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How Iguanas Beat the Heat and Still Find Things to Eat: Thermoregulation and Feeding in Oplurus saxicola

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How Iguanas Beat the Heat and Still Find Things to Eat:

Thermoregulation and Feeding in *Oplurus saxicola*

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Abstract:

Oplurus saxicola is a terrestrial, diurnal species of iguana endemic to Madagascar. Populations are located in the southwestern portion of the island in either spiny or gallery forest habitats. A focal observation study of *O. saxicola* was conducted in Parcel 2 of Andohahela National Park over a period of two weeks at the end of the dry season. The aim of this study was to determine and analyze the differences in thermoregulation and feeding behavior of *Oplurus saxicola* living in the spiny forest, as opposed to the corresponding behaviors of individuals living in the gallery forest.

Introduction:

Reptiles are widely distributed throughout Madagascar – they exist in forested habitats as well as in rocky outcrops with or without vegetation cover (Glaw & Vences, 2007). Due to their classification as ectotherms, an important aspect in reptile behavior is active thermoregulation through basking. A terrestrial or arboreal ectotherm receives radiant energy from the sun directly or indirectly from reflected solar radiation and the heat of substrate and air. Sunlight striking a surface is variously absorbed and reflected; the absorbed solar radiation converts to heat and raises the temperature of the object (Zug et al., 2001). Especially terrestrial, diurnal lizards actively search in the morning open positions on rocks or tree trunks to expose themselves to the sun and thereby reach their optimal body temperature for maintaining high levels of activity (Glaw & Vences, 2007). As an ectotherm's body temperature shifts away from the set point temperature, the animal moves, changes orientation, or changes posture to effect heat gain or loss (Zug et al., 2001).

The animal's movement can also be influenced by feeding behavior. Lizards are in general carnivorous and insectivorous, hunting all prey of suitable size, but several lizard groups have adapted to consume a certain degree of plant matter. Gerrhosaurids (*Zonosaurus* and *Tracheloptychus*) have been observed consuming fruit and flowers, and iguanas (*Oplurus* and *Chalarodon*) will almost certainly consume such food as well, although precise quantitative data are missing. (Glaw & Vences, 2007)

Oplurus saxicola is a relatively common diurnal species of iguana with a mating season from December to January. It can be found in arid areas of south-western Madagascar and typically lives on large smooth rock surfaces such as large boulders and dry riverbeds. (Glaw &

Vences, 2007) This species was observed in both the spiny forest and the gallery forest at Andohahela National Park during the end of the dry season.

Spiny Forest

Gallery Forest

Andohahela National Park (ANP) is located in south-eastern Madagascar, about 35 km west of Fort Dauphin (Figure 3). It includes and connects the humid eastern and the dry south-western portions of the island. The Anosy Mountains (1,972 m) act as a rain barrier. They cause a steep gradient of precipitation and hence an extraordinary level of species turnover in the biotic communities over the distance of a few kilometers (Theisinger et al., *submitted*).

