# Impact of temperature on *Lycosid spp*. in the field and global climate change implications.

BIOS 569 – Practicum in Biology

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**Abstract**

Spiders and grasshopper are ectotherms and therefore changes in temperature should change their activity levels. Changes in these activity levels could have fitness consequences such as lower development rates and decreasing fecundity. Because of this, global warming could have serious implications in predator-prey interactions. This experiment utilized aluminum screen cages in an old field environment and wolf spiders (*Lycosa spp*.) and measured behavior/activity of spiders over a range of temperature. Temperature treatments included a decreased temperature treatment and an increased temperature treatment; these were compared to an ambient treatment. Observations were made over twelve hours for three days. ANOVA analyses did not find any significant differences between spider activity among temperature treatments. However there was a strong trend of increased activity in the increased temperature treatments. When compared to previous data on grasshoppers in the same old field habitat, it is seen that grasshoppers begin their daily activity during the time when the spiders are most active. In the morning and the evening, the grasshoppers actively move from night refuges and higher into the grass to increase access to heat radiation. A change in global temperature could either shorten activity times for both the spiders and grasshoppers by surpassing the optimum temperatures or lengthen them by increasing the time per day that the organisms have available for activity. Understanding the impact of global warming on the environment can make understanding the interactions in an ecological community.

**Introduction**

Ectotherms are abundant in most ecological communities; a plethora of organisms control their body heat using outside sources of heat radiation. But this type of heat exchange comes with limitations. Should an organism's primary heat radiation source decrease or be removed, the dependant organisms need to either find another radiation resource or modify their behavior so that less energy is consumed. These behavioral modifications in turn may have an effect on an animal's fitness by affecting predation rates, reproduction, and survivorship (Lima 1998). An ectothermic organism must compensate for differences in ambient temperature by changing energy expenditure. This is most easily done through a change in activity. Activities intrinsic to the survival of the organisms such as foraging could increase under warmer temperatures and decrease under lower temperatures. However, if temperatures became too high, temperature stress could occur, resulting in a decrease in activity. An increase in activity also increases predation risk. Therefore a difference in temperature could have a large impact on the abilities of ectotherms to prey upon other species, as well as avoid predation themselves.

Spiders are ectothermic predators. Temperature can affect their ability to hunt if it varies too much from their optimal temperature. Ambient temperatures that are too high or too low could cause spiders to lower activity, or in extreme cases be fatal. For spiders, a decrease in activity means a decrease in predation success, which could cause a decrease in survival and reproduction rates. Spiders are grasshoppers' common predators and grasshoppers are common herbivores in grasslands (Danner and Joern 2003, Oedekoven and Joern 1998). Cooler temperatures are also associated with lower feeding and activity rates in grasshoppers. When a grasshopper decreases its activity, it can decrease its chances of being preyed upon, but also decreases its foraging rates, causing decreases in reproduction and survival rates (Pitt 1999). An increase in temperature can cause an increase in grasshopper activity, which increases foraging and predation risk. In general, an organism will change its behaviors to avoid becoming prey by hiding or changing habitat and activity levels (Sih 1987, Lima and Dill1990, Werner and Anholt 1993).

Anti-predator behavior in grasshoppers changes as they morph from nymph stages to adult stages, i.e. choice of habitat. (Schultz 1981). As spiders are often more capable of preying on the nymphs than the adults (Oedekoven and Joern 1998), this anti-predation behavior is important for their initial survival. Schmitz et. al. (1997) saw significant changes in the amount of time per day that grasshoppers were active in the presence of spiders versus when no spiders were present. This decrease in activity led to lower energy availability for grasshoppers because they spend less time feeding. This decrease in energy led to slower development rates, a decrease in fecundity, and increased death rates from starvation. This relationship between predation risk and decrease in activity has been found in other systems as well (Semlitsch 1987, Skelly and Werner 1990, and Stamp and Bowers 1991). These experiments show that though predation itself can remove organisms from a community, the risk of predation can be equally important to survival and fitness of surviving/remaining organisms (Schmitz et. al. 1997, Lima 1998).

