Predation behavior of *Gambelia wislizenii*, in response to thermoregulation requirements and prey availability

Poster Presentation by WWU Students taking summer session courses, 2006:

Biol 417a: Ecological Methods
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Figure 1. *Gambelia wislizenii* apparently visually seeking prey while also performing thermoregulatory cooling. The lizard appears to be more in BROS body position (body resting on substratum) than in FLEPOS (front legs extended, pelvis on substratum) body position. The lizard is resting in shade of *Artemisia tridentata* (Basin Big Sage, acronym ARTR).

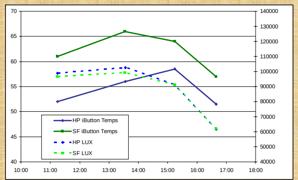

Figure 3. Daytime patterns of sunlight intensities and sunlit surface temperatures.
Comparisons of soil surface temperatures (°C, left axis) measured with Thermochron iButtons at Hardpan and Sandy Flats mesohabitats at discrete times on 7/14/06, time-matched to sunlight-intensity recordings (lux, right axis) on 7/14/06.

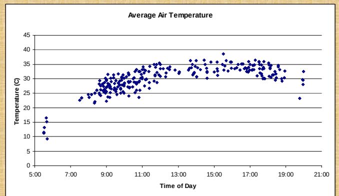

Figure 4. Air Temperatures measured with thermocouple thermometers.
Ambient air temperatures were recorded at 2 m above ground; thermocouple sensors were shaded from direct sunlight. The data points were graphed by time and temperature, omitting date (data are from June 25 to July 15, 2006), to create a curve of composite air temperatures from sunrise to sunset, while also representing the variability among days for the same time of day, as seen in the vertical distribution of dots for each time of day.

Figure 5. The more dappled shade cover of *Artemisia tridentata* (acronym ARTR, common name Basin Big Sage) on the left compared with the more solid shade cover of *Sarcobatus vermiculatus* (acronym SAVE, common name Greasewood) on the right.

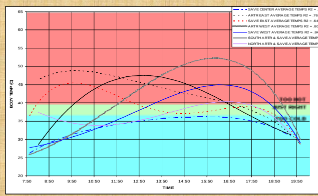

Figure 6. Among-nanohabitat comparisons of body temperatures of copper lizard models
Copper lizard model body temperatures were recorded by hand via thermocouple devices, from 7/6/06 to 7/15/06, during lizard-relevant hours. The data points were graphed by time and temperature, omitting date, to create a curve of composite copper model temperatures. The background colors represent divisions of temperature with respect to optimal body temperatures (37- 40°C) for field active *Gambelia wislizenii*.

INTRODUCTION

In contrast to the endo-thermoregulation of mammals, wherein the primary source for body heat is produced by the individual's high metabolism, desert lizards are ecto-thermoregulators. That is, lizards must thermoregulate by using the spatial variation of temperatures within a habitat. The lizards must move more frequently among microhabitats and nanohabitats to maintain body temperatures in a narrow-and-optimal range. In the desert summer, the spatiotemporal patterns of environmental temperatures limit the lizard's ability to ecto-thermoregulate, thus determining where, when, and how the lizard can be active throughout the day. A lizard that is particularly tractable for the endeavor to understand how lizards cope with the stresses of summer temperatures is the Long-nosed Leopard Lizard *Gambelia wislizenii*. In the Alvord Basin of southeastern Oregon, *G. wislizenii* are abundant, easy to observe without affecting their behavior, and are active in locations that permit researchers to easily locate and observe them.

By mid-summer, the reproductive season of *G. wislizenii* has ended, so the primary activity of *G. wislizenii* is food acquisition (albeit limited by the necessity of thermoregulation). Preliminary research has suggested that *G. wislizenii* are ambush predators, females acting a relatively long-wait ambushers and males as relatively short-wait lizard (Eleanor Rose, M.S. in Biology, WWU, 2003). Because the observations were made over cool, warm, and hot times of the day, however, it is unclear whether the differences in food acquisition behavior between males and females was more related to actual food acquisition differences or to thermoregulation differences between the sexes. Females are generally larger than males, hence body size may correlate with either thermoregulation differences or to differences in food acquisition. Hence, females may focus their search for larger prey such as lizards and thus have a longer wait from an ambush site; alternatively, larger size in females may provide more "thermal inertia" and permit them to remain stationary longer before they have to move to a thermally different microhabitat.