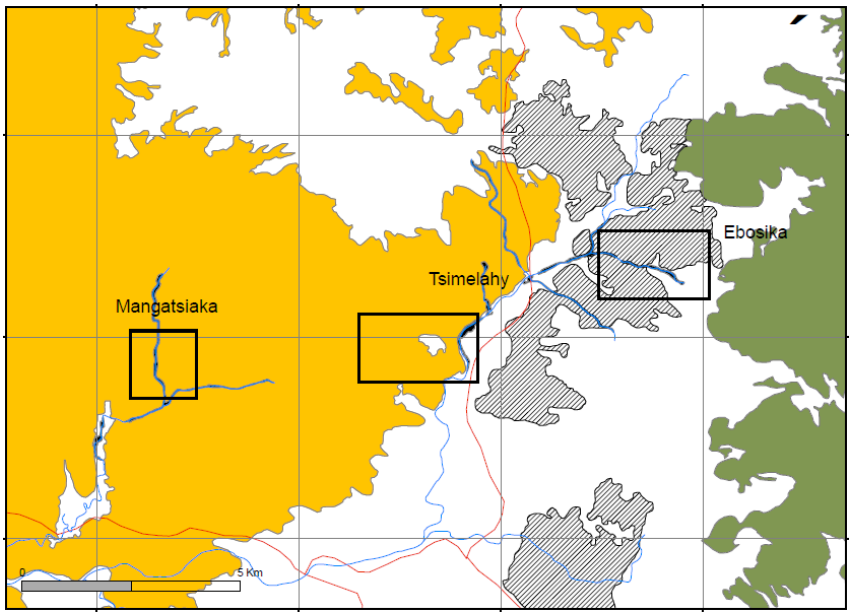


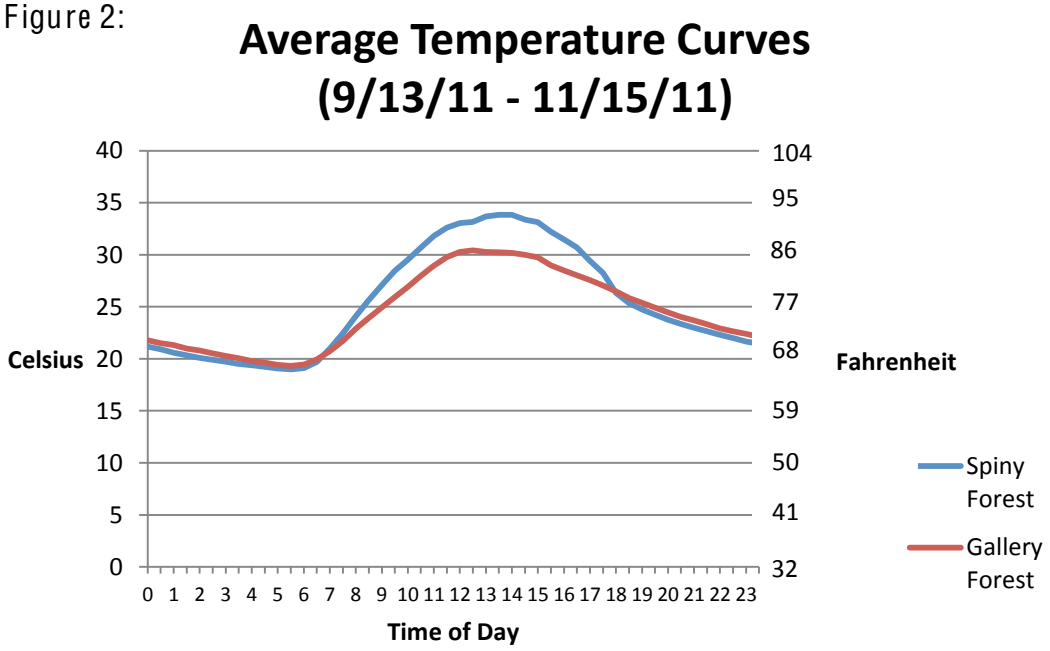
Figure 1: Yellow: dry forest; white: savannah; shaded: transitional forest; green: rain forest (Map by Jacques Rakotondranary).

The ANP, comprising 76,020 ha, is divided into three noncontinuous parcels. This study was conducted in Parcel 2, which includes dry forest, savannah and some gallery forest, as shown in Figure 1. Parcel 2 is the second largest parcel of the ANP (12,420 ha), it lies between 46°33' to 46°38' E and 24°48' to 24°58' S. The precipitation (400 mm per annum) is seasonal with almost all rain falling during the rainy season between November and April. However, the amount and duration of the rainfall is highly variable. Two permanent rivers are found in the dry forest of parcel 2: the Mananara which defines the northern borderline, and the Tarantsy which is located in the south-eastern end of parcel 2. Both have their source in the Anosy Mountains of parcel 1 (Theisinger et al. *submitted*).

Gallery forests are generally considered as long lasting forests with better resistance to fire, higher humidity and more constant climate compared to surrounding dry areas. These

characteristics and annual flooding of gallery forests result in floral and faunal compositions, which are sharply distinguished from the surrounding dry forest and savannah (Felfili, 1995; Kellmann *et al.*, 1996). Day time temperatures of the gallery forest in Parcel 2 are consistently lower than temperatures of the dry (spiny) forest, as depicted in Figure 2.

Figure 2:



A focal observation study of *Oplurus saxicola* was conducted in both the spiny forest and the gallery forest to assess patterns in thermoregulation and feeding between the two habitats. Movements from sun to shade were monitored as well as changes in posture. The goal of these observations is to determine if there is a difference in the pattern of movement from sun to shade across habitats, and to analyse the role of posture-change behavior in thermoregulation. The feeding habits of *Oplurus saxicola* were also observed during this study in order to determine their main feeding times as well as the different categories of prey that they consume. Feeding patterns were also compared between the spiny forest and the gallery forest.

Materials and Methods:

Focal animals were observed in two different transects: one gallery forest transect (46˚37.332' E and 24˚57.184' S), and one spiny forest transect (46˚35.699' E and 24˚57.671' S). Each transect was 250 meters long. Five days of observation were completed in each transect. Spiny forest individuals were observed on the 3rd, 6th, 9th, 12th, and 15th of November (2011), and gallery forest individuals were observed on the 4th, 8th, 11th, 14th, and 17th of November (2011). Every half-hour marked the start of a new 15-minute focal observation period; beginning at 6:30 AM in the gallery forest, and 7 AM in the spiny forest. Each day contained 22 observation periods, with the last gallery focal period beginning at 5 PM, and the last spiny focal period beginning at 5:30 PM. Ideally, 110 focal observations would have been completed in each transect; but occasionally, observation periods were deemed invalid due to interference, and sometimes a focal animal could not be found at the start of the scheduled observation period. Thus, 104 focal observations were completed in the spiny forest transect, and 106 were completed in the gallery forest transect. In total, approximately 110 hours of fieldwork were completed, including approximately 52 hours of valid focal observation.

