Foraging Success of Web-Building Spiders in the North Woods

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ABSTRACT

Spiders are one of the most diverse and abundant carnivorous invertebrates on the planet with the unique ability to capture their prey within a silk web their bodies produce. This study examines four web-building spider families in the North Woods of Land O' Lakes, Wisconsin to understand how different web types result in differential foraging success across multiple habitats. We studied orb weavers (Araneidae and Tetragnathidae), sheet weavers (Linyphiidae), and cob weavers (Theridiidae). The webs were observed throughout the summer month of June across multiple locations that included wet, forest, and building sites. Sheet webs were commonly found across wet and forest sites, while orb webs and cobwebs were scarce in these sites. An almost equal abundance of all three web types occurred in building sites. Daily and nightly insect counts were taken of sampled webs within sites. We found that orb webs captured the most insects through out most of the sites, even though they were not abundant in all of them. We found that body size, web size, and insect counts were all strongly correlated, which suggests that other factors are important in web success. The purpose of our study was to gain insight on how web-building spiders and their webs can act as bioindicators through prey control and habitat quality throughout various habitats, with the potential to relate our findings to similar environments for further studies.

INTRODUCTION

In certain environments, the survival of species depends on factors such as abiotic and biotic conditions, foraging decisions, and location for optimal reproduction and foraging success (Pasquet et al. 1999). There are over 40,000 species of spiders making them the largest, most diverse group of arachnids (Weber 2003). Spiders are unique due to their ability to capture prey through building webs in diverse locations such as open air, tree branches, and forest floors

(Blamires et al. 2007, Glover 2013, Uetz 1986, Prokop 2005, Gillespie 1987, Halaj et al. 2000, Shochat et al. 2004). Webs vary in structure and have recently been studied due to their ability to be strong and lightweight (Römer and Scheibel 2008, Slotta et al. 2012). Web building spiders make webs from silk, a strong protein fiber formed from alanine and glycine amino acids produced by the spider (Römer and Scheibel 2008, Slotta et al. 2012). Recent studies have shown that silk differs across spider species and web construction (Römer and Scheibel 2008, Slotta et al. 2012). Web building has been shown to be highly correlated with previous prey capture success, spider satiation, and whether or not the spider is a top predator in the area (Blamires et al. 2007).

An array of research has addressed how environmental factors correlate to foraging success of spiders. Previous research includes measuring foraging success by length of webs, location of webs (i.e. open space, shrubs, buildings), insect capture count and diversity, location of spider within its web (i.e. middle of web or hiding near web), and previous capture of prey success (Blamires et al. 2007, Pasquet et al. 1999). For example, spiders that build orb webs were found to have a positive correlation between web size and foraging success (Blamires et al. 2007, Pasquet et al. 1999). Another study showed that webs without stabilimenta, or web decoration, captured more insects but experienced increased damage from predators (Blackledge and Wenzel 1998). Other studies have found that spiders have the tendency to build webs in locations where resources are abundant (Uetz 1986, Prokop 2005, Gillespie 1987, Halaj et al. 2000, Glover 2013). It has been found that when resources are plentiful, numerous species of spiders can live in the same habitat without developing aggressive tendencies (Rypstra 1986, Glover 2013). High diversity of spiders within an ecosystem has been positively linked to habitat quality (Gollan et al. 2010, Marc et al. 1999).

Twenty families of spiders inhabit the northern woods of North America (Weber 2003). With the variety of spiders found in these woods, the diversity of web characteristics between different species of spiders can be studied. The purpose of the study is to understand what type of web is superior for foraging success. In order to understand web types, four spider families (Araneidae, Tetragnathidae, Linyphiidae, and Theridiidae) with different types of web construction will be observed in three site types. Araneidae and Tetragnathidae build orb webs, which are usually circular, two-dimensional, and vertical to the ground with a nearby retreat (Weber 2003). Orb weavers reside in a diversity of habitats where most choose to build webs in open areas, maximizing chances of successful predation (Blamires et al. 2007, Glover 2013, Halaj et al. 2000). Linyphiidae build sheet webs, which are horizontal sheets of silk that can appear dome-, bowl-, and flat-shaped, placed near the forest floor, trees, and shrubs (Weber 2003, Shochat et al. 2004). Linyphiidae are known for their sit-and-wait strategy of foraging and can survive for longer periods without food than other spiders (Riechert and Gillespie 1986, Glover 2013, Harwood et al. 2003). Theridiidae build cobwebs, tangled, three-dimensional masses of silk that are typically abundant in and around houses (Weber 2003). Species within Theridiidae are known to be social and, therefore, unlikely to cannibalize (Agnarsson 2002, Rypstra 1986).

