, 2015). Reptiles exhibit complex social behaviors but are vastly understudied due to their high diversity, locations, enclosure/care costs and their alien likeness to humans (Learmouth, 2020). Most studies looking into social behavior of geckos have kept small populations in the lab and used staged social encounters (Greenberg 1943, Regalado 2012, Golinski, 2014). These studies have looked at the social behavior of western banded geckos and dwarf geckos, as well as the copulatory behavior of Madagascar ground geckos in a lab setting with forced interactions. Although behaviors displayed in one species from these lab encounters have been used to help understand social behavioral contexts of similar species (Greenberg,1943, Regalado,

2012) they are unable to document unique behaviors that may not be exhibited in artificial settings due to stress or lack of environmental feedback.

Originally from Madagascar and small islands off the coast of East Africa, *Phelsuma laticauda* (Gold dust day gecko) was illegally brought to the Hawaiian Islands in 1974 .The Hawaiian Archipelago has no native terrestrial reptiles or amphibians, and only two native mammals due to extreme geographical isolation, allowing native plant, animal, and insect populations millions of years to evolve without defenses against predator and open niches for introduced classes of animals (Simberloff, 1995). The population stemmed from eight geckos but quickly multiplied as natural predators were limited and spread to the other Hawaiian Islands quickly, being documented in Kihei, Maui for the first time in the 90's (Strohecker, 2016). Little is known about their reproductive/social behavior in their native or introduced range, and how this may affect their ability to thrive as an invasive species. Recent studies have begun to address habitat use (Wright et al. 2021), diet and foraging behavior (Figueria et al. in press), and life history (Alascio 2022) of *P. laticauda* in Hawaiʻi. The Wright Lab in the School of Life Sciences at University of Hawaiʻi at Mānoa, has studied some aspects of day gecko behavior. *Phelsuma laticauda* have been observed to rarely forage on the ground and prefers smooth substrate types compared to other introduced lizards such as *Anolis sagrei* and *Anolis carolinensis (*Carranza 2022). *Phelsuma laticauda* and *A. carolinensis* perch twice as high compared to *A. sagrei* (Wright et al. 2021). Figueira et al. found that *Phelsuma* had less sexual dimorphism than the anoles, which suggests less intraspecific aggression. Day geckos were documented to have seemed to engage in social behaviors but studies focusing on describing the social repertoire in these lizards is lacking range wide, not only in Hawai'i.

2.0 METHODS

In this study, I used focal observations of lizards in experimental enclosures to determine the types and frequencies of behaviors that occur during intraspecific interactions. The goals of the study were to develop a social ethogram and test whether the social repertoire varies in male–male (M-M), male-female(M-F) or female-female (F-F) context interactions. Differences in interaction contexts could suggest different roles for behaviors such as courtship, aggression, or submission.

2.1 Enclosures

The behavioral interactions between male-male, male-female and female-female *Phelsuma* were observed from videos collected from 2017-2018 by Stevie Kennedy-Gold (2019). These videos were taken of lizards in experimental enclosures for a broader study of interspecific competition. Enclosures were built at the University of Hawaiʻi Waimānalo Research Station located on the east side of the island of Oahu measuring 10 m X 10 m in area. Each enclosure had the same number of plants with substrates used commonly by anoles allowing structural resource control. Geckos had ample prey accessibility in the enclosures (Wright 2019). Geckos used were caught at the University of Hawaiʻi at Mānoa and each were permanently marked with a visible implant elastomer, Northwest Marine Technology, Inc. (VIE) and marked with acrylic paint. Day gecko back patterns were photographed for additional identification factors. Geckos were randomly assigned to enclosures with geckos varying in 10% of snout-vent length to each other. Day geckos were added to enclosures with only conspecifics, or in combination with *Anolis sagrei*, and *Anolis carolinensis*. This was replicated with new sets of lizards four times starting in June 2017, October 2017, February 2018, and June 2018 running for 61 days each replication (Kennedy-Gold 2019). Using focal-animal sampling techniques the lizards were recorded by observers 2 m from the focal lizard to limit the behaviors induced by the observer's presence. Canon Vixia HF R700 video cameras were used to record the lizards and focal individuals were filmed for a minimum of 5 minutes and maximum of 20 minutes. The focus of this study was cases where another lizard interacted with the focal animal (Kennedy-Gold 2019).