During the 15-minute observation period, the times at which the focal animal moved from sun to shade, or half-shade, were recorded. Shade was defined as a complete shadow covering the focal animal, and half-shade was defined as a mixture of sunlight and shadow over the animal. The times of any cloud interference were also recorded. Afterwards, the total number of seconds spent by the animal in each category (sun, half-shade, shade, and cloud) was calculated according to the times of movement between categories. In addition, the times at which the focal animal changed posture between flat, normal, and high were also recorded, and

the total amount of seconds spent by the animal in each posture was calculated afterwards. The three posture categories are shown in the images below.

Flat Posture

Normal Posture

High Posture

During the fifteen-minute observation period, any feeding events by the focal individual were also recorded. Each attempt to feed was recorded as successful or unsuccessful, and the size of the prey (small, medium, or large) was noted for every successful attempt. Successful feeding events were determined by observed chewing motions in the focal individual. Small

prey was defined as anything with a diameter of 0.5 cm or less; examples include sweat bees and insects that were too small to see during observation (though the animal was clearly chewing). Medium prey was defined as prey with a diameter between 0.5 and 1.5 cm; examples include flower buds and small leaves. Finally, large prey was defined as any prey with a diameter of more than 1.5 cm; examples include flowers of surrounding pachypodium plants, such as Madagascar palm. Since adult amphibians and reptiles do not necessarily eat the same prey as larvae or juveniles (Zug et al., 2001), observation of individuals with snout-vent lengths of less than 7 cm was avoided.

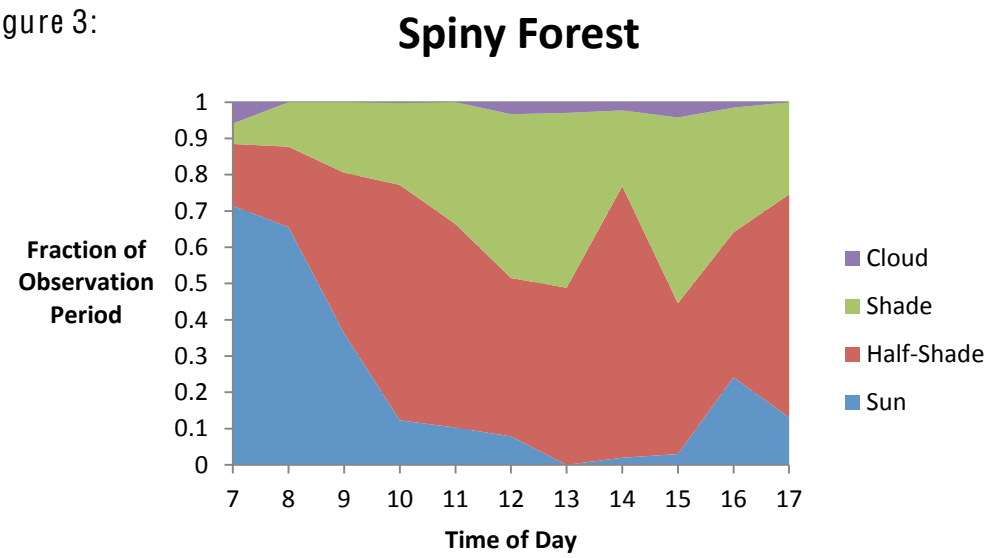
At the end of the observation period, an effort was made to capture the focal animal using a dental floss noose attached to a meter-long wooden pole. Forty-seven gallery forest individuals and sixty-four spiny forest individuals were successfully captured and marked. Once the animal was captured, its snout-vent length and full body length (snout to the end of the tail) were measured in centimeters and recorded. The animal's weight in grams and the date captured were also noted, as well as any obvious injuries, such as missing toes. Each captured individual was given a marking, and a number specific to its marking pattern. Care was taken to avoid observing the same individual more than once in one day, and also to avoid observing the same individual more than once at the same time of day across all five days of observation in each transect.

Results:

Area graphs were constructed to show the average amount of time *Oplurus saxicola* spend in the sun, half-shade, shade, or under a cloud at each hour of the day. The graph

