*Abundance of riparian spider webs as a response to temperature, rainfall, and distance from water*

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Field ecology

## Introduction

Riparian corridors are areas of land adjacent to a body of water be it lentic (still standing water such as lakes and ponds), or lotic (waterways such as rivers and streams). These corridors hold a treasure trove of hidden interactions between the organisms that inhabit the land and the water (Klapproth and Johnson 2009). The organisms that inhabit riparian areas are intimately linked to the organisms that reside within the aquatic environment. Studies such as those conducted by Nakano et al. (1999) provide a clear, in-depth look of these linkages by surveying the effects of terrestrial arthropod input removal on stream communities. With these areas in mind, many questions are raised concerning the tight interaction of species found. How are the aquatic and terrestrial food webs linked? What effects do aquatic insects have on those insects found on the land? What ecological consequences may result from degradation, alteration, or human use of these areas? In addition, how do abiotic factors such as weather and distance from streams affect terrestrial riparian predators such as spiders? This study looked at the effects of various abiotic factors on spider web density and captured prey abundance in relation to two riparian zones within the New River Valley in southwest Virginia, in order to understand these interactions.

Prior to the Nakano *et al*. (1999) study, most studies that examined inputs of terrestrial organic matter into streams were focused on terrestrial plant matter (Nakano *et al*. 1999).The question of how animals in the two environments were linked in their food webs were less clear. Reduced arthropod inputs into a stream were found to affect fish feeding patterns in a stream (Nakano et al. 1999), while it was discovered that aquatic emergent insects make up a large portion of riparian predator`s diet (Krell et al. 2015). Land types a factor in the percentage of emergent insects in a riparian predator`s diet( Krell et al. 2015), and the abundance of riparian spiders is dependent on the abundance of riparian insects (Burdon and Harding 2008). This latter point was also reported by Kato et a. (2003) with regards to a reduction in emergent insects and Tetragnathid orb weavers.

Such reports may imply that there is more to spider feeding behavior than simple abundance, otherwise it would make sense during times of the year when emerging insects were low in abundance that spiders may switch to a different food source. It should be noted that this study did not show significant decrease of spider density in the testing during the month of July, as during July the abundance of aquatic emerging insects is already naturally low ( Kato et al. 2003). With that in mind, a predator's preferred prey is not always the most common in its diet (Huseynov et al. 2005). Studies conducted on the feeding behavior of *Aelurillus muganicus,* a jumping spider in the Family Salticidae illustrates this point (Huseynov et al. 2005). *A.muganicus* is naturally myrmecopgagic, feeding on ants, and while feeding tests in a laboratory setting revealed a predisposition toward ants as a prey item, in field observations there were more sightings of predation on ticks and Lepidopteran larvae, than on ants, of which there were 11 sightings (Huseynov et al. 2005). Huseynon et al. (2005) shows some level of plasticity in prey choice, even though it also shows that prey preference might be innate, as behaviors for capturing ants were seen in laboratory spiders not previously exposed to ants.

With the findings of Krell et al. (2015) showing a large dietary dependence on emerging aquatic insects when it relates to riparian predators, the link between distance to a body of water and the effect on riparian predators comes into question. It was found that despite the vegetation among transects remaining relatively constant, there was an inverse relation between spider web abundance and distance from a stream, with webs decreasing in abundance with an increasing distance (Burdon and Harding 2008). Distance was not the only factor influencing spider density; removal of vegetation caused a 72% decrease in tetragnathid spider density on average, with a 96% reduction in areas with reduced vegetation and stream channelization (Laeser et al. 2005).

While much has been made about density of spiders as a response to distance from a body of water, how does climate as a variable effect spider abundance? Spiders will slow their feeding as a result of lessened energy requirement, however some spiders remain metabolically active enough to spin webs, as technique used in some families such as Salticidae (Aithchison 1984). Spiders too have a temperature threshold, under which activity will cease (Aitchison 1984). Certain families do remain active in cold weather under litter and snowfall, such as Lycosidae and Tetragnathidae, and winter-active spiders such as *Ceraticelus* spp. will feed infrequently down to -2 °C (Aitcheson 1984). In addition to variation in feeding during low temperatures, there is some degree of variation in spatial behavior of spiders in response to thermal patterns as well (Abraham 1983). Abraham (1983) found that spider abundance decreases in vegetation decreases as they head to the ground to over winter. This is backed up by an increase in ground spider abundance (Abraham 1983).