In our study, we examined relationships between spider body size, web size, and capture of insects. We hypothesized that spider size is positively correlated to the size of the web and that web size is related to number of insects found within webs. Larger webs are shown to have greater success capturing prey, leading to a positive correlation between spider body size, web size, and foraging success (Blamires et al. 2007, Lowe et al. 2014, Pasquet et al. 1999, Prokop 2005). This is because larger spiders will be able to create larger webs, thus covering more area than smaller spiders and their webs. Besides observing the relationship between spiders, webs, and insect counts, we were also interested in the diversity of web types across site types. By observing web types in diverse habitats, it can lead to important indications of prey control and habitat quality. We tested the hypothesis that orb weavers are more successful foragers than cob weavers and sheet weavers. We believe that orb weavers will be more successful foragers due to previous research finding orb web size to be correlated to foraging success (Blamires et al. 2007, Pasquet et al. 1999). Understanding variation in foraging success can provide insight into the abilities of different spider groups as prey control. For example, agrosystems use diverse groups of spiders to control crop pests (Riechert 1999). Spiders are important predators that are essential to proper functioning of ecosystems (Gollan et al. 2010) and can be used as bioindicators of change in prey populations and anthropogenic effects in habitats (Marc et al. 1999), making it crucial to understand their ability to forage successfully and live in diverse communities.

METHODS

We conducted our study in the north woods at the University of Notre Dame Environmental Research Center (UNDERC) located near Land O' Lakes, Wisconsin during the first three weeks of June. UNDERC is a preserved environment with little to no anthropogenic effects, suggesting webs will most likely be intact and any damage will mostly be due to environmental factors rather than anthropogenic factors.

At five locations we examined three different site types: wet sites, forest sites, and building sites. The three sites were chosen to understand relationships between web location and spider preference for habitat structure such as moist conditions, dry conditions, forest density, or anthropogenic structures. The locations were sampled during the hours of 0800 and 2000. A 5X5 m plot was placed in each site type within a location. All webs found within the plot were included in the study. Webs extending outside the plots were included only if the majority of the web was located in the plot. To examine which web structure results in greater insect capture, we measured the following: web size (cm), web type (orb, cob, or sheet), web location (tree, side of building, forest floor, etc.), and number of insects found in each web. Insect count was measured a second time during the evening to determine temporal differences in insect capture. When a spider was seen on a web, the body (cephalothorax and abdomen) size (cm) was measured and recorded to genus. Webs that were not originally recorded from the daytime sampling were not recorded during nighttime sampling.

Statistical Analysis

To assess whether larger spiders consistently made larger webs, we performed a linear regression using spider body size and web size. A second linear regression was performed to test the hypothesis that web size and insect counts are related. An ANOVA was performed to determine if differences exist in the abundances of web types found in the three different site types. We performed multiple two-way ANOVAs to determine whether web type and site type affect the number of insects found in webs for both daytime and nighttime counts. In addition, we performed a two-way ANOVA to assess differences in web size based on both web type and site type. For the spiders that were recorded to genus, a Shannon-Wiener Diversity Index was used to understand differences in spider diversity across site types.

RESULTS

Over the course of three weeks, 349 individual webs were recorded. Of these, 77 were cobwebs, 197 were sheet webs, and 76 were orb webs. Our results show that the types of webs present differ depending on site type (F (4, 340) = 3.37, p = 0.012). Wet sites and forest sites had similar trends in abundances of web types with orb webs being more abundant than both sheet webs and cobwebs, while building sites had an almost equal measurement of all three types of webs (Figure 1). Spiders occupied roughly half of the webs observed. Of the webs on which spiders were seen, a strong correlation between body size and web size was found (F (1, 195) = 67.0, $p < 0.001$), revealing that larger spiders consistently make larger webs. Because of this, we used web size in place of spider body size for the rest of data analyses. In addition, web size had a correlation between both daytime (F (1, 347) = 30.6, $p < 0.001$) and nighttime (F (1, 347) = 45.3, $p < 0.001$) insect counts.