2.2 Ethogram

I constructed the ethogram (appendix) for *Phelsuma* using other lizard ethograms (Kennedy-Gold 2019, Regalado 2012, Dugatkin 2020) for base behaviors. After watching *Phelsuma* video interactions, I added new behaviors and descriptions specific to what was seen, and deleted behaviors not displayed by the day geckos. I collected photos to depict listed behaviors for behaviors easily observed in a snapshot.

2.3 Tallying behaviors

Using the ethogram's defined behaviors, I constructed a spreadsheet to tally frequency of behaviors between gecko interactions. Using photos of the back patterns, the geckos in the videos were identified and sexes were noted for interaction type. Each gecko was assigned to be either gecko 1 or gecko 2 to follow and tally each individual's behaviors throughout the interaction. Each time a behavior was exhibited a tally under the behavior displayed was added to the row of either gecko 1 or gecko 2. This approach allowed me to practice working with the videos and identifying behaviors using the ethogram and provided the frequency of different behaviors exhibited by each individual. However, it was difficult to document the sequence of behaviors using this method. As a result, I also scored the videos using software (next section).

2.4 BORIS

After running tallies on an Excel sheet, I used Behavioral Observation Research Interaction Software (BORIS) to analyze the data (https://www.boris.unito.it/). BORIS is a sequencing software that allows behaviors to be keyed in the video at the time the behaviors were displayed, limiting the back and forth of tallying the videos on an Excel spreadsheet and providing a sequence of all the behaviors exhibited by each individual during the interaction. I uploaded all the videos to the software and assigned each behavior from the ethogram with a letter key. The behaviors of each individual were scored in the video, in M-M interactions, Male 1 and Male 2 was determined by the individual that interacted first being Male 1. In M-F interactions the male was always considered gecko 1 and the female gecko 2. Using the analysis software on BORIS, behavioral tallies were calculated for the designated gecko 1 and gecko 2 interactions. I put all the tallies in a spreadsheet including video, subject, behavior, frequency, treatment, video date taken, lizard ID, sex, plot, and replication number. The behavior tallies graphs were created showing the number of occurrences of behaviors in the interaction (Friard and Gamba, 2016).

2.5 Occurrence

To determine when behaviors occurred, I calculated the number of videos with interactions out of all videos taken during each replicate. I then plotted the proportion of videos with each interaction type by replicate. Replication 1 was named summer (June-August 2017), 2 named Fall (October-December 2017), 3 named Spring (February- April 2018), and 4 named Summer 2 (June-August 2018).

2.6 Interactions

For interaction types that were exhibited in a few videos, I summarized behavioral patterns. For interaction types that appeared in a larger number of videos, I used my BORIS results to sum the total occurrences of each behavior for each individual and plotted the total number of occurrences for each behavior by males and females overall. To test if males and females differ in the frequency of behaviors for each of the 21 behaviors (mating was omitted due to having only one video and the interaction was too brief) I conducted a paired t-test, where each pair was the male and the female in a video. I asked, is the mean difference between males and females different from 0? (With 21 tests you expect 0.05 to be significant due to chance alone.)

3.0 Results

Out of the 141 videos of focal observations of individual *Phesluma*, 64 contained two interacting individuals. Of the 64 videos containing interactions, 24 videos containing M-F interactions were used and four M-M interactions were used. Only one video contained a F-F interaction from the dataset, so the F-F interaction was omitted. Other videos were omitted for not having both individuals in the frame, duplicate video, or short presence of interaction. In the M-M interactions eight different individuals, ranging from 59-64mm SVL, and four unique pairs were documented. In the M-F interactions 30 different individuals and 18 unique pairs were recorded.