Because the effects of temperature on spider predation are not well documented, my experiment was designed with the intention of quantifying the effect of temperature on the activity of spiders. My hypothesis is that the spiders will show higher activity when exposed to higher temperatures and activity will decrease when exposed to cooler temperatures. Because spiders are ectotherms, it is highly probable that changes in ambient temperatures affect their behavior; this is important because an increase in spider activity may also increase the perceived risk of predation of the grasshoppers, thus changing grasshopper activity rates. The effect of temperature on grasshopper behavior has been measured at my site. Therefore, I can compare my data with data previously gathered on grasshoppers to infer what effects temperature might have on predator-prey interactions. By evaluating the behavior of spiders at different temperatures in this experiment against the same data for grasshoppers, conjectures about their interactions can be made.

Overall, it is important to know the reactions of the spiders and grasshoppers to temperature increase, as grasshoppers can be good bio-indicators of global warming and the spiders can affect grasshopper behavior. Changes in temperature have been shown to alter grasshopper-spider interactions in other grassland systems (Chase 1996). It's possible that changes in the behavior of an organism in an ecological community could indicate changes in the abiotic factors of an ecosystem. Higher activity rates in spiders could indicate higher activity rates in grasshoppers due to warmer temperatures. My study is important because predictions associated with global climate change indicate that ambient temperature will change, which can have significant implications for behavior and predator-prey interactions, especially among ectotherms.

**Materials and Methods**

The study site for this experiment was an old field that was clear-cut fifty years ago on the University of Notre Dame Environmental Research Center (UNDERC) in the Northwoods of Vilas Co., Wisconsin and Gogebic Co., Michigan. The most dominant grasshoppers at my site are *Camnula pellucida* and *Melanoplus dawsoni*. I used wolf spiders (*Lycosa spp.*), which are common predators of grasshoppers in grasslands. Spiders were captured for this experiment with pitfall traps in grassy meadows around the UNDERC property and transferred to aluminum cages for behavioral observations. The aluminum cages used for the first set of observations were 0.1 $m^2$ basal area with metal edges buried in the ground. Initially these cages were open at the bottom to provide a natural habitat of grasses for the spiders, but this style of cage complicated the observations as spiders could not be found in them, so aluminum screening was placed at the bottom of the cages and secured with tape. During the first observation the spiders were able to move under the screen and were lost. Therefore, a second type of cage was built for successive observations. This cage was also 0.1 $m^2$ basal area and closed with binder clips, but it was a cube shape made entirely out of aluminum screening so that the spiders could not be lost, unlike the tent-shaped cages that were previously used.

*Behavioral Observations:*

To test the effect of temperature on spider behavior, I created one treatment of increased temperature by covering the cages with 3 ml plastic sheeting and one treatment of decreased temperature by shading cages with 80% shade cloth. Temperature treatments were set up 0700 each day when the sun was high enough to shine on the cages and left up until 1300. Six cages were used per day and each of the cages was assigned a temperature treatment; two cages for each temperature treatment and two control cages. Treatments were assigned randomly to cages that occupied an 8.0 $m^2$ area and cages were secured to the ground with stakes so that they could not blow away. I added a small amount of *Phleum pretense* to each cage, covering about 20% of the cage bottom. This simulated the meadow environment more closely and provided the spiders with cover. A thermometer was placed in each cage so that temperatures could be measured in each treatment.

Behavioral observations were conducted in six cages per day from 0700 to 1800. On the day of an observation, the spiders were released into the cages and allowed to adjust to the new surroundings for 30 minutes before beginning observations. Spider activity (moving/not moving) and the location of the spider for each cage were recorded three times per hour. Temperature in the cage was also recorded at this time. Before recording behavior, I quietly observed each cage for two minutes and thirty seconds, so that my movements did not affect spider behavior. Weather disturbances and the inability to locate the spiders in the cages were also noted as they occurred. Ambient temperature at the site was recorded using a weather station. This was done for three days resulting in six replicates of each temperature treatment. Different spiders were used for each different observation day.