As seen above with Nakano et al. (1999), alteration of trophic interactions can cascade down an ecosystem. With the removal of terrestrial inputs, we see that the Dolly Varden Char in turn depresses the abundance of aquatic herbivorous insects. The removal of inputs can be seen as a model stand-in for increased spider abundance, which in turn not only reduces insects that may fall out of trees into streams by capturing said insects in webbing, but also by capturing adult insects that return to water sources to mate and lay eggs. Flying insects and their larvae including caddisflies and mayflies are an important food sources for fish such as trout and grayling (Ball 1961). If cold weather sees a depression in spider abundance, then warming planetary temperatures could lead to changes in riparian food webs described above. This study may also show, based on spider web abundance in relation to distance from the water, how degradation of riparian corridors might affect spider density over all. Such alterations could very well be a matter of public concern, as with a decrease in spider abundance an increase in pest abundance is likely without being said pests being predated by the disappearing spider population. This could lead to an increase in public health threats in insects such as mosquitos and the spread of parasites and arboviruses, as well as threats to agriculture such as locusts and other Orthopterans.

With all these variables considered, and a study planned three questions remain. (I);How do abiotic factors such decreasing winter temperatures along with prior weather patterns such as rainfall affect spider abundance and average amount of prey captured in webs? (II); How does an increase in distance from water affect the average prey amount captured in webs?

Based on the information provided, I hypothesize that with decreasing temperatures, due to decreasing metabolism and a migration towards the ground, overall spider-web abundance will likewise decrease as average temperatures, as well as low and highs decrease. In addition, webs further from the water along both the x and y axis will see a decrease in captured emerging insects due the insects having greater space to disperse

**Methods:**

*Study site*

This study was conducted at two sites in the New River valley: Pandapas Pond and the New River at Whitethorne boat launch. These two locations were chosen due to ease of access. Both sites had a clearly defined trail with water on one edge, and woods or other non-water features the opposite edge.

*New River at Whitethorne boat launch*


*Satellite image of Pandapas pond, courtesy of Google Maps*

*Variables*

The predictor variables in this study were time of day, average temperature, weather of the prior day (rainfall in cm, prior day low temperature, and prior day high temperature), distance from water in along a horizontal axis, as well as a vertical axis, or the height of the web off the water or ground. The responses measured were web abundance per set transect, web size, web type (orb web vs non-orb web vs single strand), as well as the percent of emerging aquatic insects in the web. For the latter point, emerging aquatic insects includes those that spend a considerable amount of time near water or have an aquatic life stage such as gnats, mosquitoes, midges, mayflies, and stoneflies. When possible, spiders were categorized by morphospecies. Non-orb webs in this study were full webs that did not follow the typical orb weaver pattern. Single stranded webs were those webs that were one or many strands, but had no pattern and did not fit into the other two categories.

*Sampling*

The edge of the trails on the non-water side was searched for spider webs, as were the areas adjacent to the water. When a web was found, measurements relating to distance and weather were taken. Air temperatures were taken in degrees Celsius, and time of day was also recorded. The distance to the back edge of the web from the edge of the water to the web was measured and recorded using a meter tape, to see how far a spider would build from the water's edge. With a smaller tape measure, distance from the water along a vertical axis was measured from ground or water to the bottom of the web. The bottom of the web was chosen to determine how low a spider would build its web, as the hypotheses that lower webs would capture more prey was due to the emerging insects leaving the water. In addition, the diameter of the web was also recorded from edge to edge. Due to the nature of the webs and visibility issues of accurately seeing two different strands, the diameter measurement was taken to the nearest half centimeter. Several specimens were collected for a minor feeding trial as well as for further identification if possible.

A consistent route was kept as much as possible along both systems, although several instances of inconsistent routes occurred, making it necessary to take distance measurements in order to standardize the captured data. Any data belonging to days were it was impossible to recreate the survey route with confidence were discarded. In order to find the area of the transect measured, the length of the transect was used as well as the width. To find this at the New River site, the closest web found was used to find the distance to the water, with the furthest web being used to calculate the total width of the trail followed. This worked at the New River because the width of the trail is relatively consistent, and surveys along the wood side of the trail were limited to the edge. For Pandapas, due to the circular nature and lack of tree cover, Google Maps was used to measure the transect area for the most accurate result. Google Maps proved impractical at the New River site due to the amount of tree cover.