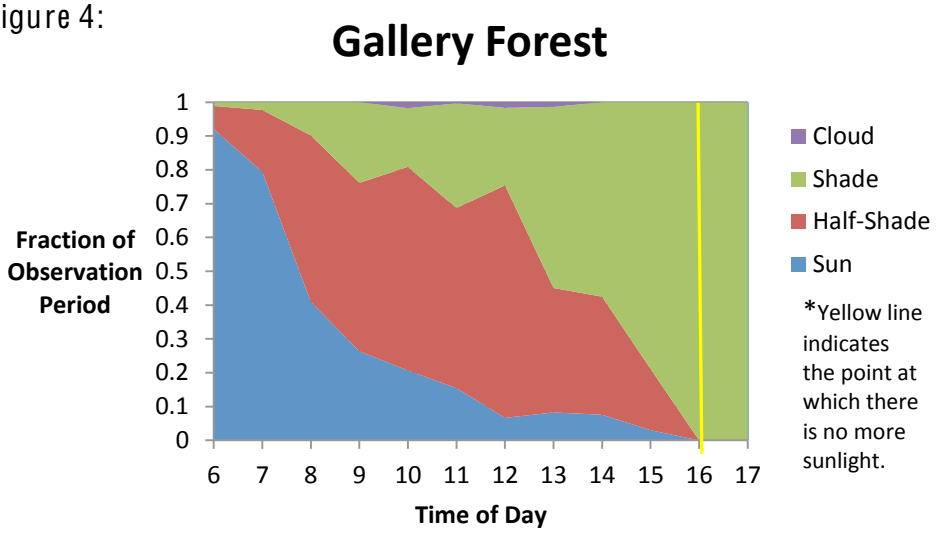
corresponding to the spiny forest (Figure 3) shows two distinct peaks in the fraction of time spent in the sun: one peak occurs in the early morning between 7 and 8AM, and the other occurs in the late afternoon at 4PM. It is clear that the majority of time is spent in either half-shade or shade between the hours of 10AM and 3PM.

Figure 3:



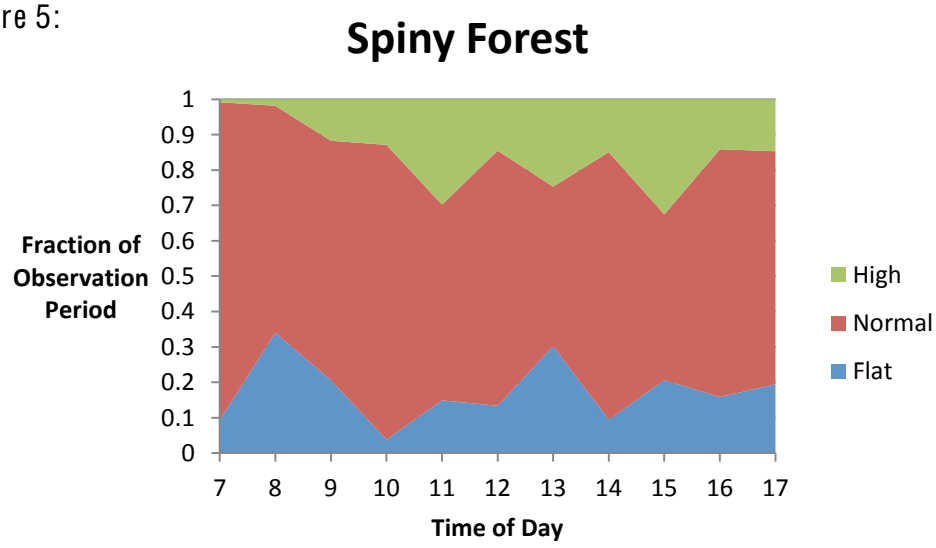
In the gallery forest (Figure 4), there is only one peak in the amount of time spent in the sun. This peak, beginning between 6 and 7AM at approximately 90%, has greater intensity than its spiny forest counterpart, which shows a maximum of about 70%. In addition, the descent of the gallery forest sun peak is more gradual than that of the corresponding peak in the spiny forest; the end of the gallery forest peak plateaus around 12PM as opposed to 10AM in the spiny forest. The second sun peak observed at 4PM in the spiny forest is completely missing from the gallery forest graph because by 4PM, the gallery forest transect is mostly shielded from the sun by surrounding cliffs and vegetation.

Figure 4:



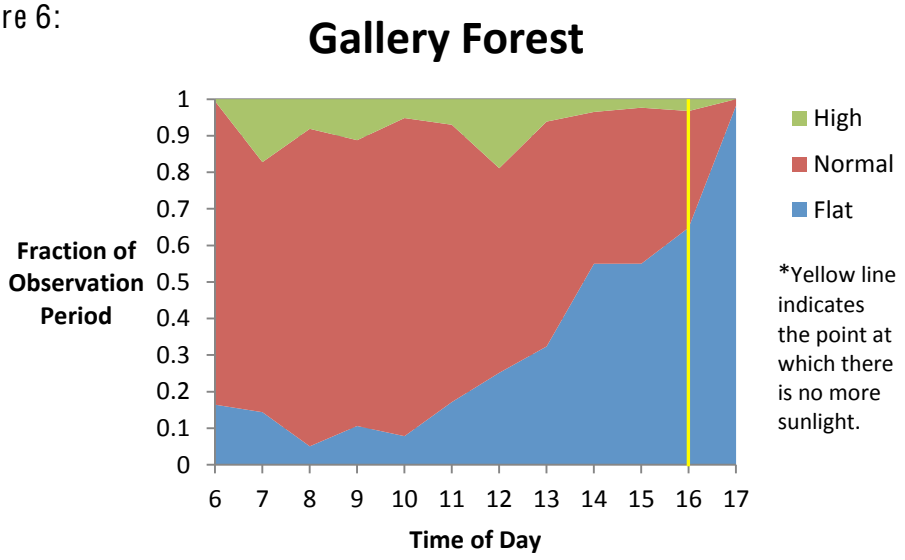
Area graphs were also constructed to show the average amount of time *Oplurus saxicola* spend in flat, normal, and high posture at each hour of the day. The graph corresponding to the spiny forest (Figure 5) shows that the majority of time is spent in the normal posture with little variation throughout the day.