*Analysis:*

Analysis of the data was done using SYSTAT v. 10. Because the spider activity was quantified as a proportion of moving observations per total observations the data was transformed using an arcsine transformation. Time periods were pooled over all observation days and also for the times 0700-1100, 1100-1500, and 1500-1800 to match Pendergast (2002), so that grasshopper and spider behavior could be compared over specific time periods of the day. Data were analyzed using one-way analysis of variance (ANOVA).

## Results

*Temperature Treatments analysis:*

The increased temperature treatment exhibited the highest overall temperatures, until the 1300 hour of observation, when the greenhouses were removed from the cages (Fig.1). The shade treatments exhibited the lowest temperature over all treatments until the 1300 hour of observation (Fig.1) while control had intermediate temperature similar to the shade treatment. After 1300 the greenhouses and the shade cloths were removed from the cages because the sun was too high for the shade cloth to be effective and the greenhouses were possibly causing heat physiological stress, and all three treatments became similar in temperature.

*Behavior analysis:*

Average daily activity rates of spiders were not significantly different among treatments ($p=0.550$, $df= 17$, $F= 0.886$). However, strong trends were found in the data showing that the shade cages on average had less activity than the controls, and the controls had less spider activity than the greenhouses (Fig. 2).

For the pooled data per time periods 0700-1100, 1100-1500, and 1500-1800, the ANOVA tests were also not significant. For the morning and evening time periods similar trends were present, ($p=0.496$, $df= 17$, $F=0.756$) and ($p=0.373$, $df=17$, $F=1.104$) (Figs. 3 and 5) During these time periods the increased temperature treatments had the highest amount of spider activity and the decreased temperature treatments had the lowest amount of spider activity. For the afternoon treatments behavior/activity rates were similar among treatments, ($p=0.993$, $df=17$, $F= 0.007$) (Fig. 4).

**Discussion**

The results in my experiment were unexpected. The changes in temperature for the greenhouse treatments were very different from either of the other treatments but ANOVA did not find them significantly different. Many issues were faced in the achievement of this experiment and in the methods many problems occurred that I was not able to correct for various reasons. The most influential issues were that many replicates were lost in the first day of observation, and time was a constraining factor due to weather problems and the length of the study period. Attempts to add

**Figure 1.** Average temperature in enclosures for the three temperature treatments and ambient temperature is plotted against time, from 0700 to 1800. Arrow indicates the time, 1300, when the treatments were removed.

