The effects of web surface area and elevation on prey capture rate of cobweb weaving spiders.

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Abstract
This study examines various abiotic and biotic factors that influence the capture rate of cobweb weaving spiders in a deciduous forest in Pellston, MI. The spiders studied were of the family *Theridiidae*. Spiders and their corresponding webs were identified, marked, and observed for six days. Capture rate, web elevation, web surface area, spider size, and spider presence were compared over two separate sites. A significant relationship was found between capture rate and surface area, in which capture rate increases with surface area (p-value = .008). Significant results were demonstrated regarding the mean capture rate and web location in which webs on Grapevine trail demonstrated a higher capture rate (.339 prey items/12hrs) than webs on Pinepoint Trail (.237 prey items/12hrs). Capture rate is higher during the day (.36 prey items/12hrs) than at night (.21 prey items/12hrs). Additional correlations between location, elevation, and surface area were also observed. This research demonstrates various ecological implications of the spiders' niche in the ecosystem studied.

Introduction

Spiders play an important role in the ecosystems of northern Michigan forests. In the temperate forests of North America, spiders account for a large percentage of arthropod predator biomass (Aitchison and Sutherland, 2000). Although it is known that spiders substantially impact the density of their prey, (Wise, 1993) how spider web dimensions and elevation effect prey capture has not been fully explored. These relationships in orb web spiders have been previously described, though corresponding research on cobweb spiders is relatively sparse. Cobwebs are three-dimensional webs of no particular shape or pattern, generally appearing as irregular meshes of web (Kaston, 1944). The majority of *Theridiidae* spiders spin three-dimensional cobwebs, often using sticky lines (gumfoot threads) to anchor their non-sticky, wool type nets to the substrate (Agnarsson, 2004). This study exclusively analyzed cobweb spinning members of the *Theridiidae* family. *Theridiidae* is one of the largest spider families, with 2214 species and 86 genera, (Platnick, 2005) and a common spider family in the Douglas Lake landscape (the species *Theridion frondeum* was especially prevalent).

Spiders invest significant energy in the construction of their web, constituting the entire search phase of the foraging sequence (Rypstra, 1982). Therefore, spiders spend a majority of their time on their webs once constructed (Enders, 1976). Correlations have been found between the size and shape of orb webs, and resulting foraging success and predation risk (Gillespie, 2002). Additionally, previous studies of orb-weaving spiders address the selective pressure on web construction: webs of higher surface area favor prey capture, but also increase the risk of predation. It was found that orb-weaving spiders favor closed, protected web locations, regardless of the decrease in foraging opportunity (Blamires, 2007). This study addresses similar questions concerning cobweb weaving spiders. Specifically, the correlation between capture rate and spider presence (as an indicator of predation) and the surface area of cobwebs was addressed. It was hypothesized that spiders in webs of greater surface area would be more effective at capturing prey, but would also be more susceptible to predation. Additionally, this study investigated the difference in the surface area and capture rate of webs in two separate locations. As both locations were similar in vegetative composition (likely resulting in similar foraging and predation pressures), it was predicted that there would be no significant difference in the surface area or capture rate of webs in the two locations.

Elevation is another important factor in prey capture. Differing elevation of webs within a spider population allows for the capture of variety of prey items. Grounded webs are potentially more effective in the capture of terrestrial prey though possibly more susceptible to flooding, damage by debris, and disruption by terrestrial animals. Webs of higher elevation allow for a greater capture rate of flying insects (Foelix, 1996), but also impose a greater risk of predation. This study examined the effect of elevation on foraging success against predation risk. It was hypothesized that prey capture would increase with elevation. However, it was also hypothesized that as web elevation increased, risk of predation and damage to web (resulting in web abandonment) would also increase linearly.

Materials and Methods

Data were initially taken on 20 individual cobwebs with their respective spiders. Webs were chosen within the first 500 meters of the Grapevine Point Nature Trailhead, and approximately 10 meters off the path, within the University of Michigan Biological Station temperate deciduous forest. These webs were selected on May 23, 2012, in the early afternoon. Later, on May 26 2012, ten additional webs from the same location were added to the sample, again in the early afternoon. At each web's location, trees were marked with red flagging tape at eye level, and a flag with the web's corresponding number was placed in close proximity.