Figure 5:



In the gallery forest (Figure 6), the majority of time is spent in the normal posture from 6AM until approximately 12PM - at which point, time spent in the flat posture begins to steadily increase. From 2PM until the end of the day, it is clear that the majority of time is spent in the flat posture.

Figure 6:



In order to compare the amount of sun exposure experienced by *Oplurus saxicola* with the height of their posture, the following values were assigned to each category: Cloud = 1, Shade =1, Half-shade = 2, Sun = 3, Flat = 1, Normal = 2, High = 3. Holistic values for sun exposure and posture were calculated based on this scale of 1 to 3.

Figure 7 shows that as sun exposure in the spiny forest hovers between shade (cloud) and half-shade from approximately 9:30AM to 5PM, posture remains almost constantly normal. In the gallery forest (Figure 8), posture and sun exposure follow the same downward trend from 9AM to 5PM.

Figure 7:

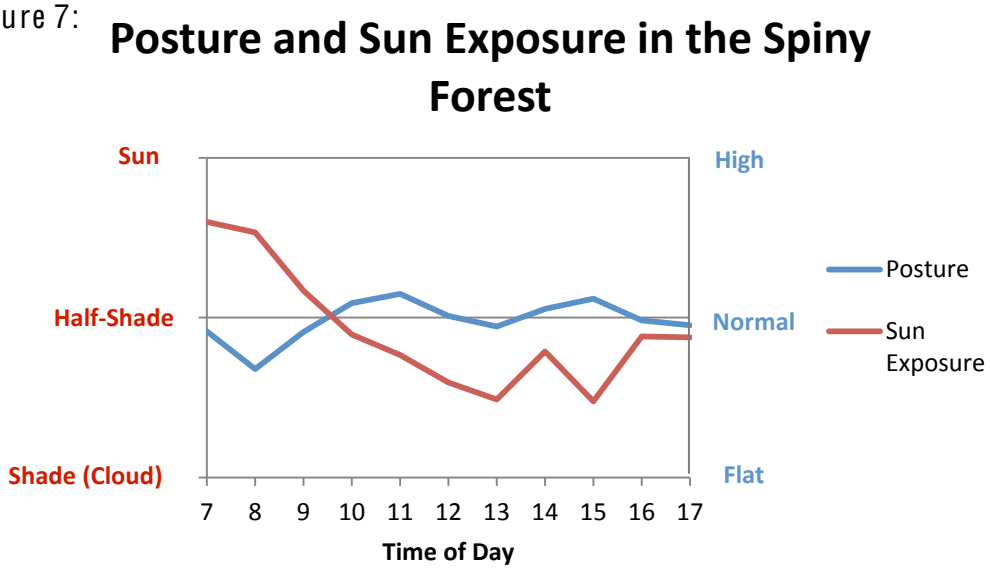
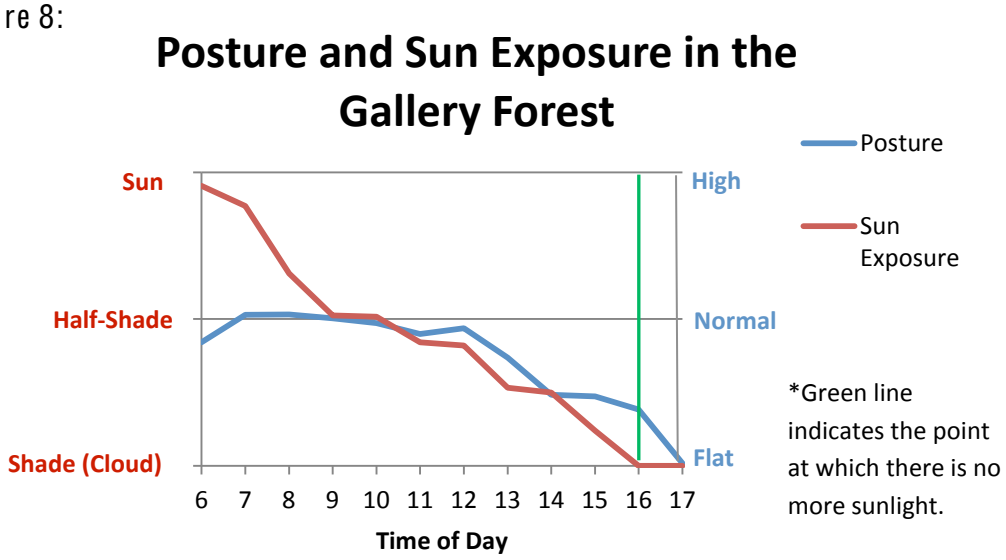