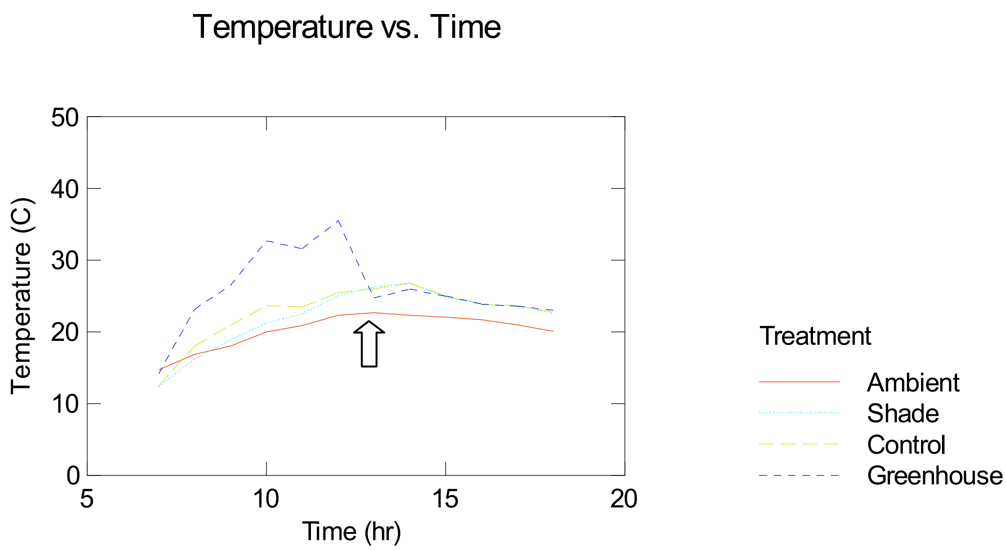



**Figure 2.** Average daily spider activity for each of the different temperature treatments.

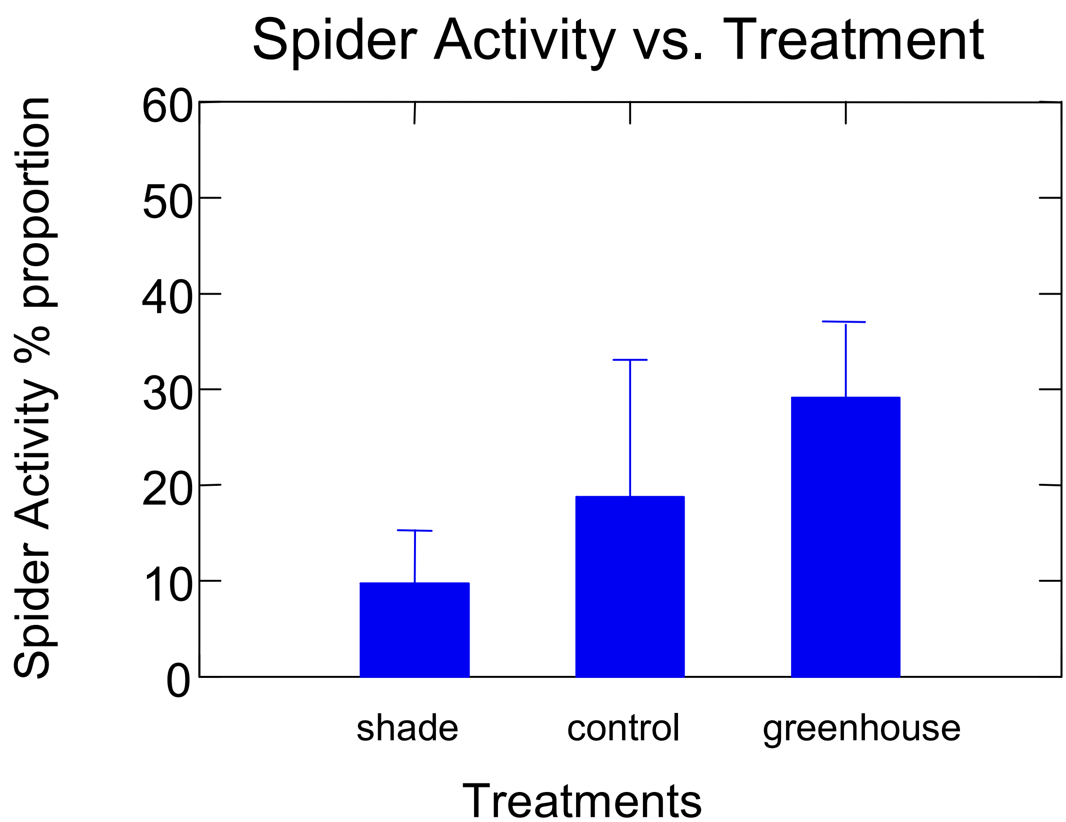


**Figure 3.** Average spider activity during the morning time period (0700-1100) for all observation days versus the temperature treatments.