The focus of this research is on identifying the microclimatic and nanoclimatic conditions in the Alvord Basin that are optimal for *G. wislizenii* activity levels and whether foraging behavior differences do exist between the sexes during the peak activity times of mid-morning when thermoregulation putatively is less of an influence on lizard behavior. Because past research has indicated that grasshoppers and whiptail lizards are important prey in summer, availability of grasshoppers and whiptails among mesohabitats and among times of day will be measured and compared with past research to determine how variation in prey abundance causes differences in the observational data obtained.

HYPOTHESES TESTED

An initial hypothesis is that where and when *Gambelia wislizenii* can be most active will depend on particular spatiotemporal patterns of temperature among nanohabitats and microhabitats. We expect that direct sunlight, soil substratum (substrate) temperatures, and wind speed will be the greatest effectors of spatiotemporal variation in temperatures.

Our second, related set of hypotheses is based on previous research. The null hypothesis is that during the periods of the morning when environmental temperatures are least limiting to food acquisition behavior, male and female *G. wislizenii* will behave similarly, despite their body size differences and different energetic needs. Thus, the differences encountered in prior studies between males and females may be attributed to 1) low sample sizes for each time/temperature period and 2a) thermoregulation differences between sexes at some times of the day, rather than food acquisition differences per se, or 2b) the occurrence of both short-wait and long-wait ambushing episodes for both males and females, thus compounding the low sample size problem even further. The alternative hypothesis is that female *G. wislizenii* are relatively long-wait ambushers, whereas males are relatively short-wait ambushers and that this difference may be related to the differences in prey sought—lizards by females but insects by males—rather than the difference in behavior being a result of thermoregulation.

METHODS

Soil surface temperatures were recorded with Thermochron iButtons every 10 minutes from noon on 4 July 2006 to mid-morning on 15 July 2006. Ambient air temperatures at 2 m above ground were collected at various times each day for the same general time period. Air temperatures were recorded at 2 meters in the shade, exposed to wind, using thermocouple thermometers (all temperatures taken with thermocouples were taken once the temperature readings were constant for at least 5 seconds).

Copper lizard models were used to simulate body temperatures of *Gambelia wislizenii* in standardized situations. Models were made to represent two common lizard body positions; ALEBNTS (All Legs Extended, Body Not Touching Substrate) and BROS (Body Resting On Substrate, Fig. 1). The intermediate position FLEPOS (Front Legs Extended, Pelvis on substrate, Figure 2) was not used in this analysis, but was used in 2005. The models were positioned around *Sarcobatus vermiculatus* (Greasewood, acronym SAVE) or *Artemisia tridentata* (Basin Big Sage, acronym ARTR) and alternated among the four cardinal compass directions to provide information on thermoregulation sites at various times. A copper lizard model was also placed in the center of a *Sarcobatus vermiculatus* to simulate the consequences for lizard body temperature if a lizard were to be stationed continuously in the deepest of deep shade.

Visual surveys for grasshoppers were conducted on nine days through late June and early July on nine 10 by 40 meter plots, three plots each at hardpan, sandy flat, and dune mesohabitats on and very near the 200 x 200m lizard study plot. Each 10 x 40m plot was evenly subdivided by placing wire flags at the corners of sixteen 5 by 5 meter quadrats. Plots were visually surveyed only once per day, and the same 8 of 16 quadrats were sampled on each plot. Each quadrat was sampled three times in each of three time periods (hence 9 days): 08:00-11:30, 12:00-15:00, 15:00-20:00. Searchers first visually scanned open areas on the ground in the 5 by 5m quadrat and then proceeded to scan each perennial plant. Plants were first examined without disturbing the foliage, then with palms up and fingers spread-and-extended, upward (basal-to-crown) combing (foliage between fingers) sweeps of the peripheral foliage were performed to induce grasshoppers to reveal themselves. Grasshoppers were identified by color, form, and size (referenced to held ruler); grasshopper behavioral responses to the hand sweeps also were recorded.

Focal observations of individual lizards were made with two observers standing about 5-10 m away, with particular attention paid to not disrupt the animal's normal foraging behavior. Real-time behaviors were orally documented by one or both observers into an audio micro-cassette recorder or a Hi-8 camcorders. In the last half of the study, most lizard behaviors were video recorded. One observer was responsible for taking microclimate data, recording plot coordinates of the lizard, and stating the precise time periodically; that person also helped find the lizard if it left the field of view of the person making the audio or video recordings. During focal observations when video recording, one observer usually operated the video camera, whereas the other observer provided most of the oral documentation of the lizard behavior. Each change in lizard behavior was recorded, as well as location description of lizard and time at which the behavior occurred; thus, exactly when and where each behavior began and ended could be documented.