Past weather patterns for the day prior to the sampling day was compiled using the app WeatherSTEM for temperatures and rainfall based on the Kentland Farms station. Transect P1 did not have recorded temperatures, so using weatherSTEM an average was found using the time of day at 3:05 pm, with four additional time points leading up to and following 3:05 pm at ten minute intervals. Average temperature for all transects and dates were done using weatherSTEM and the recorded time of day to be consistent, as weatherSTEM data differed from thermometer readings due to variables such as shade and wind, and could potentially skew the data pattern. WeatherSTEM was used to find the rainfall of the prior day in centimeters, as well as the low/high temperatures of the prior day from 12:00AM to 11:59PM using the data mining function.

In addition to the observational study, a minor feeding trial was also planned as part of this study, however, due to lack of spiders in the webs in the field, this portion failed as only two spiders survived to the feeding test and neither ate.

The study focuses on spiders at large, although when possible, spiders were grouped into morphospecies based on characteristics, and in the absence of an individual spider, the webs found were grouped by type. According to Dr. Brent Opell of Virginia Polytechnic Institute and State University, most Araeindade, or “orb weavers”, have since died off this late in the year ( Personal Correspondence 2019), so the study was altered to not be as discriminate. In support of this decision, with regards to riparian spiders and their relation with emerging aquatic insects, Marczak and Richardson (2007) found subsidy exclusion affected multiple spider families, and that the abundance of multiple orb-weaver families could be controlled by the level of emerging insects.

*Statistical analysis*

Statistics for the study were run in the program R, utilizing linear models and generalized linear models. Predictor variables included average temperature, prior day low temperatures, prior day high temperatures, prior day rainfall totals, as well as horizontal and vertical distances of the web from the water or ground. The response variables tested were spider web abundance, as well as average prey captured in webs on a given day. Site was also included as a fixed effect in all models, except in cases were AIC analysis suggested that a model without site provided a better fit, in which case site was left out entirely.

Prior to analysis spider web abundance data were log transformed to an approximate normal distribution. From here, a linear model was used to analyze the effect of various predictor variables on web abundance. In order to avoid pseudoreplication, and because many predictor variables were measured on a per survey basis, the prey abundance data per web were averaged for each survey date prior to analysis. This was done for horizontal distance data as well, in which distance x and distance y were also averaged, as each varied within a day transect unlike weather findings.For web level data with average prey abundance as a response variable, Gamma or Gaussion with a generalized linear model were used depending on a right skewed vs normal distribution. Certain generalized linear models within web level data relating average prey captured with prior day low temperatures, high temperatures, rainfall, and distance measurementswould not work with site included in the code, so a duplicate line of code without site included was used, and for all other web level models, this was replicated using AIC analysis to compare the models and find the best fitting one. Based on AIC analysis, models for horizontal and vertical distance use site as a fixed effect, with AIC values of 15.24219 and 8.31427 respectively, both of which were smaller figures than the AIC for models that did not contain site as a fixed effect (16.74145 and 10.95693). Models for average temperature(AIC without site =12.33710 vs 13.29622), prior day low temperatures(AIC without site =15.47232 vs 16.46479), prior day high temperatures (AIC without site=12.34677 vs 13.20669) , and rainfall totals(AIC without site=16.41881 vs 16.52341) did not include site as a fixed effect.  For transect level data, linear mixed effect models with site included as a random effect were used to relate spiderweb density to the temperature variables listed above as well as rainfall.

## **Results**

Average temperature during a sampling period was not found to have a significant effect on spider web abundance ($p=0.176, t=1.630$, Figure 1). In addition, there was also no found significant effect of prior day low temperatures (p=0.1380, t=1.840,Figure 1.1)