I observed 22 different behaviors in the interaction videos, and these are described in the ethogram (appendix). Many of the behaviors exhibited and on the ethogram were similar to other lizard study ethograms (Kennedy-Gold 2019, Pandav 2007). One behavior that was unique to the *Phelsuma* was the "Yoshi tongue" display (ethogram, appendix).

Using the videos with both M-F and M-M interactions and comparing them against all the videos containing *Phelsuma*, I determined when peak interaction times were based off when the video was taken. In Figure 1, we can see that most of the interactions of M-F and all the M-M interactions happened in summer (June-August 2017) and summer 2 (June-August 2018).

In the four M-M interaction videos, one gecko in every case was the stalker and the other moved a lot to avoid the stalker. In three out of four of the cases there were attacks, with the attacker always being the gecko identified as the stalker. Which individual is the attacker/stalker is not determined by size, as all possible size matchups and outcomes were seen. Figures 2-5 show the tallies of the behaviors by each individual in the interaction. Stalk behavior in cyan and move behavior in teal shows these behaviors as the most frequently exhibited in M-M interactions.

Using the BORIS frequency tallies, I created a plot and sorted the behavior frequencies by more common in females, more common in males, and if the behaviors were similarly displayed in both sexes (Figure 6). Tongue-touch, curl, stretch, snap look, air lick, eat and survey posture were displayed (Panel A, Figure 6) almost equally by male and females. This suggests that these are general behaviors that are not specific to M-F interactions. In contrast, attack, eye-lick, jump, parallel stance, body glide, head bob and stalk were all displayed more by males than females (Panel B, Figure 6). These behaviors suggest that the males are the pursuers or aggressors of the M-F interaction. Behaviors displayed primarily by females consist of spot switch, full back display, half back display, tail lift, Yoshi-tongue, tail wag and move (Panel C, Figure 1). After conducting a paired t-test, parallel stance, body glide, head-bob, stalk, tail wag, and move were found to have significant differences between males and females. This difference is marked on Figure 1 with asterisks by the significant behaviors.

4.0 DISCUSSION

M-F and M-M interactions vary in behavior frequencies. In M-F interactions there are behaviors that are predominantly shown by male and others by females. This suggests that behaviors are in response to what the other sex is doing while others are general background behaviors, occurring equally in both males and females implying that these behaviors are not being driven by the interaction. Behaviors that appear to be nonspecific background behaviors are tongue touch, curl, stretch, snap look, air lick, survey posture and eating. Many of these behaviors are likely related to foraging, which individuals of both sexes need to engage in regardless of social interactions. Further comparison to behavioral frequencies when lizards are not interacting would be necessary to test whether lizards change these behaviors in the presence and absence of the other sex. That behaviors that have differences in frequencies between the sexes may have important fitness consequences. These behaviors are potentially delivering information about each individual's identity or quality through visual, chemosensory, or tactile cues. This is important because if a male or a female accepts or rejects the other it can lead to potential copulation or aggression. The fact that M-F interactions peaked in summer further supports the hypothesis that these behaviors are important for copulation because the timing of interactions corresponds to a peak in recruitment of juveniles from August to December (Alascio 2022). The roles of these different behaviors could be tested further, for example by swabbing for pheromones in behaviors that could facilitate chemical exchange such as body-glides, spot switches and tail wagging.

In M-M interactions there is little data, but all the videos suggest that one animal was the dominant animal because one animal was always the stalker. It is surprising that who the aggressor was not based on size, as evidenced by the fact that most of the males varied in length by just a few millimeters. This little difference in size could also be the reason for aggression because without overall size as a cue the lizards might need a more direct interaction to establish a hierarchy. This could be tested more by setting up interactions in a lab setting and experimenting with different sized geckos, with and without the presence of females and at different times of the year as interactions were highest during summer. The overall rarity of M-M interactions compared to F-M interactions is consistent with high home range over overlap observed in the enclosures (Wright unpublished data), and the relatively low sexual dimorphism in head size observed in this species (Figueira et al. in press).