A meter stick was used to measure the lowest and highest elevation of the web. The width and depth of web measurements were taken with a ruler. All webs were assumed to be approximately rectangular prisms for later measurements of surface area and volume calculations. At each web the spider was removed by blowing on them and/or tapping the web gently as to cause minimal damage to the spider and/or the web. The spider was placed in a 150 cm^3 vial. On site, using a toothpick, spiders were marked with yellow or green acrylic paint tested as non-toxic to vertebrates. The paint was placed on the abdomen to be least likely to inhibit spider behavior or predation detection. Each spider was measured with a ruler while inside of the container and assigned a size class. Size classes were defined as: $.25\ cm \leq x < .5\ cm$, $.5\ cm \leq x < .75\ cm$, $.75\ cm \leq x < 1\ cm$, $1\ cm \leq x$. Additionally, existing prey items in the web were marked to avoid interference in future data collection. The spider was then released back onto its web. This process was repeated for each web.

Data were collected at 7:00 AM and 7:00 PM over the span of 6 days for the primary sample of 20 spiders, and 4 days for the secondary sample of 10 spiders. As data were collected, the presence/absence of the spider was noted, as well as any prey items captured. Notes were also taken for any relevant information (i.e. web damage, other spiders present, etc.). New prey items were marked to, again, avoid interference in future data collection.

On the sixth day a large rainstorm came through the area and consequently destroyed or partially destroyed the 30 original webs. As a result of the storm, 30 new webs were selected along Pinepoint Trail at the University of Michigan Biological Station, within the first 500 meters of the trailhead, and within approximately 10 meters off the path. Using the same procedure, data on presence/absence and prey items were collected for six days at the Pinepoint site.

New webs were found and were measured using the same procedure used for the original 30 webs. After data collection was complete, the webs were removed from the same site, condensed into a ball by hand, and placed into small labeled vials. These webs were weighed on a scale with accuracy of one ten-thousandths of a gram. Comparisons were made between the weight (mg) and the volume (cm^3), as well as the weight (mg) and surface area (cm^2). It was found that volume is not an accurate predictor of density, but weight and surface area showed a strong correlation. Thus we were able to estimate the weight of the webs based on their surface areas. Analysis regarding elevation of web may still hold relevance, though potential differences in density cannot be ignored as a confounding variable.

In order to statistically analyze the data collected, T-tests and linear regressions were performed in SPSS 19 to determine significance. The effect of surface area on capture rate and elevation was studied using linear regression. The relationship of elevation on capture rate was also studied using linear regression. Independent T-tests were used to study the effects of location on surface area, elevation, capture rate, spider size, and spider. The same test was used to analyze the effect of time of day on spider presence and capture rate. Finally, the relationship between spider presence and capture rate was studied using a linear regression.

Results

A significant relationship, in which capture rate increases with surface area, was demonstrated (p=.008) (figure 1.). However, there was no significant trend between capture rate and web elevation (p=.902) (figure 2.). Additionally, the data demonstrated a significant relationship between location and capture rate, in which webs on Grapevine trail were found to have a greater capture rate (.339 items/12hrs) compared to Pinepoint trail (.24 items/12hrs) (p=.05). A significant relationship was established between capture rate and time of day; a greater capture rate was recorded in the evening (.36 items/12 hrs.) than in the morning (.21 items/12 hrs.) (p<.001), thus more prey items were caught during the day than during the night. However, no significant trends were demonstrated between spider presence and capture rate (p=.251) (figure 3.), spider size and capture rate (p=.488), nor between time of day and spider presence (p=.418).

Regarding web elevation, no significant relationship was found between elevation and spider size (p=.173) or elevation and web surface area (p=.680). The data demonstrated a slight trend between spider presence and elevation in which presence increased with elevation, although this relationship was not statistically significant (p=.137) (figure 4.). There was a significant correlation between location and web elevation (p=.006) in which webs had a higher mean elevation at Pinepoint trail (64.24 cm) than at Grapevine trail (31.30 cm).