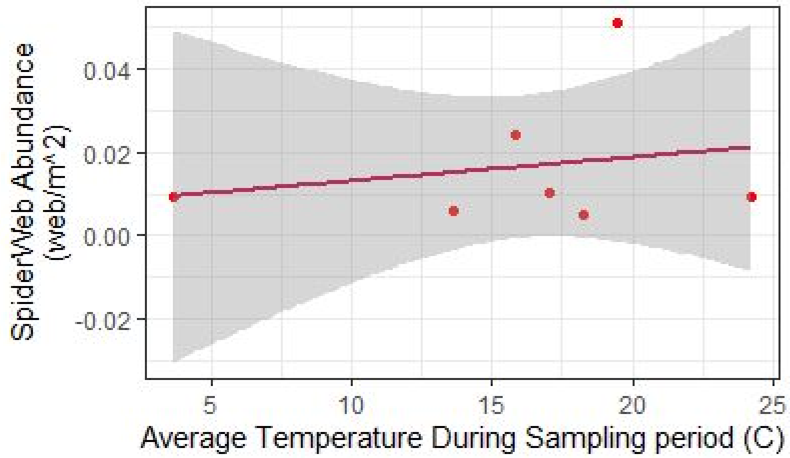


*Figure* 1 : *Effect of Average Temperature on web abundance in a given transect*

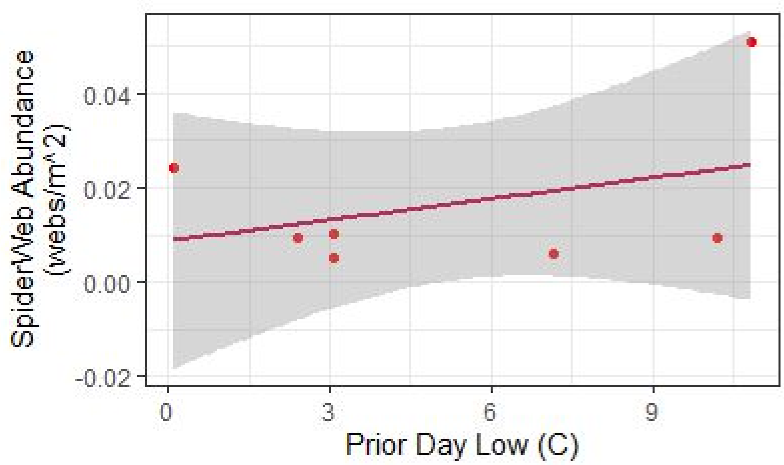


*Figure* 1.1 : *Effect of prior day low temperatures on web abundance in a given transect*

The effect of prior day high temperatures on spider web abundance was not significant (p = 0.10730, t = 2.058, Figure 1.2). There was no found effect from the prior day rainfall total on spider web abundance (p = 0.7049, t = -0.403, Figure 1.3).

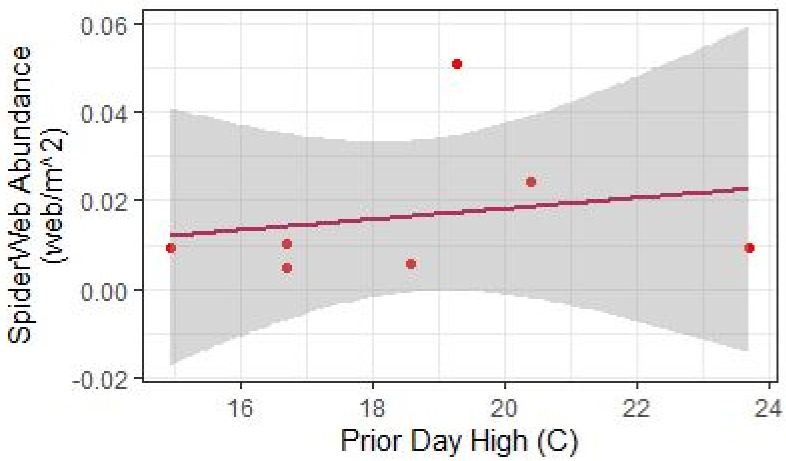


*Figure* 1.2 : *Effect of prior day high temperature on web abundance in a transect.*

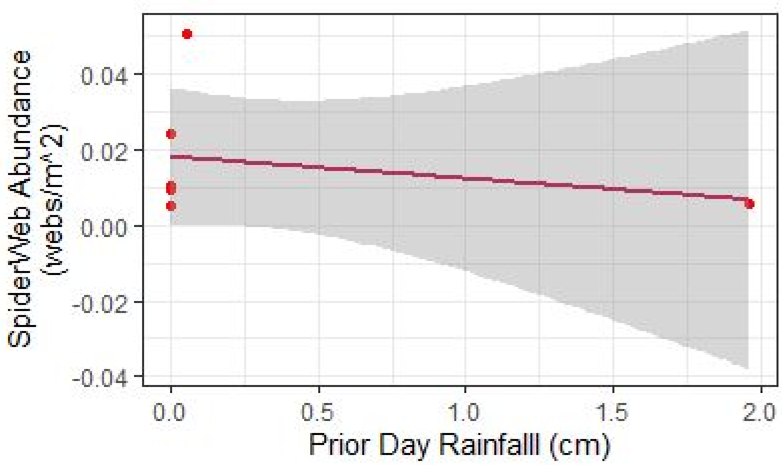


*Figure* 1.3 : *Effect on prior day rainfall totals on web abundance in a transect.*