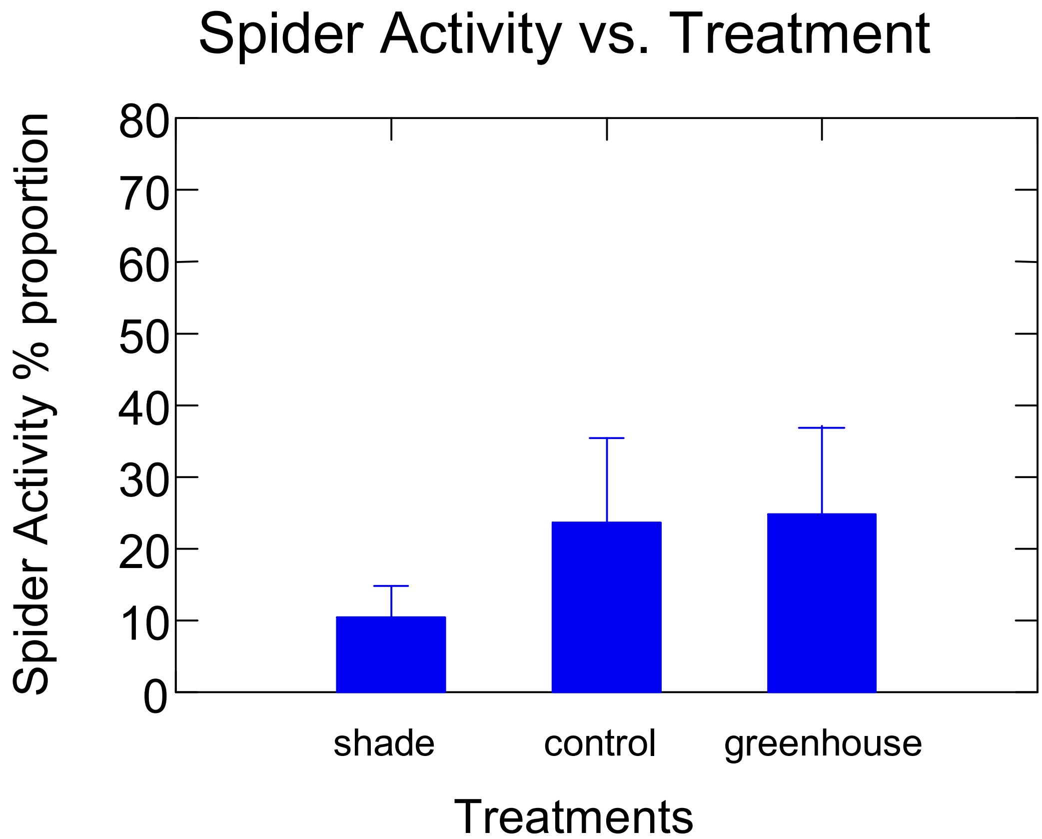


**Figure 4.** Average spider activity during the afternoon time period (1100-1500) for all observation days versus the temperature treatments.