One video out of the metadata contained a female-female interaction. The interaction was brief but involved attacking and stalking similarly displayed in the male-

male interactions. With only one video it is hard to determine if it was standard behavior for F-F interactions, if the individuals reacted the way they did due to the time of the year, or how often females would interact. This could be an interest for future research to see if F-F interactions are rare and if the one video out of the 141 videos of the *Phelsuma* is an accurate representation of how often females interact with each other in nature. F-F interactions could be set up in the lab and interactions filmed to use for behavior analysis.

5.0 CONCLUSION

Overall, this study documented that gold dust day geckos have a complex social repertoire. Most pairwise interactions occurred between males and females and are likely related to courtship. The sexes differed in how they behaved while interacting, and future studies exploring the function of these different behaviors for transmitting information about individual identity or quality, and their ultimate effects on fitness, are warranted. Several behaviors may be important for transmitting chemical cues (e.g. body glide, tail wag), detecting chemical cues (e.g. Yoshi tongue), or transmitting visual cues (e.g. parallel stance, full and half back displays), and these functions may not be mutually exclusive. Additional field observations as well as targeted laboratory studies would help test some of these hypotheses. Future work should also consider whether specific sequences of behaviors occur during female-male interactions, rather than just the different frequencies of behaviors, as this may shed additional light on how plastic vs. stereotyped these behavioral interactions are. Finally, the low level of intraspecific aggression observed in this study may allow this species to attain high densities in small areas, which in turn could facilitate their spread as invasive species.

Figures

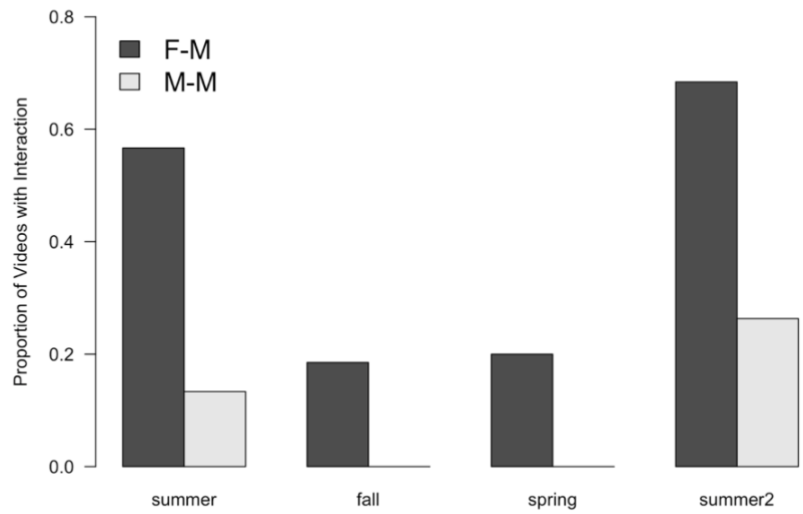


Figure 1: Shows proportion of videos with interactions (M-M, F-M) and the time the interactions occurred summer (June-August 2017), fall (October-December 2017), spring (February-April 2018), summer 2 (June-August 2018). F-M interactions are in dark gray and M-M in the light gray. The peak interaction periods in summer and summer 2.

