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Effect of physiological condition and refuge presence on flight initiation distance in common side-blotched lizards (*Uta stansburiana*)

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ABSTRACT

Optimal escape theory proposes that an animal will flee from potential danger at a distance that best balances competing needs, which includes resource and energy acquisition, as well as safety. Flight initiation distance (FID) and distance fled (DF) are measurable responses to threats. We surveyed the Sweeney Granite Mountains Desert Research Center in the Mojave Desert to examine how the common side-blotched lizard, *Uta stansburiana*, flees in response to potential threats influenced by physiological and environmental factors. We hypothesized the following: male *Uta stansburiana* will have a lower FID than their female counterparts. FID will have an inverse relationship with rock cover, shrub cover, and temperature, while DF will increase as temperature increases. We discovered that FID and DF for *Uta stansburiana* is not effected by sex or shrub cover, while substrate temperature marginally increases DF. Finally, rock coverage and crevice presence did not affect FID but it did decrease DF. Ultimately we found a complex relationship between our predictors and FID and DF in *Uta stansburiana*. Further studies elaborating on findings regarding environmental and physiological factors must be conducted in order to understand more about *Uta stansburiana* flight behavior.

Keywords: *Uta stansburiana*, common side-blotched lizard, flight initiation distance, flight behavior, Mojave Desert

INTRODUCTION

Animals constantly analyze threats to balance safety with the acquisition of resources and expenditure of energy to survive. A common manifestation of this risk assessment is the choice of *if* or *when* to flee in the presence of a perceived threat. While fleeing to cover can ensure safety, it costs energy, time, and resources; therefore, immediate flight upon the perception of danger does not always increase the fitness of an organism (Ydenberg and Dill 1986). The optimal escape theory proposes that an animal will flee from potential danger at a distance that best balances these competing needs (Ydenberg and Dill 1986, Cooper and Frederick 2007). This distance from the organism to the perceived threat when flight first occurs is considered the flight initiation distance (FID), and the distance the organism travels during flight is its distance fled (DF) (Ydenberg and Dill 1986).

Contextual elements such as predator type, physical conditions of the animal, and composition of the surrounding environment all can alter the balance between these competing risks, which can change the FID and DF of an organism (Ydenberg and Dill 1986). How and when an organism responds to threats can influence its overall survival and success, which shapes the composition of a population. Therefore, investigating what factors are influencing the risk assessment of individuals is important to understand the health and structure of a species in a given habitat.

Major contextual components influencing the risk assessment of individuals are organismal and environmental factors. Organismal differences in physiology such as sex or body condition can alter FID and DF (Samia et. al 2015, Stankowich and Blumstein 2005). Studies have frequently found that males flee less readily compared to their female counterparts; however, varying mechanisms for this pattern, such as differences in physical structure, mating strategy, or territorial behavior have been proposed (Samia et. al 2015, Qin et al. 2015). Body condition can also affect the ability of an organism to flee, as organisms that are exceptionally large or in better physical health tend to be able to move faster and further (Hertz 1982). Additionally, FID and DF can change depending on environmental parameters such as season and accessibility to physical refuges (Martin and López 1994, Samia et. al 2015). Seasonal factors including breeding behaviors or carrying young often influence how or when an individual will flee, including how close it stays to cover (Samia et. al 2015). Research has shown that access to refuge has also shown to decrease flightiness, likely due to increased proximity to safe shelter from potential predators (Zani et al. 2009). In total, these contextual factors can influence risk analysis and flight behavior of many organisms.