There was found to be a marginally significant relationship between average temperature (p= 0.0908,t= -2.091, Figure 1.4) during the sampling period and the average prey abundance per web on a given day. There was no significant effect from prior day lows on average prey abundance per web on a given day( p= 0.216, t=-1.414, Figure 1.5). Prior day highs however did have a marginally significant effect on average prey per web on a given day (p=0.0792, t=-2.199, Figure 1.6). Interestingly, prior highs for web transect data also had a minor marginally significant effect on web abundance(p= .10730, t=2.058).

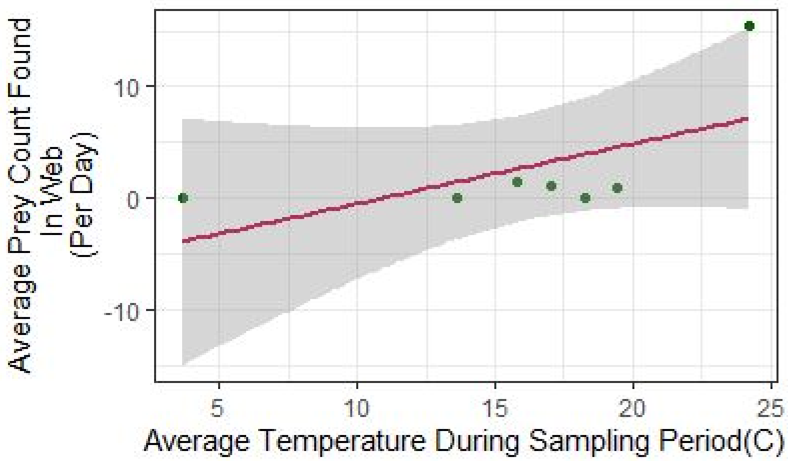


*Figure* 1.4 : *Effect of average temperature on average prey in web on a given day*

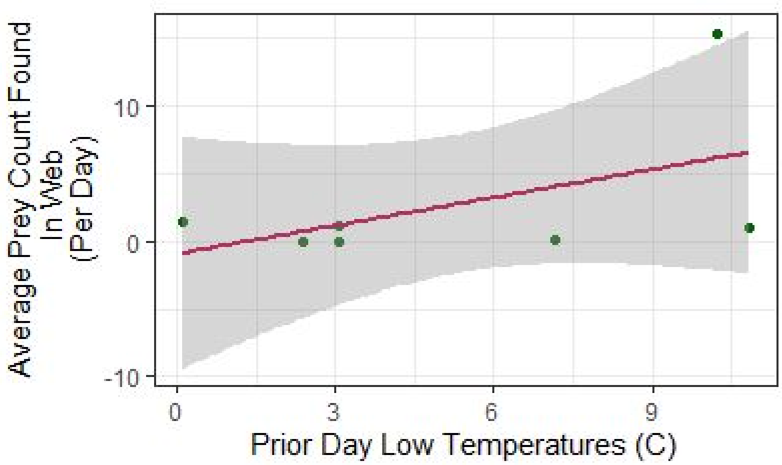


*Figure* 1.5 : *Effect of prior day low temperature on average prey in web on a given day*

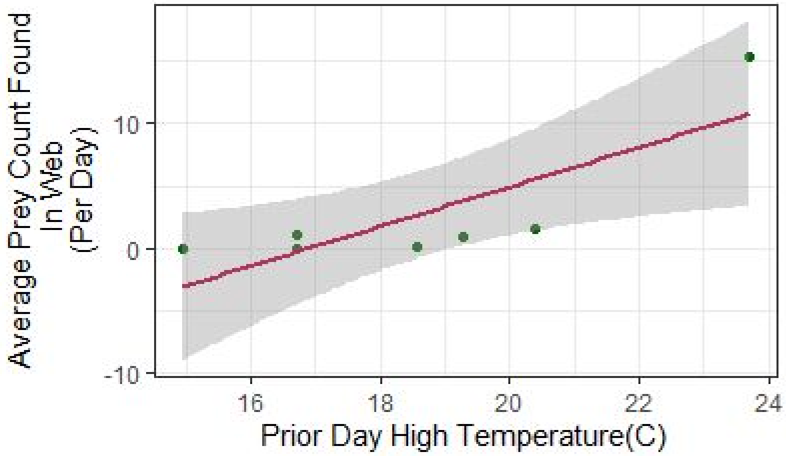


*Figure 1.6 : Effect of prior day high temperatures on average prey in web on a given day*