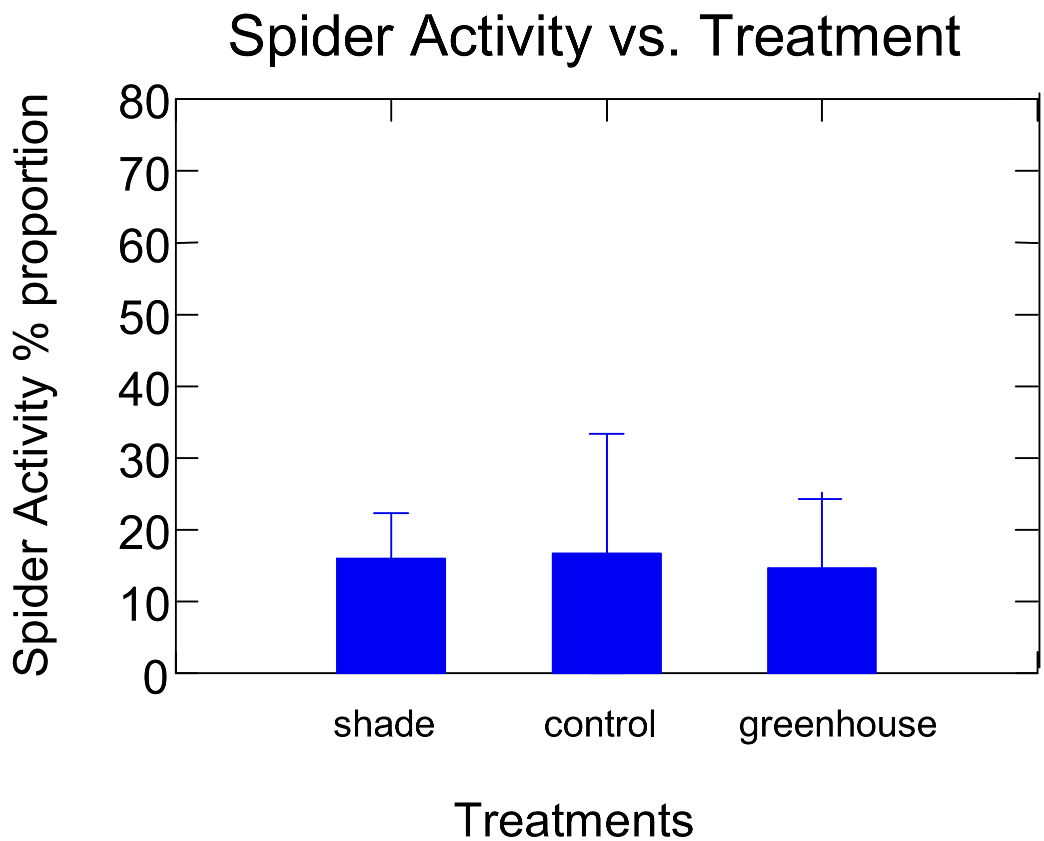
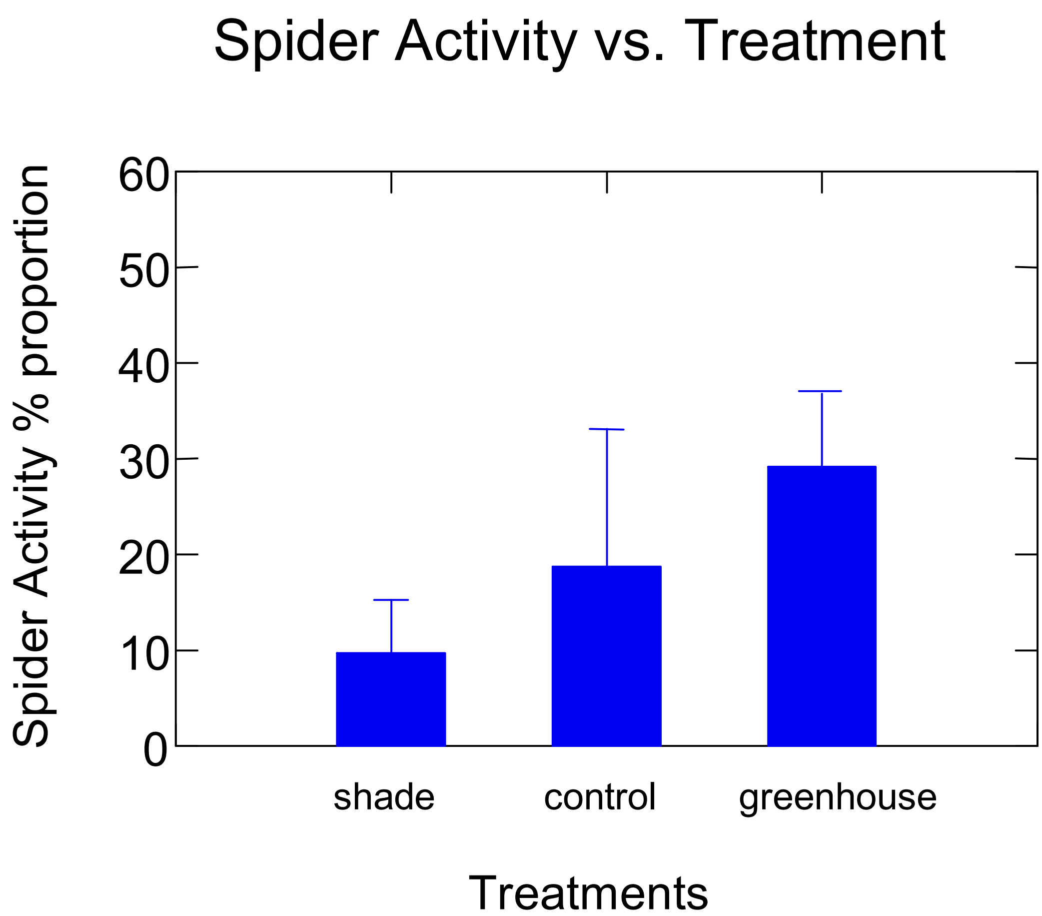