A group of animals whose threat analysis and flight behavior are especially context-dependent are ectotherms, specifically lizards. Lizards, like all ectotherms, require external sources of heat from their environment in order to regulate body temperature and conduct metabolic maintenance (Dreisig 1984). At warmer temperatures, their metabolic rates, sprint speeds, and endurance increases, which allows for effective escape at shorter FIDs and the capability to flee further distances (Bennet and John-Alder 1984, Waldschmidt and Tracy 1983). Conversely, FID is found to be shorter at lower temperatures due to lower metabolic rates (Wilson and Cooper 2007). Due to this, lizards must carefully balance time spent absorbing energy from the sun in the open, where they are vulnerable to predation, and time spent in cover where they are less vulnerable but lose access to direct thermal energy. Preferred refuges of lizards generally consist of dense, low lying shrubs, as well as crevices both in and beneath rocks (Cooper 2000). Additionally, lizards often exhibit sex-dependent differences in behavior; for example, males conduct more risk-taking behavior in the presence of a predator compared to females (Samia et. al 2015). This multitude of factors that influence flight behavior in lizards make them a particularly interesting group to examine optimal escape theory. While much research has been done regarding lizards and FID, the specific factors contributing to these observed patterns remain unclear. Although many differing explanations have been suggested for both physiological and environmental impacts on lizard FID, further research into these relationships is necessary.

Due to the importance of escape in survival and the uncertainty surrounding flight in lizards, we examined some of the physiological and environmental factors underpinning flight decisions in lizards. In this study, we looked at the effects of sex and body temperature as well as shrub and rock cover on FID and DF. We examined these relationships to address some central questions: will observed patterns with rock cover be consistent with previous findings? Will physiological limitations such as body temperature be more influential in determining FID and flight distance, or will different habitat conditions significantly impact flight in these lizards? We hypothesized the following: male lizards will have a lower FID than their female counterparts, and FID will have an inverse relationship with rock cover, shrub cover, and temperature, while DF will increase as temperature increases.

METHODS

The common side-blotched lizard (*Uta stansburiana)* is common throughout southern California deserts and coastal regions, and can be found in various parts of the western United States and Mexico. We conducted our study in the mixed desert scrublands of the Sweeney Granite Mountains Desert Research Center (GMDRC). This reserve is located in the eastern Mojave Desert, located 128 km east of Barstow in San Bernardino County, California (34° 48' 20" N, 115° 39' 50" W). The reserve ranges in elevation from 1,128 to 2,071 m, with air temperatures up to 33°C in the summer and as low as -1°C in the winter. Habitats within GMDRC include creosote flats, cactus yucca scrub, desert riparian zones, and rocky granite terrain. Plant species such as Nevada jointfir (*Ephedra spp.)*, antelope bitterbrush (*Purshia tridentata*), interior goldenbush (*Ericameria linearifolia*) and blackbush shrubs (*Coleogyne ramosissima*) constitute a majority of shrub refuges for *Uta stansburiana* in this area.

We surveyed 0.55 km^2 of the GMDRC for *Uta stansburiana* during various times of day, ranging from 09:00 to 17:00. We conducted our study during late spring, from May 4–7, 2022, with generally sunny conditions and air temperatures ranging from 20.5°C to 28.5°C throughout the duration of the study.

To conduct this study, we first visually located *Uta stansburiana* from approximately 6 m, where they did not yet perceive us as a threat. Using binoculars, we determined the sex of the individual based off of throat color and body pattern. If blue speckles were present on an individual's back, accompanied by a bright blue or orange throat, the individual was determined to be male. If an individual had brown and white splotches or stripes with no blue speckling on the body, as well as no color on the throat, the individual was determined to be female. After sexing the lizard, we approached it at approximately 1/4 m per second, until it fled from its perch location. Once the individual fled, we defined its FID as the distance between the person approaching the lizard and the initial location of the lizard. Additionally, we measured the distance the lizard fled from its initial resting location to its final, post-flee location. At the initial location of the lizard, we measured the temperature of the substrate underneath the individual as a proxy for body temperature, and laid out two 4 m transects which would intersect with one another at the 2 m mark. One transect was aligned with the north and south direction and one aligned east and west. Using the line intercept transect method, we quantified percent coverage of shrubs both dead and alive that were 50 cm or less in height along the 4 m transects. 50 cm was chosen to be our cutoff point as low lying shrubs appeared to provide better shelter for *Uta stansburiana*. In addition to measuring shrub coverage, the transects also served to form a 2 m radius circle around the lizard's initial location. Within this area, we visually estimated the percent rock coverage and noted if crevices that serve as hiding spots, determined to be 3 cm of rock overhang or more, were present.