There was no found significant effect on average prey captured in a web on a given day when it came to the distance from the stream or shoreline along a horizontal axis to the web (p=0.740, t=-0.365, Figure 1.7). There was, however, found to be a marginally significant effect on average prey captured in a web on a given day in regards to the distance from the water or ground along a vertical axis to a web (p=0.078, t=2.634, Figure 1.8). Just as there was no significant effect from prior day rainfall on web abundance(p=0.7049, t=-0.403), there was found to be no significance effect from prior day rainfall and average prey count per web on a given day (p=0 .578, t=0.595, Figure 1.9).

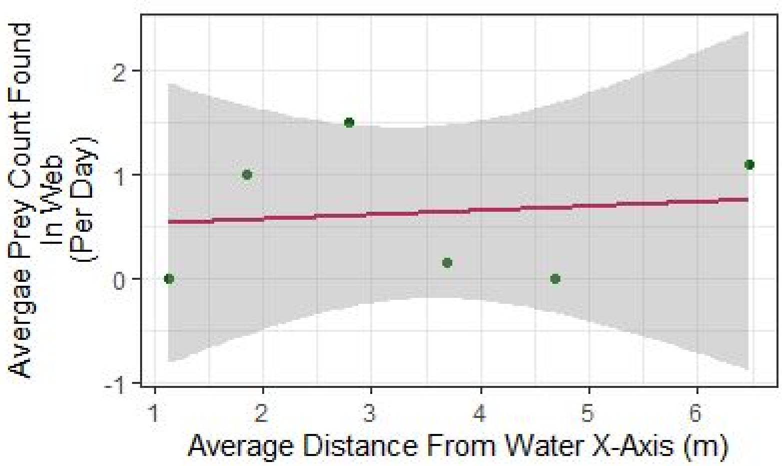


*Figure 1.7 : Effect of distance from water along horizontal axis on average prey in web on a given day*

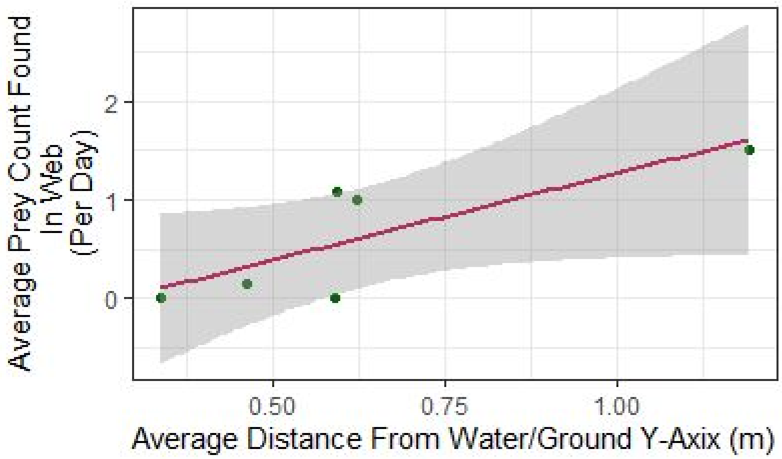


*Figure 1.8 : Effect of distance from water/ground along vertical axis on average prey in web in a given day*