Time ranges of recordings were split up into four time periods based on prior research results on *G. wislizenii* activity, including 8:30-10:00 (time 1), 10:00-11:30 (time 2), 11:30-4:00 (time 3) and 4:00-7:00 (time 4). Observers strived to record equal numbers of male and females at each time period. Repeat observations of specific lizards at each time period were avoided. Statistical analyses were performed with Systat 11.0, and graphs were made with Excel and Sigma Plot 9.0.

STUDY SITE

The ecological setting used for this observational-descriptive study of the food-acquisition behavior *Gambelia wislizenii* was a desert scrub habitat in the Great Basin Desert. The location of the study plot was the north end of the Pueblo Valley in the Alvord Basin, in Harney County, OR, to the southeast of the famous Steen's Mountain. This rain-shadow desert was chosen because it has a suitably low species diversity of plant and animal species so the system is more amenable to study than other more complex habitats. Moreover, the open aspect of the habitat and the predominately low-lying shrubs enables one to observe lizards throughout their daily activity periods. The comparisons that can be made among three prevalent mesohabitats and three prevalent microhabitats also make it relatively easy to seek lizard behaviors as related to spatial variation in the habitat.

Figure 12. This female *Gambelia wislizenii* recently swallowed an adult western whiptail lizard (*Aspidoscelis tigris*) that weighs about two-thirds of her own body mass!

RESULTS

Temperature & Thermoregulation

Sunlit soil surface temperatures (iButton measurements) varied with soil type. The fine, reflective particles of clay and the flat, uniform surface of the hardpan mesohabitat has a lower temperature throughout the day compared to grainy, irregular, light-absorbing surface of the sandy flat (Figure 3). The ambient air temperatures, as measured by hand-held thermocouples, varied with time of day similarly among days (Figure 4), so air temperatures are somewhat predictable. The iButton at the perimeters of the east sides of both ARTR and SAVE measured peak sunlit soil surface temperatures in the mid-morning, whereas the sunlit soil surface temperatures on the west perimeters of both plants peaked in mid-afternoons. Copper model temperatures differed between corresponding nanohabitats under SAVE and ARTR. Models under SAVE were commonly cooler than under ARTR, because shade is typically deeper under SAVE (Figures 5 and 6). Judging from the open sunlit soil temperatures (Figure 3), air temperatures (Figure 4) and copper lizard model temperatures placed in mix of near-plant soil temperatures (Figure 5), the peak time for *G. wislizenii* activity is mid-morning. That time should be when a minimum of overt thermoregulation occurs, as is shown in Figure 7.

Prey v. Predator Distribution and Abundance

Grasshopper abundance was greatest in the dune mesohabitat, and lowest in the hardpan mesohabitat (Figures 8 and 9). Note also that grasshopper abundance in 2006 was similar to 2005, but significantly lower than in 2004 (Figure 8). Although grasshoppers were most abundant in the dune mesohabitat, the *Gambelia wislizenii* were seen just as often in the sandy flats (N = 161 sightings) as on the dunes (N= 157), but as expected, *G. wislizenii* were seen less often on the Hardpan (N= 109). Most grasshoppers were seen on ARTR (four highest categories were: 75 ARTR, 34 Open, 15 Dead wood, 14 SAVE); similarly most *Gambelia wislizenii* seen near perennials were also at ARTR. Most *Gambelia wislizenii* sightings, however, occurred in open microhabitats (N = 300 sightings in open v. 68 under ARTR, 26 under SAVE, and 20 under all other plants), perhaps where the field-of-view is best for this visually-searching predator. *Aspidoscelis tigris* were most commonly seen at dunes mesohabitat (*A. tigris* sightings: 67 D, 28 SF, 25 HP) and open microhabitat (sightings: 77 open, 19 ARTR, 13 SAVE, 11 other plants). Temporal availabilities of grasshoppers and whiptail lizards, two common prey of *G. wislizenii*, were highest in the morning (Figures 9 and 10), when *G. wislizenii* could focus on food acquisition and not on thermoregulation (Figure 7).

Gambelia wislizenii sexual di-ethism?

When comparing movements of females and males for mid-morning, when thermoregulation putatively will least bias the movement data, the only difference we found in the major parameters of movement were for the distance moved and time taken to move between ambush sites (Figure 11). Both sexes were similar for frequency of change in ambush sites and for time spent per ambush site. Moreover, whereas most individuals were classic long-wait ambushers, a minority of both males and females displayed the short-wait ambush mode (moving 30-40% of the time, Figure 12). Both sexes spent similar amounts of time directed toward movements for thermoregulation (Fig 7). Prey capture attempts (Fig 13) were similar equal for both sexes, and data were pooled for an overall rate of 15 captures per 488 minutes (2 per hour) of focal observations.