Data collected were analyzed using JMP Statistical Software V16 (SAS Institute Inc.). Linear regressions were used to compare substrate temperature, percent shrub cover, and percent rock cover to FID and DF. Student's t-tests were used to test the effect of sex and presence of crevices on FID and DF.

RESULTS

Sex of *Uta stansburiana* had no effect on FID or DF (Table 1, Fig. 1). Substrate temperature showed no statistical effect on FID, but showed a marginal correlation between increasing temperature and increasing DF (Table 1, Fig. 2). DF of lizards decreased with increasing rock coverage (Table 1, Fig. 3). DF was also shorter when crevices were present rather than absent (Table 1, Fig. 4). Shrub cover showed no correlation with FID or DF (Table 1).

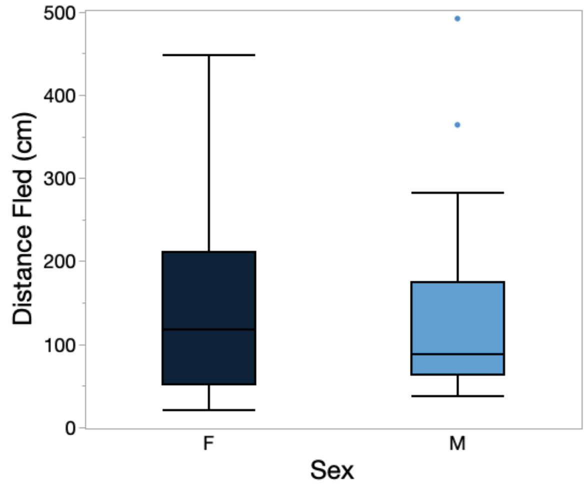

Figure 1. The effect of sex on distance fled in *Uta stansburiana*. Males and females of *Uta stansburiana* were approached at a constant speed until they fled from their original position. The distance they fled from their original to their final position was recorded and compared across sex. There was no difference in distance fled between males and females.

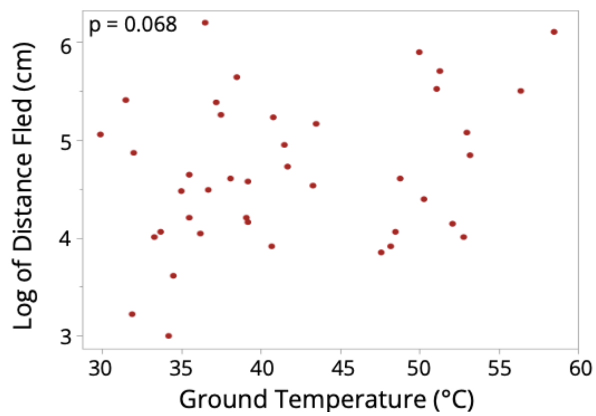

Figure 2. The effect of ground temperature on the log transformation of distance fled in *Uta stansburiana*. *Uta stansburiana* were approached at a constant speed until they fled from their original position. The temperature of the substrate at that location was measured. The distance they fled from their original position to their final position was recorded, log transformed for normalcy, and compared to the temperature of the substrate underneath their original position. A marginal but non-significant relationship was found between increased substrate temperature and increased distance fled.

Table 1. Summary statistics table of results. Linear regressions were used to compare substrate temperature, percent shrub cover, and percent rock cover to flight initiation distance (FID) and distance fled (DF) of *Uta stansburiana*. Two Student's t-tests were used to test the effect of sex and presence of crevices on FID and DF.