Regarding location, the data supported a significant relationship between location and spider presence; spiders were found 77% of the time at Pinepoint trail compared to Grapevine trail where the spiders were found 53% of the time (p<.001). However, no trend was found between location and spider size (p=.277). Additionally, the mean surface area at Grapevine trail (310.92 cm^2) is significantly smaller than the mean surface area at Pinepoint trail (1478.17 cm^2) (p=.001).

Discussion

The hypothesis that capture rate would increase as a function of web surface area was supported. Analysis did show a correlation between capture rate and the surface area of the web, most likely due to the potential for increased contact with prey that a greater surface area provided.

In contrast to the hypothesis, the capture rate of webs of higher elevation did not differ from webs of lower elevation. These results are compatible with past research of orb-weaving spiders, in which foraging success was not related to the elevation of the web, and similar types of prey were intercepted at any web height (Prokop, 2005). In this study, terrestrial prey items were observed in all elevations of webs, and it is likely that terrestrial prey items were climbing the web substrates. Additionally, elevation did not appear to have an effect on predation on spiders, as elevation had no significant effect on the presence of the spiders. As all spiders observed measured less than one centimeter, it is possible that these spiders were unlikely to be detected by predators regardless of elevation. Both trails have dense foliage that limited light, especially in the range of the observed webs, allowing for protective camouflage of the spiders.

The study provided evidence that a significant difference in capture rates did exist between Grapevine and Pinepoint trails, in which a greater capture rate was demonstrated at Grapevine, thus refuting the initial hypothesis. This significance may be due to variation in observation dates between the Grapevine and Pinepoint trail areas. As the necessity for the Pinepoint trail observation period was unforeseen, the study was subject to uncontrolled variation in weather and temperature. Temperatures were significantly lower during the observation period at Pinepoint, causing potential prey items to be less active, and therefore less likely to be caught in a web. Differences in capture rates between the two sites may also be due to differences in location characteristics. Grapevine trail is farther from the water, and of higher elevation than Pinepoint trail. It is possible that these characteristics compose a more desirable environment for spider prey.

Additionally, the study provided evidence of a relationship between the elevation of the webs and the sites in which they were found. Webs at Pinepoint trail had a significantly higher elevation than those at Grapevine trail. This may be due to bias in the selection of webs at Pinepoint, as webs were selected immediately following a storm; the potential sample may have been altered by effects of the storm from factors such as flooding or fallen debris. Webs near ground level may have been more susceptible to these damages, and therefore not available for selection. Additionally, surface area of the webs was significantly larger at Grapevine trail than at Pinepoint trail, which is most likely due to damage of the webs caused by the storm.

No significant relationship was observed between capture rate and spider presence. Although several spiders experienced low foraging success throughout the observational period, they most likely chose not to abandon their webs due to the substantial energy investment in web construction. Had the observation period been extended, spiders experiencing minimal success may have abandoned their webs.

Spider presence was significantly higher at Pinepoint trail versus Grapevine trail. This may be due to the colder weather experienced by spiders during the Pinepoint observation period, as spiders closer to their lower threshold for temperature may be less likely to leave their webs. Additionally, webs selected at Pinepoint trail had already withstood several days of storms. Selected webs may have been better adapted for storms and cold weather than the webs selected during temperate weather at Grapevine trail; thus, spiders at Pinepoint trail may have been less likely to abandon their web. It is also possible that human error affected finding the spiders, as spiders camouflage well within their surroundings.

Finally, time of day proved to be a significant factor in prey capture. More prey items were captured during the day than during the night, possibly indicating the majority of spider prey items are diurnal rather than nocturnal. Additionally, prey may be less active (and less susceptible to capture) during the night as a result of lower temperatures.