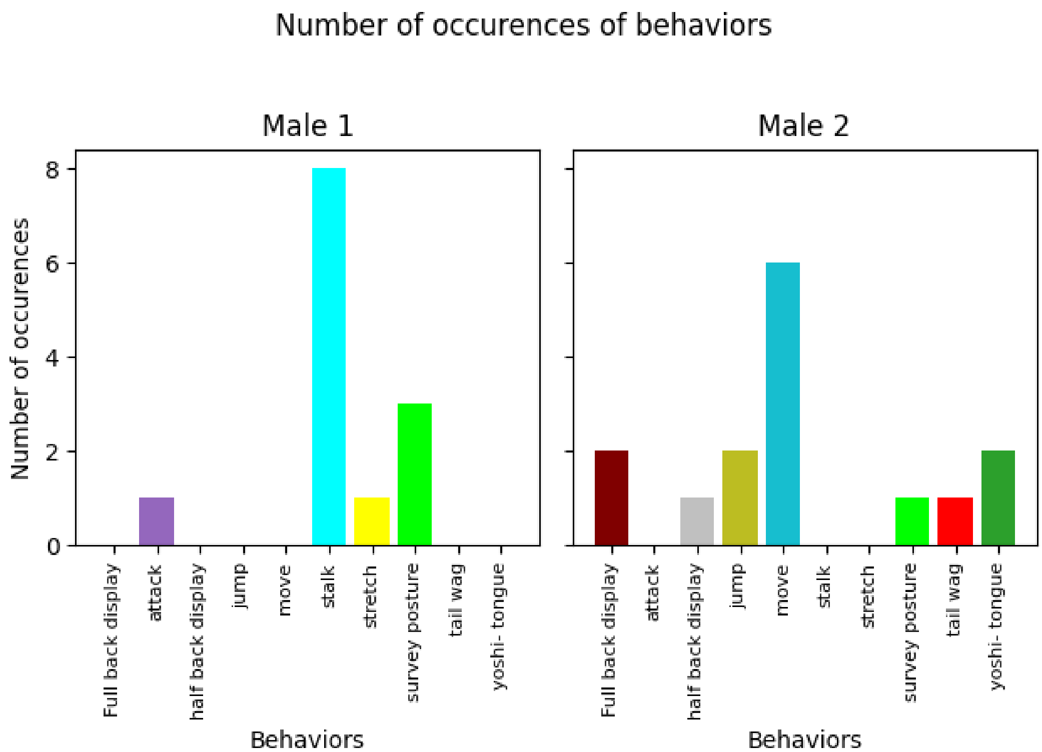


Figure 2: Shows Male 1, PLAT102 with a SVL of 62 mm and is identified as the stalker while Male 2, PLAT100 with a SVL of 61 mm identified as the mover