Figure 8:

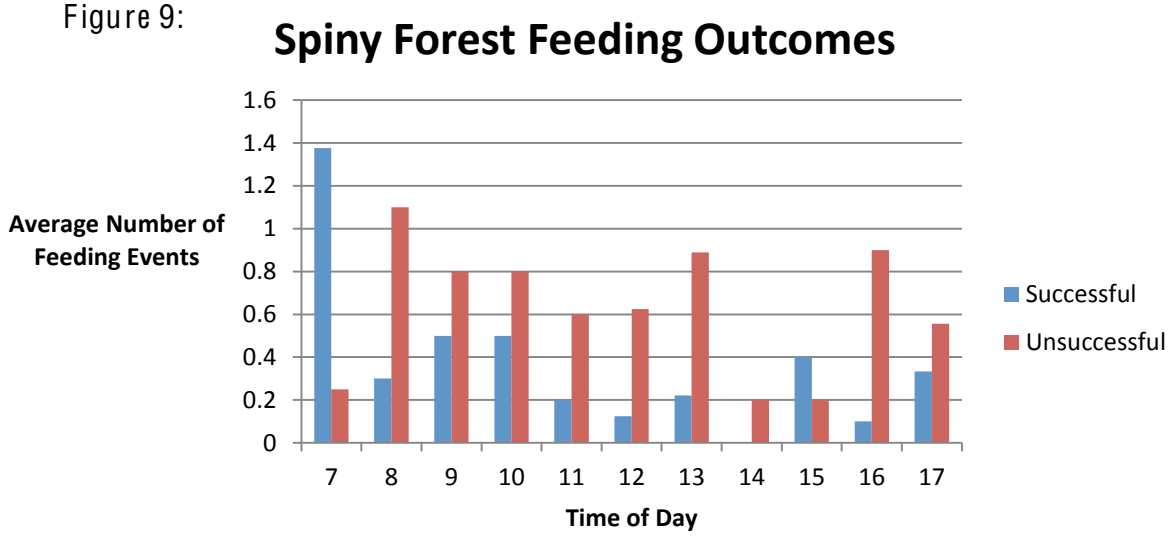


Both Figure 7 and Figure 8 show an initial gap between posture and sun exposure during the early morning hours.

In order to evaluate feeding behavior observed in the spiny forest and the gallery forest, vertical bar graphs demonstrating the average number of successful and unsuccessful feeding events during each hour of observation were constructed for both transects. In the spiny forest

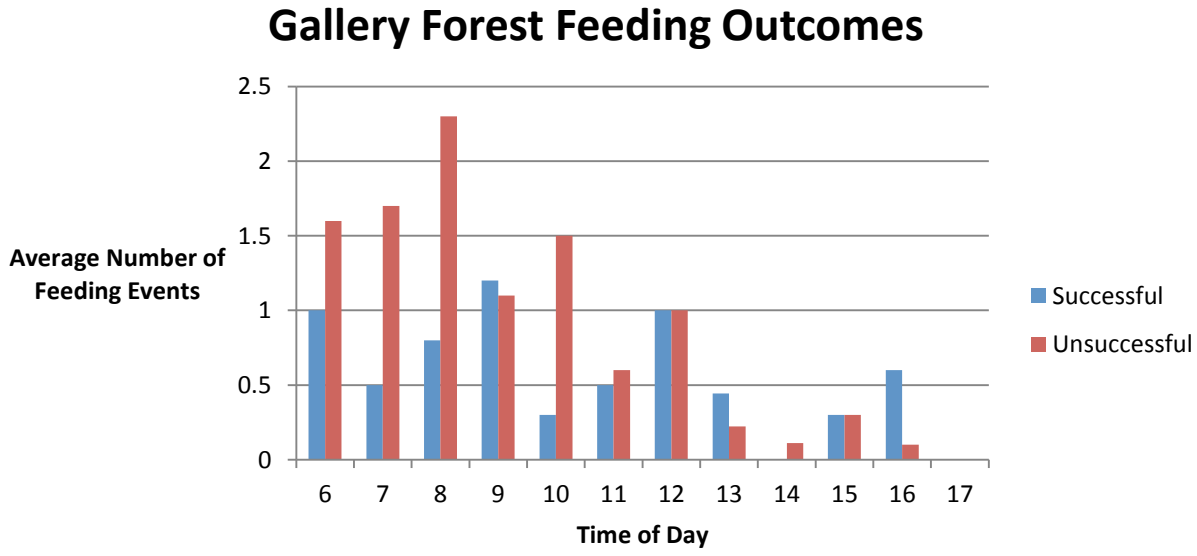
(Figure 9), feeding is most successful during the hours of 7AM and 3PM. All other hours have a feeding success rate of less than 50%.

Figure 9:



In the gallery forest (Figure 10), feeding is 50% or more successful during the hours of 9AM, 12PM, 1PM, 3PM, and 4PM.