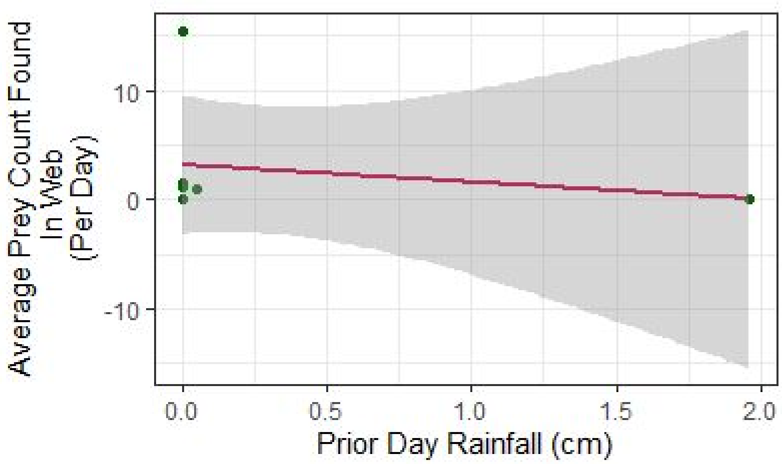


*Figure 1.9 : Effect of prior day rainfall total on average prey in web on a given day*

**Discussion**

*Summary of study*

This study attempted to look at the relationship between declining temperatures and overall rainfall and their effect on spider web abundance, as well as of temperature and rainfall, in addition to distance from the water on average prey captured in webs on a given day. The hypothesis for this study was that as average temperatures, as well as prior day lows and highs decreased, so too would spider web abundance as metabolism and activity levels slow. As distance from the streamline or shoreline along an x-axis increased, as well as distance from the water's edge or ground along a y-axis, there would be a decrease in captured prey due to increasing space for said prey to disperse prior to capture

*Analysis and Hypothesis*

Much of the data compiled fell outside the parameters of normality and significance. Even when the abundance data for the transect level was log transformed, only the relation between prior day high temperatures and abundance came close to a level of marginal significance . As such, data on declining average temperatures and prior day lows could not be used to make any inference on their effect on spider web abundance. While it may be tempting to use the relationship between prior day highs and spider web abundance to support the hypothesis that a decline in temperatures causes a decline in web abundance, the fact that the significance of the relationship lies just outside of what could be considered to be marginally significant, as well as the non-significance of the other two temperature variables, makes it hard if not impossible to evaluate this part of the hypothesis. An alternative hypothesis, that a decrease in prior high temperatures alone, due to an effect on spider feeding activity, or perhaps some link to emerging aquatic insects, causes a decrease in spider web abundance, is a better fit based on the data analysis performed and the statistical results found. This alternative hypothesis, and the explanation behind it, is also supported by the fact that the relation between prior day high temperatures and average captured prey per day was also marginally significant. It should be noted as well that there was a marginally significant relationship as well between average temperature over a sampling period and average captured prey per day, so some care should be taken when considering the effect of prior day high temperature on prey abundance, and by extension web abundance based on the proposed alternative hypothesis.

For web level data, there was no significance between the distance from a body of water along a horizontal-axis, and average prey abundance. However, along a vertical axis, the relation was found to be marginally significant. With this, no statements can be made for the horizontal axis component of the hypothesis, however the hypothesis that with an increase in distance along the vertical axis comes a decrease in average prey abundance can not be supported, as with a marginally significant relationship there is a positive correlation between increasing distances and increasing average prey abundance in webs. An alternative hypothesis to explain this, is that due to emerging aquatic insects flying after leaving the water, or when returning to it, those webs that are made at higher elevations have an increased probability of capturing flying prey items.

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*Past works*

Past scientific studies found that with an increase in distance from a body of water, there was a decrease in spider web abundance (Burdon and Harding 2008). Unfortunately, due to limitations in the experimental design, such a claim could not be tested in this study. Likewise, failure to find a significant relation between prior day low temperatures and spider web abundance does not allow for the data gathered to support or deny Aitcheson`s (1984) statements regarding ongoing metabolic activities for processes such as web spinning. Abraham`s (1983) statement regarding an increase in ground spider abundance could not be attested for as this study did not look at such populations.

*Caveats*

This study should be approached with some level of skepticism when it comes to drawing conclusions based on pure numbers and statistical analysis. Many areas of this study broke down due to a failure of experimental design and improper sampling techniques. One large example of this is drawing conclusions from web abundance. Due to improper transect sampling, it was necessary to try to faithfully recreate the areas of the sites samples and group them by date transects and then find the spider web density by finding web per area. While length of the transects were measured to a high degree of confidence using meter tape for the New River and Google Maps for Pandapas, finding area was more challenging and were the most error probably occurred. The area was most likely over estimated, which causes the web abundance measurements to be lower than they may be in all actuality, especially considering some dates were sampled with a second person not attached to this project. For consistency, WeatherSTEM was used to gather all weather data, even though ***most*** transects and temperature measured with a thermometer. This decision was made when it became apparent that the WeatherSTEM was presenting different measurements than the thermometer was, probably due to windchill and shaded areas that WeatherSTEM could not take into account, so as not to skew the patterns in temperature that were serving as a predictor variable.