Linear Regression with Flight Initiation Distance (FID) as the Response Variable				
X Variable	*Sample Size*	*R^2*		*p-value*
Substrate Temperature	41	0.0536		0.1451
Rock Coverage	41	0.0115		0.5043
Shrub Coverage	41	0.0106		0.5211
Linear Regression With Distance Fled (DF) as the Response Variable				
X Variable	*Sample Size*	*R^2*		*p-value*
Substrate Temperature	41	0.0831		0.0676
Rock Coverage	41	0.1323		0.0194
Shrub Coverage	41	0.0049		0.6651
Student's T-Test Comparing Male Vs. Female				
Y Variable	*Male Sample Size*	*Female Sample Size*	*Test Statistic*	*p-value*
FID	20	20	t = 0.58	0.5632
DF	20	20	t = 0.03	0.9784
Student's T-Test Comparing Presence Of Crevice Vs. No Crevice				
Y Variable	*Sample Size With Crevice*	*Sample Size Without Crevice*	*Test Statistic*	*p-value*
FID	29	12	t = 0.19	0.8533
DF	29	12	t = -1.5	0.0073

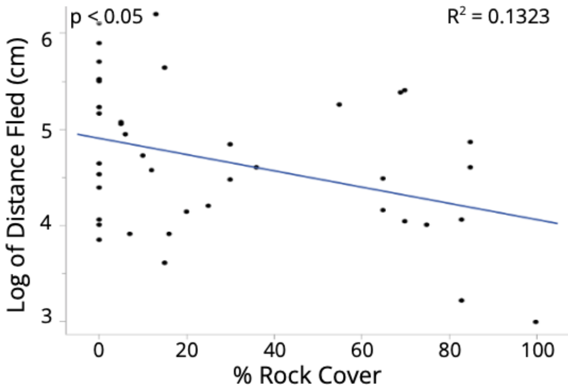

Figure 3. The effect of rock cover on the log transformation of distance fled in *Uta stansburiana*. *Uta stansburiana* were approached at a constant speed until they fled from their original position. A visual estimate of the percent rock cover within a 2 m radius of the original position was then calculated. The distance the lizards fled from their original position to their final position was recorded, log transformed for normalcy, and compared to the percent rock cover. It was found that as rock cover increased, the distance fled of *Uta stansburiana* decreased.

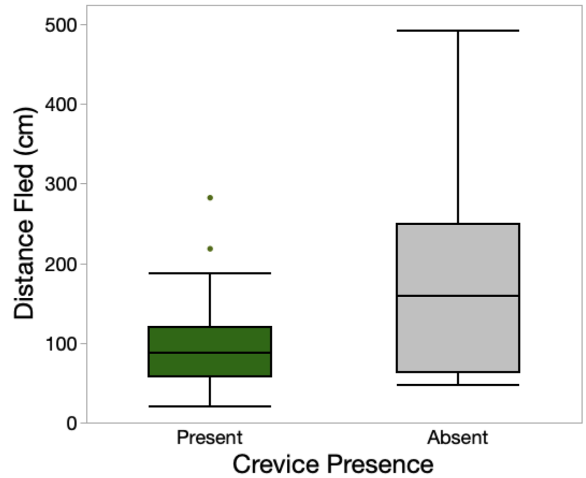

Figure 4. The effect of crevice presence on distance fled in *Uta stansburiana*. Individuals of *Uta stansburiana* were approached at a constant speed until they fled from their original position. Whether crevices were present within a 2 m radius of the original position was recorded. The distance the lizards fled from their original position to their final position was recorded and compared across crevice presence. Distance fled of *Uta stansburiana* decreased when crevices were present in the environment.