Figure 10:



Although there are a greater number of successful feeding periods in the gallery forest than in the spiny forest, there is very little difference between the overall feeding success rates of each habitat (Spiny forest feeding success rate = 35.9%, Gallery forest feeding success rate = 38.5%). In addition, when the total number of feeding events (both successful and unsuccessful) is compared between the two habitats by the hour (Figure 11), one can see that both spiny forest individuals and gallery forest individuals follow the same general feeding pattern. Most feeding events occur during the morning hours, almost zero feeding events occur at 2PM, and a short, less eventful feeding period occurs in the late afternoon.

Figure 11:

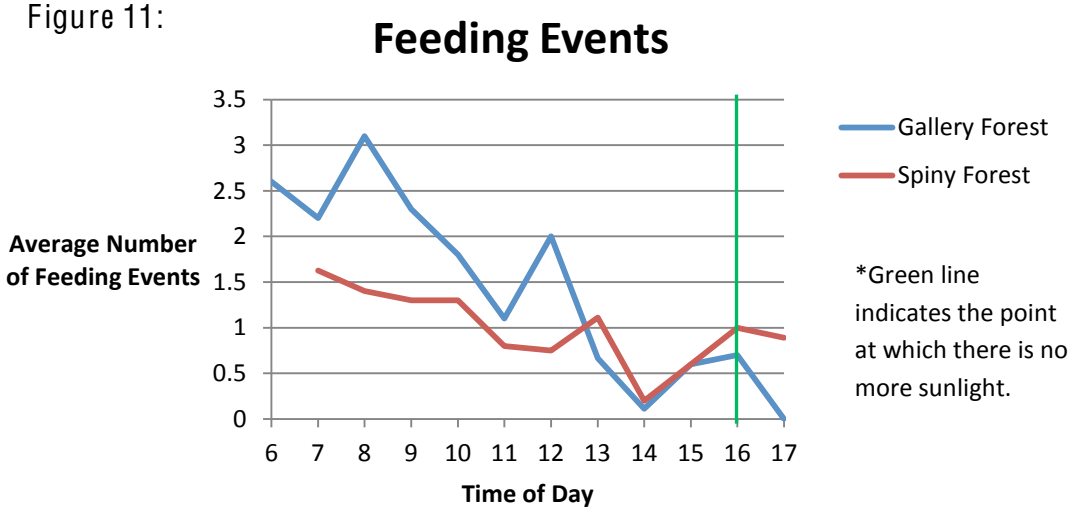


Figure 11 also demonstrates that individuals from the gallery forest consistently feed more than individuals from the spiny forest from 6AM to 12PM. Then, from 1PM to 5PM, gallery forest individuals consistently feed about the same or less than spiny forest individuals. In general, gallery forest individuals do feed more; a total of 156 feeding events were observed in the gallery forest, as opposed to a total of 103 feeding events in the spiny forest.

Figures 12 and 13 show that the gallery forest provides *Oplurus saxicola* with a greater variety of prey sizes than the spiny forest. (Spiny forest prey sample size = 37, Gallery forest prey sample size = 60)

Figure 12:

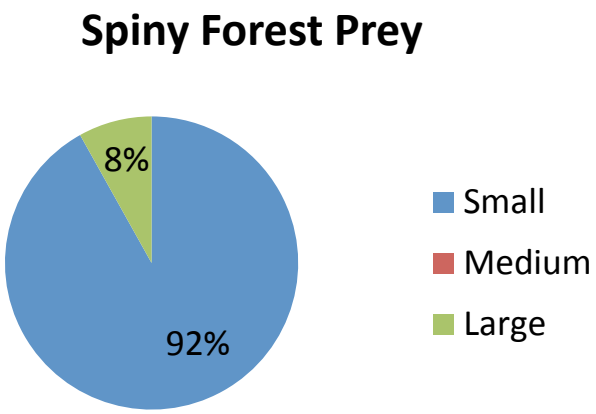
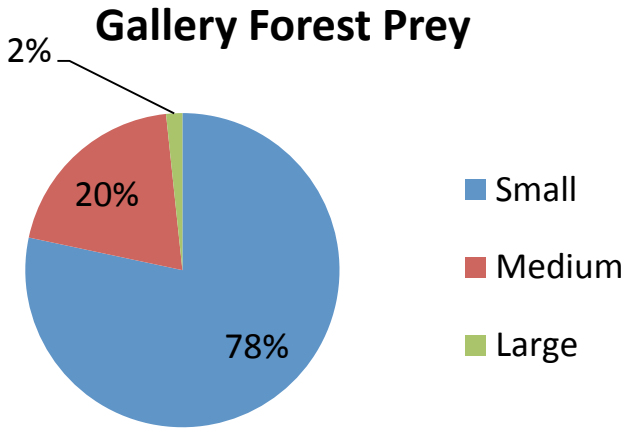


Figure 13:



Discussion:

Thermoregulation behavior in *Oplurus saxicola* does vary based on habitat. Since the spiny forest experiences more extreme temperatures (Figure 2), the iguanas living there have less tolerance for midday sun than their gallery forest counterparts. Spiny forest individuals spend

the most time in the sun during the early morning and late afternoon; during the hottest part of the day, they stay in the shade or half-shade (Figure 3).