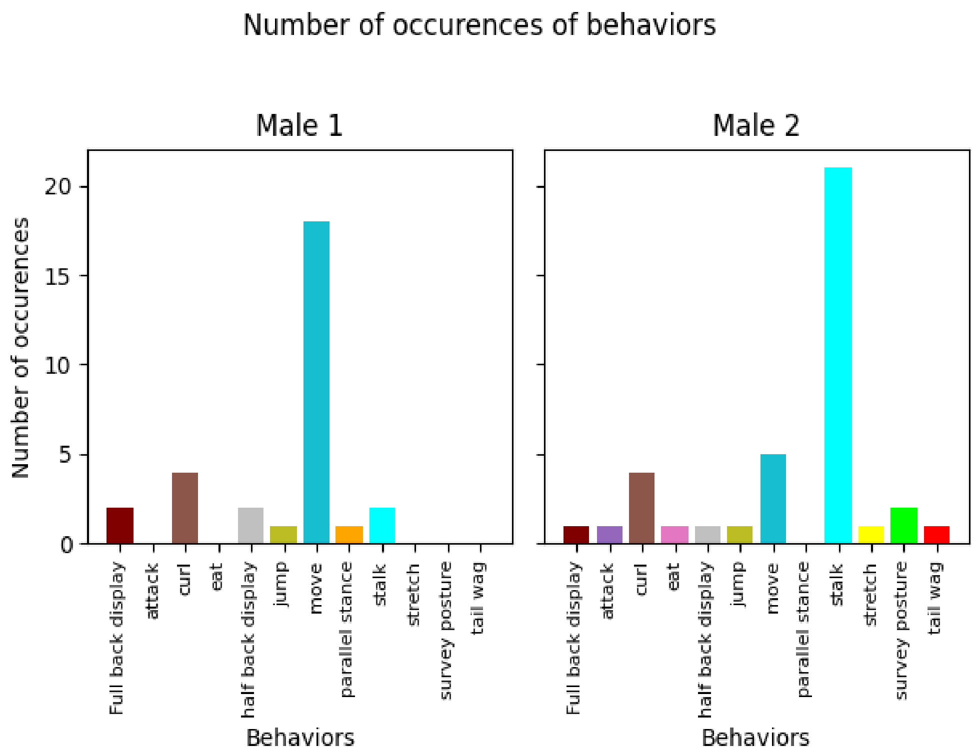


Figure 3: Shows Male 1, PLAT 101 with a SVL of 64 mm and is identified as the mover while Male 2, PLAT 111 with a SVL of 60 mm is the stalker

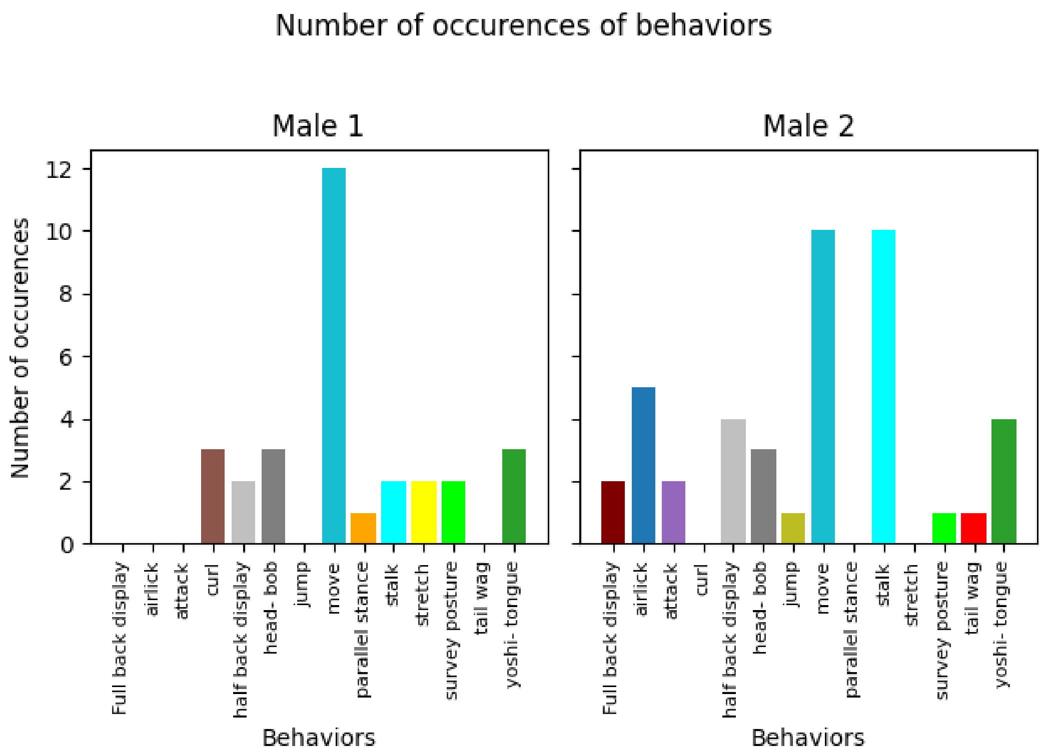


Figure 4: Shows Male 1, PLAT 98 with a SVL of 63 mm and is identified as the mover while Male 2, PLAT 108 with a of SVL 64 mm is the stalker