Several limiting factors persisted during this experiment. First, the variation in temperature and weather throughout the observation period created an unstable environment for exploration of the spider/prey relationship, and made comparison between sites difficult. Further, the timespan of the study was not adequate to sufficiently test spider abandonment and predation. Additionally, human error in finding and identifying prey and spiders, as well as possible recounting of prey, may have led to inaccuracy. In future studies, a larger sample size of webs in varying locations is necessary to further support the hypotheses proposed in this study. To more accurately describe spider presence, spiders should be tagged instead of painted, and a more concrete method of identifying and marking prey items should be developed. Surface area in this experiment was calculated based on the equation of a rectangular prism. In future studies, a more precise measurement would better allow exploration of the relationship between surface area and prey capture. Finally, future exploration of spider/prey relationships in a variety of different areas of temperate forests would improve understanding of the factors that influence capture rate.

Statistical Analysis

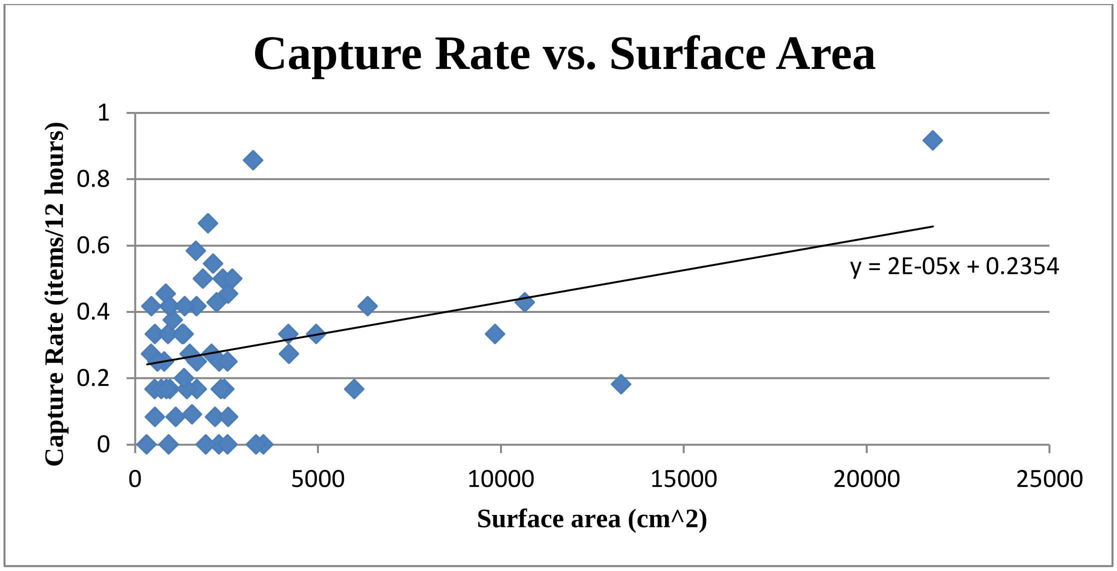
Table 1

Relationship	P value	R^2 value
Capture Rate vs. Location	.05	
Capture Rate vs. Surface Area	.008	.116
Capture Rate vs. Elevation	.902	.000
Capture Rate vs. Spider Presence	.251	.023
Capture Rate vs. Time of Day	<.001	
Capture Rate vs. Spider Size	.488	
Elevation vs. Spider Presence	.137	.038
Elevation vs. Location	.006	
Elevation vs. Spider Size	.173	
Elevation vs. Surface Area	.680	.003
Location vs. Spider Presence	<.001	
Location vs. Spider Size	.277	
Location vs. Surface Area	.001	
Time of Day vs. Spider Presence	.418	