In the gallery forest, day time temperatures are generally lower due to the effect of the nearby river. In addition, rocky cliffs and some forest cover shield the gallery forest transect from full sun exposure, especially towards the end of the day. Presumably due to limited sun availability, the second peak that spiny individuals spend in the sun is not observed in gallery forest individuals (Figure 4).

Oplurus saxicola also switches between three different postures in order to regulate its body temperature. The normal posture (back legs, lower abdomen, and tail flat against the ground, upper abdomen/chest propped up by the front legs) is seen most often. The flat posture (full body spread out against the ground) allows reptiles to gain heat from the ground when there is not enough sun or heat from the ambient temperature. Finally, the high posture (entire abdomen, and sometimes tail, elevated from the ground) is used when reptiles have already reached their optimal body temperature and don't need to absorb any more heat from the ground. Since both temperature and sun availability are higher in the spiny forest, high posture is slightly more common. In the spiny forest focals, high posture reaches a maximum of approximately 30% of the observation period (Figure 5), as opposed to a maximum of approximately 20% in the gallery forest focals (Figure 6). Conversely, flat posture is much more prevalent in the gallery forest than in the spiny forest. From 2PM to 5PM, gallery forest individuals spend more than 50% of the observation period in the flat posture (Figure 6), whereas flat posture in the spiny forest reaches a maximum of less than 40% (Figure 5).

Perhaps the difference in high posture between the spiny forest and the gallery forest is not as dramatic as the difference in flat posture because high posture is a very energy-expensive position to hold. An iguana may pause in a sunny area and assume high posture for ten seconds before running off to find a place with more shade, where the rocks are cool enough to stay in normal posture. It is rare to see an iguana maintain high posture continuously for more than one minute. Flat posture, on the other hand, requires a very minimal amount of energy – it is not uncommon for iguanas to stay in the flat posture for prolonged periods of time.

In the gallery forest, there is a strong correlation beginning at 9AM between the amount of sun exposure the focal receives and the height of its posture (Figure 8). Before 9AM, the posture height is much lower than the level of sun exposure. This pattern can also be seen in the spiny forest between 7AM and 9:30AM (Figure 7). Posture height is normally much lower than sun exposure in the early morning because the iguanas are mostly in the sun to warm up after a cool night, but there is no need for them to be in high posture since the rocks haven't heated up yet.

Although there is little difference in the overall feeding success rates between habitats, there is a clear difference in the pattern of successful feeding periods in the spiny forest as opposed to the gallery forest. (A successful feeding period is defined as an hour with a feeding success rate of 50% or more.) The spiny forest has two successful feeding periods: one in early morning, and another in late afternoon (Figure 9), while the gallery forest has five successful feeding periods spread throughout the day (Figure 10). This difference is due largely to the higher midday temperatures of the spiny forest. During the late morning and early afternoon, the first priority of spiny forest individuals is to find shade and avoid high temperatures as much as possible – not to feed. There is also a clear difference in the variety of prey size consumed in

each habitat. Gallery forest individuals feed on three different categories of prey size (Figure 13), as opposed to only two categories in the spiny forest (Figure 12). This difference is due simply to the greater variety and abundance of prey available in the gallery forest.

Although gallery forest individuals have more overall feeding events (unsuccessful and successful combined), individuals from both habitats follow the same general feeding pattern (Figure 11). Figure 11 also shows that gallery forest individuals feed more than spiny forest individuals during the morning hours, and less or the same as spiny forest individuals during the afternoon. The fact that gallery forest individuals have very little sun exposure during the afternoon (Figure 8) could account for lower activity levels, and thus, less feeding events during this period.

Conclusion:

Both thermoregulation and feeding behavior in *Oplurus saxicola* depend on the species' surrounding habitat. Differences in posture and movements from sun to shade are evident between the spiny forest and the gallery forest. Spiny forest individuals favor the normal posture throughout the day and spend the most time in the sun during the early morning and late afternoon. Gallery forest individuals, on the other hand, favor the flat posture during the afternoon, and do not spend much time in the afternoon sun. *Oplurus saxicola* of both habitats are omnivores, eating insects as well as flowers and leaves. Both populations also seem to be opportunistic feeders, attempting to feed on whatever is available. Gallery forest individuals feed throughout the day; whereas spiny forest individuals have two distinct times (early morning

and late afternoon) when feeding is most successful. In addition, gallery forest individuals feed more often and consume a greater variety of prey than their spiny forest counterparts.

Further Study:

This study could be repeated during the mating season of *Oplurus saxicola* in order to determine the effect of mating on thermoregulation and feeding behavior. Another similar study could be done focusing solely on juvenile *Oplurus saxicola* to analyze differences between adult and juvenile behavior.

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