DISCUSSION

4.1 Physiological Parameters

We found no difference in FID and DF between male and female lizards. This refuted our prediction that males would have shorter FID and DF. Sex did not have a significant effect on flight behavior; however, a meta-analysis of 42 lizard species found consistently shorter FIDs in males compared to females (Samia et. al 2015). Our research was performed in the middle of spring, which is the breeding season for lizards in this area (Tinkle 1967). Perhaps female lizards became less flighty during this time due to an increased need for access to food and thermal energy to meet the nutritive demands of developing eggs or protecting nests (Samia et. al 2015). To parse out this disagreement between past findings and our research, it would be useful to look at the FID and DF of both sexes in different seasons. This would be informative in regards to different energy management techniques in different seasons, and allow for the observation of non-gravid females.

Substrate temperature, which was used as a proxy for lizard body temperature, was found to only have marginal positive correlation with DF, which failed to reject our null hypothesis. We did, however, see a trend that followed the same direction as previous literature, which demonstrated a relationship between higher body temperatures and increase in both sprint speed and DF (Hertz 1982, Wilson and Cooper 2007). It is possible that lizards select sunning spots that are closer to cover when substrate temperatures are lower in order to flee to safety quickly despite their slower sprinting speeds, however, we cannot draw any definite conclusions. For the future, measuring the sprinting speed of lizards or endurance in relation to substrate temperature could reveal new relationships between body temperature and the flight behavior of these lizards.

4.2 Environmental Parameters

Our data showed that the distance an individual fled was lesser when there were crevices present, as well as a higher percentage of rock coverage in the area. Our results align with previous studies that found *Uta stansburiana* prefers rocky habitats, likely because it is harder for predatory snakes to climb, and the rocks provide nearby crevices that can house an individual (Zani et al. 2009, Cooper 2000). Availability of various hiding spots can allow *Uta stansburiana* to spend less energy fleeing from predators, but future experimental studies are needed in order to confirm or deny this relationship.

Contrary to our predictions, shrub cover did not influence the FID and DF of *Uta stansburiana.* Although our hypothesis was rejected, our predictions have been seen in other species of lizards, such as the Algerian Sand Racer (*Psammodromus algirus*). *P. algirus* was found to have longer FID and DF when there was less foliage on shrubs to provide cover (Martin & Lopez 1995). This trend was seen both within and between seasons in *P. algirus* habitats. FID and DF in this species was longer in the spring than in the summer, when the abundance of leaves on shrubs provided denser coverage (Martin & Lopez 1995). As for *Uta stansburiana*, investigating the seasonal shift of leaf density within winter-deciduous plants communities, such as catclaw acacia (*Acacia greggii*), can potentially uncover whether the FID and DF of *Uta stansburiana* changes in response to a widespread, seasonal change in shrub cover. These studies can inform us as to what potential behavioral and energetic shifts occur when environmental drivers, such as droughts or season, decrease shrub cover (Báez et al. 2013, Hereford et al. 2006, McAuliffe & Hamerlynck 2010).

We found no effect of shrub cover on FID or DF of *Uta stansburiana.* It is worth noting however, that our study solely looked at the effect of 50cm tall shrubs or shorter. Other factors relevant to *Uta stansburiana* using shrubs as a protective refuge have been found to influence the decision and preference of this species. Leaf litter has been found to be an important component of lizard refuges, as patches of leaf litter allow lizards to hide their exact location within the refuge (Martin & Lopez 1995). In addition, studies have found that structural components of shrubs, such as concealment, visibility, and the widespread cover on flatter slopes are important factors that play into habitat preference (Hibbitts et al. 2013, Camp et al. 2012). Studying if *Uta stansburiana* prefers shrubs of different species, structures, or coverage will be interesting within the context of decreasing shrub cover in the Mojave Desert.

To conclude, this study's results contradict previous findings on *Uta stansburiana's* response to threats in terms of sex, elaborated on findings regarding environmental factors, so further research must be conducted in order to understand more about *Uta* flight behavior. It is worth noting that *Uta stansburiana* did not respond strongly to perceived threats within different levels of shrub cover. If the current drought in California continues as projected, the plant richness and density of this habitat could decrease. If *Uta stansburiana*, commonly found in California, exhibits the same flight responses in different environmental conditions, they could be left exposed to predators more often.

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