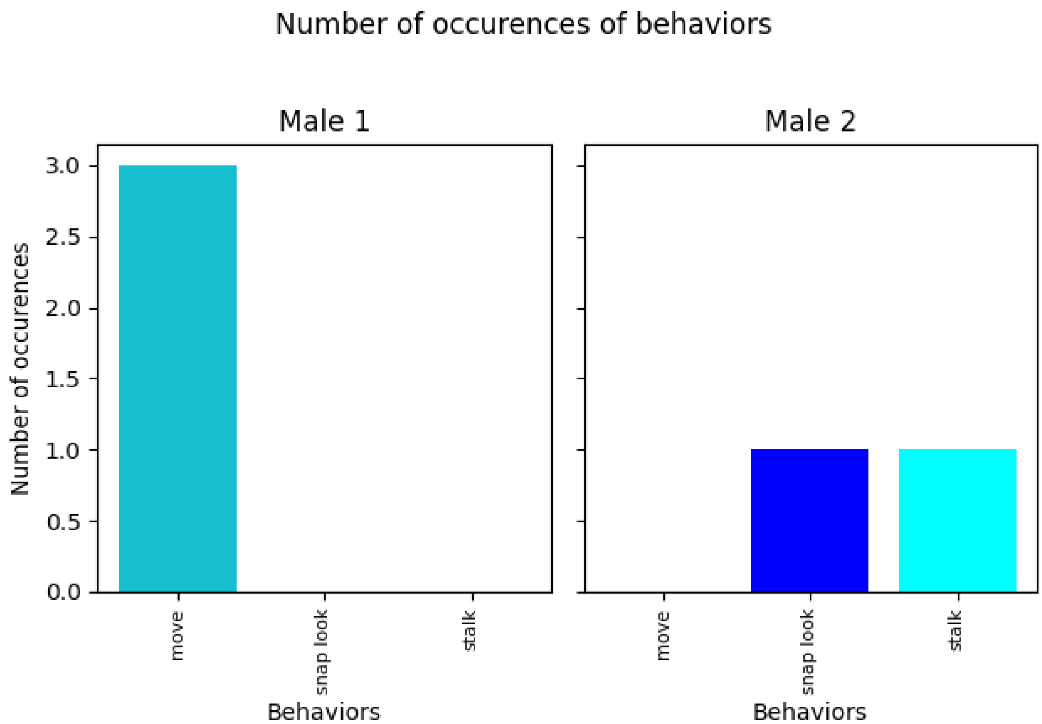


Figure 5: Shows Male 1, PLAT 26 with a SVL of 59 mm and is identified as the mover while Male 2, PLAT 39 with a SVL of 59 mm is the stalker