<u>Web Characteristics</u>

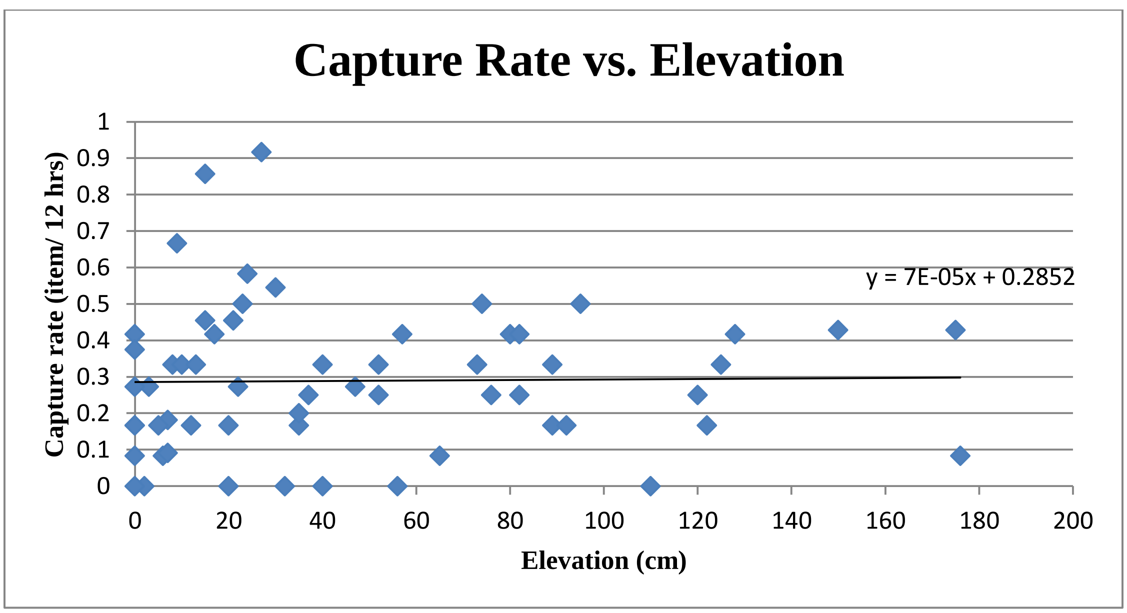
	Presence	# of prey	Web Elevation (cm)	Size Class	Surface Area (cm^2)	Capture Rate (prey /12 hrs)
GP	0.53	3.63	31.3	2.40	3742.6	0.34
PP	0.77	2.79	64.2	2.62	1711.1	0.24
Total	0.65	3.21	47.8	2.51	2726..9	0.29

Figure 1.



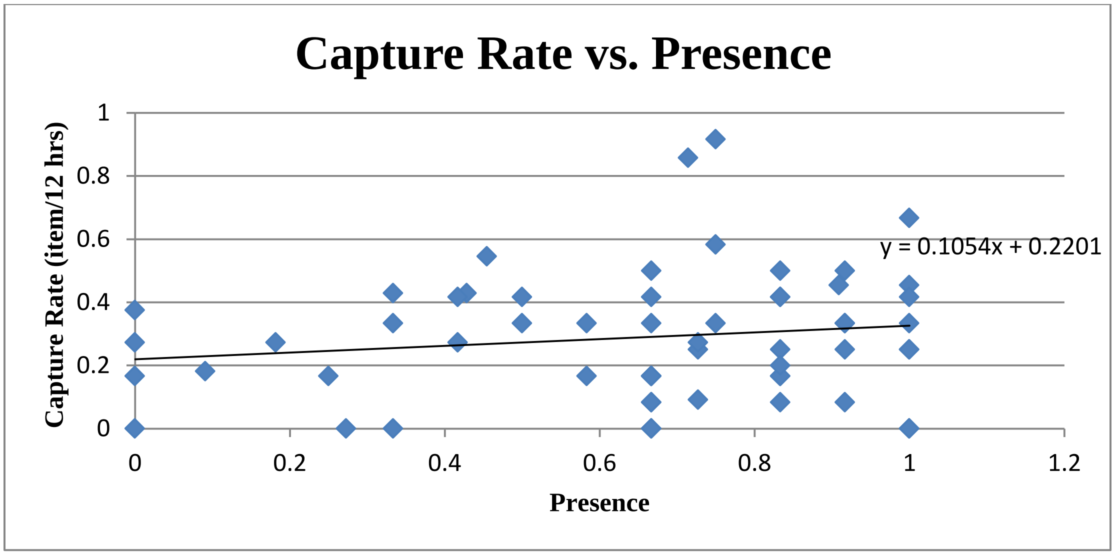
This graph demonstrates the effect of surface area on capture rate of cobwebs. A significant relationship (*p*=.008) was established.