**Figure 5.** Average spider activity during the evening time period (1500-1800) for all observation days versus the temperature treatments.



more observation days were not possible. Despite this, I was able to find strong trends in the data.

Although the averages of the activity in the cages were not significantly different, trends were present that do suggest that higher ambient temperature results in higher spider activity. Because the spiders are ectotherms, this trend is expected. The trend occurred in activity per day data and for activity data in the morning and evening. This is interesting, because the morning showed a strong trend which is expected, but a similar trend was seen in the evening though the temperatures of all the treatments were similar in the evening. Perhaps this could be due to the cages retaining some of the heat radiation or because the spiders, regardless of the overall temperatures, might be most active in the morning and evening. Perhaps this is because the spiders tend to be nocturnal predators, and they base their activity more on time influences when the temperatures are not too extreme.

Spider activity could have very strong effects on the behavior of grasshoppers. Pendergast (unpublished data) showed that in the same old field, grasshoppers were active in the morning and in the evening when they were rising from the lower levels of the vegetation where they stay in the absence of heat. It is at these times that the spiders are most active. Thus, if in the presence of each other, the grasshoppers might have to remain low in the vegetation until a higher temperature or later in the day because their movement gives the active spiders a higher probability of preying upon them in the morning and the evening. Under low temperatures, the grasshoppers decreased activity (Pendergast unpublished data), and I was able to see this trend in the spiders. In the presence of each other, the grasshoppers may have to make a trade-off between foraging and predation risk. This will result in a lower survival, decreased fecundity, and slower development rates.

Should a difference in global climate change occur, the spider-grasshopper interactions could change and have an effect on the old-field food chain. In general higher temperatures result in higher activities for both the spiders and the grasshoppers. However, higher periods of inactivity could occur for both species, if the warmest part of the day is higher than the optimal temperature because organisms are subject to physiological stress when ambient temperature rises above their optimal temperature. A mild increase in the temperature could result in higher activity in the grasshoppers, making them more susceptible to predation from the spiders, but it is likely that the remaining grasshoppers will have a larger food supply and less competition, and no trophic cascade will occur. Global climate change might also cause temperature decrease in areas of the world. Should this be the case, the grasshoppers will display lower levels of activity, and spiders should be able to decrease the grasshopper density and indirectly increase the amount of vegetation present resulting in a trophic cascade (Chase 1996). A trophic cascade could dramatically change the vegetation in a habitat, and therefore change the primary productivity of the habitat. By observing the behavior of the ectotherms in a habitat, it could be possible to understand the consequences of global warming and use these organisms as bio-indicators of global climate change.

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