Figure 13. *Gambelia wislizenii* displaying stalking behavior (a grasshopper is on the ground, just out of camera view) similar to *Felis domesticus*, the common housecat!

DISCUSSION

Data on the light-intensities of sunlit and shaded nanohabitats and related soil substratum temperatures can be used to explain some of the patterns of activity by *Gambelia wislizenii*. The higher foliage density of SAVE, as corroborated by the lower light intensities measured under SAVE than under ARTR, provides nanoclimate variation among plant microhabitats that should be conducive to thermoregulation by *G. wislizenii*. Moreover, if *G. wislizenii* switch use of substrata from sand to hardpan in response to rising ambient temperatures, then it can be inferred that *G. wislizenii* use the differences in temperature between hardpan substratum and sand substratum to optimize thermoregulation. Movements solely directed toward thermoregulation, such as moving a short distance from sunlit sand in open microhabitats to the shade of a SAVE, were similarly rare for both sexes. The low amount of overt thermoregulatory behavior in mid-morning, however, verifies the efficacy of restricting the focal observations of G. wislizenii from 09:00-10:30, when the temperature is at a range when lizard activity can be devoted entirely to food acquisition.

Copper lizard models representing common lizard body positions were placed on sandy substratum at the four cardinal compass locations around the two predominant perennials on the study site. A copper lizard model is accurate enough at representing lizard body temperatures to show the body temperature of a lizard if it were in a particular location at a particular time. Models placed in east perimeters of both perennials, for example, rapidly warmed in the early morning, thus showing that these locations enable early-morning lizard basking. These east-side models became very hot before mid-morning, however, hence lizards could not remain there. By early afternoon these same copper lizard models were shaded and cool enough to infer that a lizard could be stationary in those positions without overheating. Of course, sunlight on west sides of perennials contrasted greatly with the east sides, so it is expected that lizards could easily maintain body temperatures by shuttling between sunlit and shaded nanohabitats.

Grasshopper abundance was similar to 2005, but much lower than in 2004 and perhaps 2003 when Ellie Rose first obtained suggestive data that led her to tentatively conclude that female *G. wislizenii* may use long-wait ambush predation more often than male *G. wislizenii* (who may have move more often in search of grasshoppers). Grasshopper and whiptail lizard distribution and abundance among mesohabitats were similar to past surveys, with the greatest numbers predominately found on dunes and sandy flats. As expected, *G. wislizenii* spatial distribution was similar to the spatial distribution of its prey.

Female *Gambelia wislizenii* may travel further between ambush locations (Figure 11), perhaps related to optimal locations for ambushing lizards. Data derived from summer 2006 focal observations during the times of the morning that are least influenced by thermoregulatory needs reveal, however, that males and females are largely similar in food acquisition behavior. And although results of most focal observations showed lizards to move much less than 20% of the time, there were the unusual few focal observations wherein individuals moved nearly 40% of the time (Figure 12). This schismatic contrast in movement rates was seen also in 2003, 2004, and 2005. A statistical analysis combining data among years may reveal patterns that have not been clear with the limited data sets within each year. Alternatively, larger data sets for each size and sex class of *G. wislizenii* for each time and temperature combination for any 10-day period of the activity season, wherein patterns of prey abundance are known may have to be performed over the course of a single activity season before lizard foraging patterns are discernible and causes for those patterns can be identified.

CONCLUSION

The hypothesis that air and soil surface temperatures and solar radiation strongly affect *Gambelia wislizenii* behavior for most of the day, but least during mid-morning was supported by data from iButtons, light meters, thermocouples, and copper models (Figures 2-6) and by the relatively little overt thermoregulation in midday (Figure 7). Due to time constraints for analysis relative to the prodigious amount of time needed to transcribe the many hours of focal observational data obtained, Biol 417a,b class requirements were met with transcriptions only from the focal observations at mid-morning. Further studies (Biol 494 students) will expand the analyses of the effects of soil substratum temperatures, air temperatures, and sunlight intensity on microhabitat and nanohabitat use by *G. wislizenii*.

The hypothesis that there is sexual di-ethism in food acquisition of *Gambelia wislizenii* was not supported. For most major features of food acquisition behavior, males and females were similar. Females moved further per change in ambush location (Figure 11), however, and it may be inferred that female *G. wislizenii*, as larger lizards than males, may more often seek larger prey (i.e., lizards) than do the males.