Figure 2.



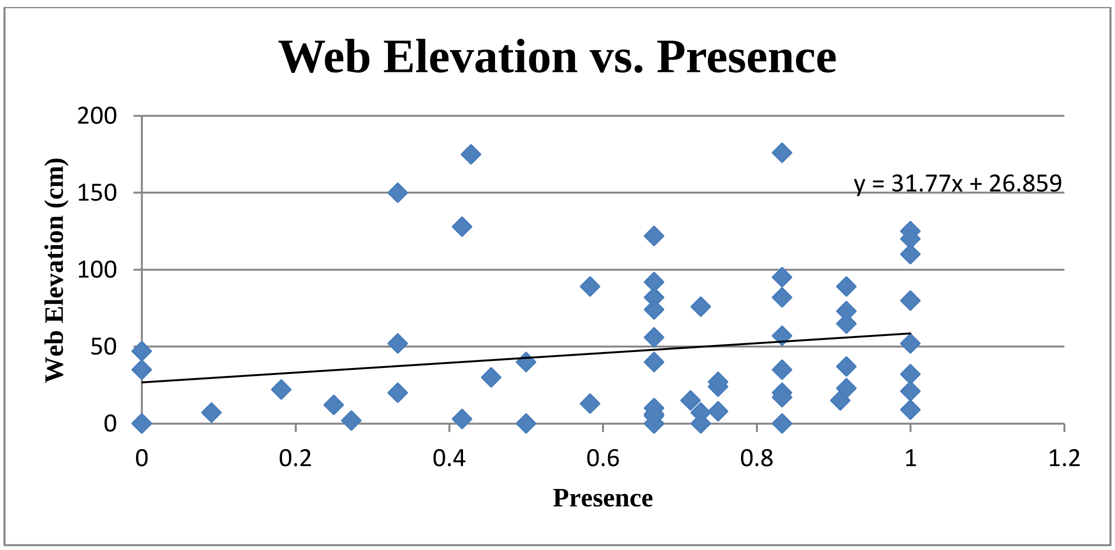
This graph demonstrates the relationship between capture rate and elevation. No significant trend was established (*p*=.902).

Figure 3.



This graph demonstrates the relationship between capture rate and spider presence. No significant trend was established (*p*=.251).

Figure 4.



This graph demonstrates the relationship between web elevation and spider presence. Although insignificant, a trend is demonstrated (*p*= .137)

Resources

Agnarsson I. 2004. Morphological phylogeny of cobweb spiders and their relatives (Araneae, Araneoidea, Theridiidae). Zoological Journal of the Linnean Society 141: 447-626.

Aitchison, C.W. and Sutherland, G.D. 2000. Diversity of Forest Upland Arachnid Communities in Manitoba Taiga (Araneae, Opiliones). Canadian Naturalist 114(4): 636-65 1.

Blackledge, T. A., and Gillespie, R. G. 2002. Estimation of Capture Areas of Spider Orb Webs in Relation to Asymmetry. Journal of Arachnology 30: 70-77.

Kaston, B. J. (1944). Descriptions of Families and Keys to the More Common Genera. Pages 61-263 *in* J. F. Bamrick and E.T. Cawley, editors . How to know the spiders. Wm. C. Brown Company Publishers, Dubuque, Iowa, USA.

Platnick, N. I. 2005. The World Spider Catalog. American Museum of Natural History 6:5.

Prokop, P., and Gruglakova, D. (2005). Factors affecting the foraging success of the wasp-like spider argiope bruennichi (aranae): Role of web design. Biologia, 60(2), 165-169.

Rypstra, Ann L. 1982. Building a better insect trap; An experimental investigation of prey capture in a variety of spider webs. Oceologica, 52: 1, 31-36.

Wise, D. H. (1993). Spiders ecological webs. (p. 17, 142). Cambridge : Cambridge University Press.