All this could be solved by a properly implemented experimental design. Data was recorded during a “test run”, with many variables not being recorded as of yet. Ideally all such variables should have been decided on before any sampling to avoid running into the issue of having recorded good data for the response variable, but having left out recordings for many of the response variables. All temperatures should have been recorded using a thermometer in order to find the average temperature, and all distance measurements should also have been taken properly.

The largest issue was an improper transect design. Rather than simply walking a fixed route, which did not in all actuality occur, and surveying the water areas and vegetation along the trail edge, set transect areas should have been used in order to create an accurate area and web count. The water side of the trails and the wooded side were not evenly sampled, which not only made it improbable to get an accurate area estimation instead of overestimating, but made it impossible to correlate distance of water with spider web abundance, since it could not be said that the distance from the water was evenly sampled. To alleviate this in future studies, a fixed square transect should be used for area measurements, and spot transects should be used in tandem to allow for distance to be used as a predictor variable for web abundance. This would also allow for better recording and analysis as distance as a predictor variable for web abundance, as the study in its current design did not allow for even sampling of distance. A proper redesigned transect system would also rule out sefl-replication as it could be ensured that the same transect was not being sampled twice.

The big takeaway from this project is that certain abiotic factors such as prior day high temperatures and the height at which a spider builds it webbing influences the behavior of spiders in the form of their web building activity, as well as how much prey is captured by a spider`s web. It is important to study these factors due to their relation to changing global weather patterns, as well as the insight that certain spatial aspects of ecological communities, in this case vertical vegetation, are important if we want to maintain healthy interactions among communities in riparian ecosystems.

## **Works Cited**


Abraham, B. 1983. Spatial and temporal patterns in a sagebrush steppe spider community (Arachnida, Araneae). The Journal of Arachnology 11: 31-50.

Aitchison, C. W. 1984. Low Temperature Feeding by Winter-Active Spiders . The Journal of Arachnology 12: 297–305. doi: 10.1007/978-3-642-71552-5_19

Ball, J. N. 1961. On the food of the brown trout of Llyn Tegid. Proceedings of the Zoological Society of London 137:599–662.

Burdon, F. J., and J.S. Harding. 2008. The linkage between riparian predators and aquatic insects across a stream-resource spectrum. Freshwater Biology 53: 330–346.

Kato, C., T. Iwata, S. Nakano, and D. Kishi. 2003. Dynamics of aquatic insect flux affects distribution of riparian web-building spiders. Oikos 103:113–120.

Cotton, M. J., and C. H. S. Watts. 1967. The ecology of the tick Ixodes trianguliceps Birula (Arachnida; Acarina; Ixodoidea). Parasitology 57: 525–531.

Huseynov, E. F., F. R. Cross, and R. R. Jackson. 2005. Natural diet and prey-choice behaviour of Aelurillus muganicus (Araneae: Salticidae), a myrmecophagic jumping spider from Azerbaijan. Journal of Zoology 267:159–165.

Klapproth, J. C., and J.E. Johnson. 2009. Understanding the Science Behind Riparian Forest Buffers: Effects on Plant and Animal Communities. Virginia Cooperative Extension. https://www.pubs.ext.vt.edu/420/420-152/420-152.html.

Krell, B., N. Röder, M. Link, R. Gergs, M. H. Entling, and R. B. Schäfer. 2015. Aquatic prey subsidies to riparian spiders in a stream with different land use types. Limnologica 51:1–7.

Laeser, S. R., C. V. Baxter, and K.D Fausch. 2005. Riparian vegetation loss, stream channelization, and web-weaving spiders in northern Japan. Ecological Research 20: 646–651.

Marczak, L. B., and J.S.Richardson. 2007. Spiders and subsidies: results from the riparian zone of a coastal temperate rainforest. Journal of Animal Ecology 76: 687–694.

Nakano, S., H. Miyasaka, and N. Kuhara. 1999. Terrestrial-aquatic linkages: Riparian arthropod inputs alter trophic cascades in a stream food web. Ecology 80: 2435–2441.