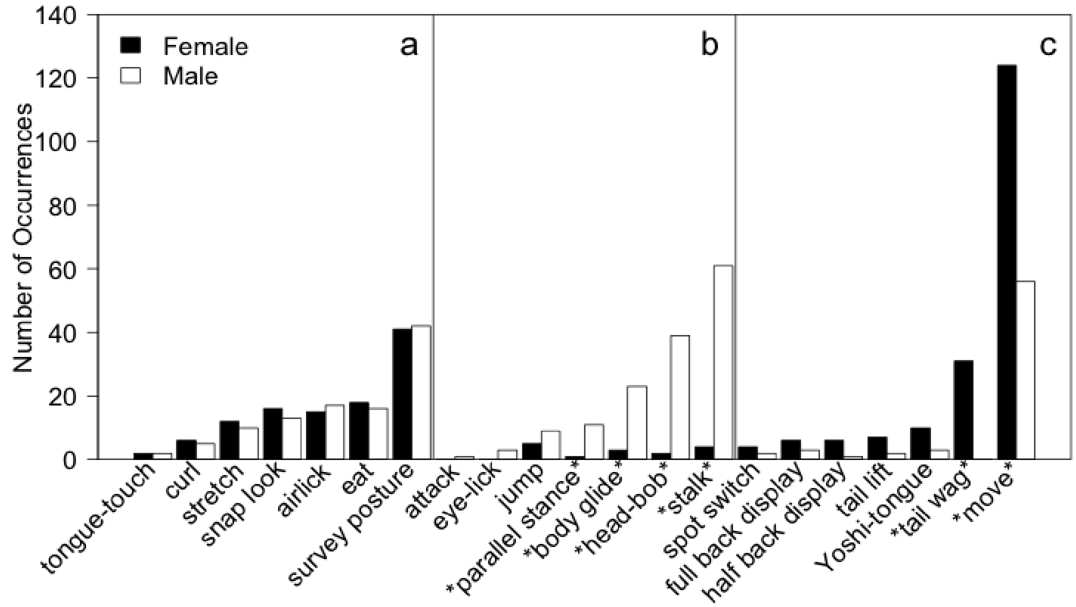


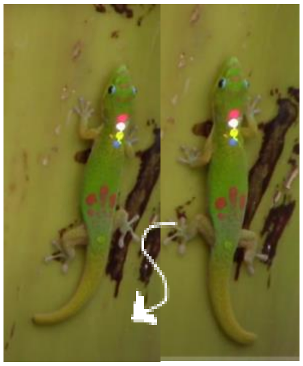
Figure 6: Total number of occurrences of different behavior types from interactions between males and females. Panel a shows behavior that occurred with similar frequency for males and females. Panel b shows behaviors that were more common in males. Panel c shows behaviors that were more common in females. Behaviors with asterisks are those where males and females are different ($p < 0.01$ in paired t-tests).

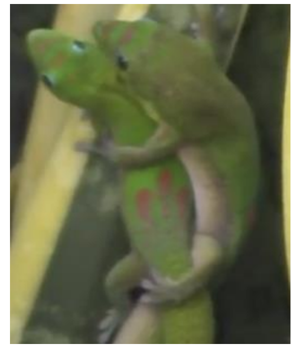
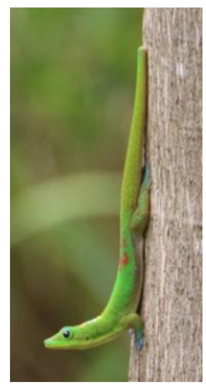
APPENDIX

Behavior Ethogram:

Behavior	Description	Example
Air-lick	Fast extension of tongue outside of mouth without touching a surface.	
Tongue-touch	Apparent touching of substrate with tongue	
Yoshi Tongue	Sticks tongue out of mouth cavity past the lower jaw and holds the tongue straight out of the mouth for a few seconds before pulling it back into mouth.	
Eye-Lick	External use of tongue to wipe on one eye	

Attack	Physical jump attack onto another lizard (may include biting)	
Curl	Movement of body into a serpentine-like position	
Eat	Capturing, consuming, and swallowing of prey	
Head-bobs	Repeated up and down or side-to-side movement of the head and neck, does NOT include lifting of tail	
Jump	Forward lifting and transport of entire body into air from one area to another area	

Move	Run or walk motion	
Snap look	Abrupt turning of head horizontally (left or right) in the direction of a stimulus	
Tail Lift	Lifts from the base of the tail in an up and down motion.	
Tail-wag	Slow and wide side-to-side sweeping movements of the tail from the base in an S like movement.	
Stalk	Movement of body in the same direction of a stimulus	

Mate	Locked into each other with the male on top and cloaca together.	
Stretch	Extended movement of one or more limbs away from the central body.	
Survey posture	Vertical orientation of the body where head is facing towards ground, may involve head-bobs	
Body glide	Steps over other geckos to rub underside (especially tail region) on back of another gecko.	

Spot switch	Gecko 1 walks to where gecko 2 was while gecko 2 goes to gecko 1 original position.	
Parallel Stance	Stand still parallel to each other in proximity (<6in.) like train tracks. Heads facing the opposite direction.	
Full Back Display	Flashes back to the other gecko by lifting front and back feet off the substrate on one side.	
Half Back Display	Flashes back to another gecko by lowering the body to the substrate on one side and extending limbs on the other.	

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