An in-depth study of prey in the stomachs and fecal pellets of male v. female *G. wislizenii* should be done to determine whether female *G. wislizenii* behavior is matched by a greater tendency to eat lizards, and whether male *G. wislizenii* behavior is matched by a greater tendency to eat arthropods. Moreover, larger sample sizes for focal observations throughout the activity season are needed for subadults and adults of both sexes before we will be able to discern the size and sex-related patterns of food acquisition and thermoregulation, with particular reference to short-wait ambushing v. long-wait ambushing and the relative benefits and drawbacks of either ambush mode. Similar in-depth studies of food acquisition for other lizards also need to be done so that the major features of adaptedness in behavior, morphotypes, and physiotypes can be compared among animals differing in modes of food acquisition.

Figure 2. *Gambelia wislizenii* visually seeking prey, in classic FLEPOS body position (front legs extended, pelvis on substratum).

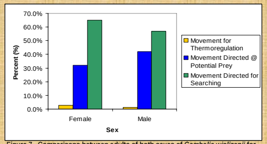

Figure 7. Comparisons between adults of both sexes of *Gambelia wislizenii* for the 3 most common types of movement during 09:00-10:30 hrs.
Note: 1) how similar males and females are in activity patterns (no statistical difference), and 2) little movement behavior is involved in overt thermoregulation in mid-morning. Thus, it can be inferred that most behavior is related to food acquisition at 0900 to 1030 hrs (N = 9 of each sex, data collected 7/3/2006 to 7/15/2006.

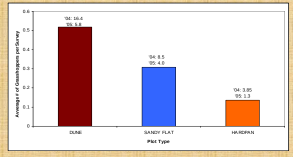

Figure 8. Grasshopper abundance compared among three mesohabitats in the Alvord Basin in early July 2006.
Eight 5 x 5m quadrats were visually inspected for grasshoppers once per day for nine days (evenly spread across 3 times of day) on three 40 x 10 m plots for each of three mesohabitats (9 plots total). N = 199 grasshoppers. Note the average numbers of grasshoppers found in 2004 and 2005 (above bars).

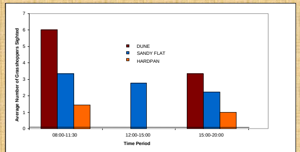

Figure 9. Average number of grasshoppers found in each mesohabitat in early July 2006.
A total of 199 grasshoppers were seen during designated survey time periods utilizing the nine 40 x 10m plots divided into sixteen 5 x 5m quadrats, from which 8 quadrats were surveyed.

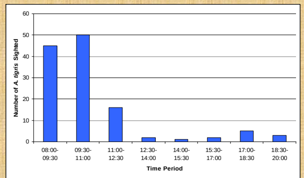

Figure 10. Comparisons of the number of western whiptail lizard (*Aspidoscelis tigris)* sightings across an array of consecutive 1.5 hr periods throughout the day in summer 2006.
Data are summed across 20 days in summer 2006 (6/25/06 to 7/14/06, N = 119 sightings). Note the similarity in timing of peak abundance of this prey item of *G. wislizenii* with the *G. wislizenii's* other common prey, grasshoppers (see Figure 9).

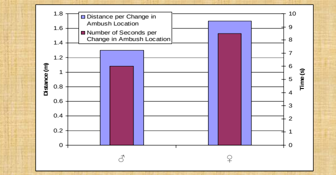

Figure 11. Movement comparisons between male and female *Gambelia wislizenii*.
Females appear to move further per change in ambush position (trend data only, with N = 5 females and 6 males) and females took longer per change in ambush location (N = 9 each sex, t = 2.5, p < 0.05, data collected 7/3/2006 to 7/15/2006). Thus, these data support the hypothesis that larger lizards (F) tend to move farther between ambush sites, because females seek larger prey (which tend to be more widely separated than smaller prey).

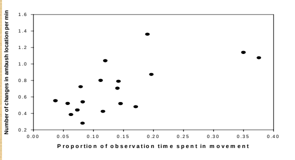

Figure 12. Activity levels of *G. wislizenii*.
Time spent moving (sexes pooled, N = 18, mean 0.14, SE = 0.022, data collected 7/3/2006 to 7/15/2006) and the frequency of changes in ambush location (N = 18, mean = 0.7, SE = 0.07) corroborate past years' data: whereas most individuals are moderately active (most near 10% of the time), intermittently individuals can be very active (35-40% of the time). These activity levels are high for ambushers, but they are much lower than activity levels of the wide, intensive forager *Aspidoscelis tigris*.