A total of 879 insects were counted over the three weeks during daylight hours. We found differences in the number of insects in webs during the day depending on the types of sites the webs were located in (F (2, 340) = 7.41, $p = 0.001$). Webs found in building sites had a higher abundance of insects captured than webs found in both wet sites and forest sites (Figure 2a). The size of webs within different site types also played a role in foraging success (F (2, 340) = 3.45, $p = 0.033$), with larger webs typically containing more insects (Figure 3). The number of insects captured during the day was affected by web type (F (2, 340) = 5.08, $p = 0.007$) as well as web size for the different types of webs (F (2, 340) = 9.79, $p < 0.001$). Orb webs were consistently larger than both sheet and cobwebs and showed the highest average insect count within all three sites (Figure 2a). Sheet webs had the second highest average insect count within wet sites and forest sites while cobwebs displayed the second highest average insect count at building sites (Figure 2a).

A total of 1,003 insects were found in webs during night observations. Site type did not affect the nightly insect count (F (2, 340) = 2.80, $p = 0.062$); however, we found differences in insect count depending on web type (F (2, 340) = 7.38, $p = 0.001$). Similar to daytime, web size remained a factor in insect count at night for both web type (F (2, 340) = 9.79, $p < 0.001$) and site type (F (2, 340) = 3.45, $p = 0.033$). Orb webs were larger than both sheet webs and cobwebs and demonstrated the highest average insect count for both wet sites and building sites (Figure 2b). The average insect count of sheet webs varied depending on site type with higher average insect count in forest sites, second highest average insect count in wet sites, and lowest average insect count in building sites (Figure 2b). Cobwebs exhibited the lowest average insect count in both wet sites and forest sites but second highest average insect count within building sites (Figure 2b).

Out of all the webs, we recorded 195 spiders from a total of 11 genera. We found that building sites exhibit the highest diversity of spiders (H = 2.00) while wet sites are less diverse (H = 1.58), and forest sites have the lowest diversity (H = 1.31; Figure 4).

DISCUSSION

The purpose of this study was to understand the foraging behavior of web-building spider families in the North Woods by observing insect counts across web types in multiple habitats. As hypothesized, orb webs had the highest insect count; however, we cannot conclude that these webs are optimal for foraging success. Since body size, web size, and insect counts are correlated through out site types and web types, it is difficult to determine foraging success. This is because different spiders potentially require different amounts of insects to survive. Due to this finding, our hypothesis that orb weavers (Araneidae and Tetragnathidae) are more successful foragers than two other families of web-building spiders: cob weavers (Theridiidae) and sheet weavers (Linyphiidae) is not directly supported in this study. Further research will need to be conducted by observing correlations between spider body size, spider weight, number of insects consumed, and insect capture count to fully determine foraging success across these four families that we studied.

We found that sheet weavers were most abundant across in wet and forest sites and least abundant in building sites, which could be due to the family's web site preference and foraging behavior. Field observations suggest that sheet weavers had a preference to build their webs in juvenile Balsam Fir and North Eastern Hemlock. Similarly, a study found that sheet weavers preferred tied, dense branches of Douglas firs compared to bare branches (Halaj et al. 2000). Sheet weavers were also almost always seen on their web, which could be due to Linyphiidae's ability to reduce their metabolism rate and sit-and-wait for prey to be caught in their webs, a technique they highly depend on for foraging that other spiders can usually not tolerate (Riechert and Gillespie 1986, Glover 2013, Harwood et al. 2003). Sheet webs in our study had the highest average insect count at night in the forest site, barely surpassing orb web insect counts. This is best explained by web size. For example, Linyphiidae tend to have smaller webs and thus capture less prey (Harwood et al. 2001), correlating body size to web size, as seen in this experiment.

Orb webs were not abundant in wet sites or forest sites but were second most abundant in the building sites. This could correlate to similar studies that found orb weaver populations to be less abundant in areas that lack anthropogenic structures (Uetz 1986) and more abundant in urbanized areas (Lowe et al 2014) where they can avoid potential predators (Blamires et al. 2007, Glover 2013). Some individual spiders from the two families of orb weavers built webs on the same structure together. Similarly, one study found that some long-jawed orb weavers (Tetragnathidae) clump their webs together, but do not become aggressive towards each other in areas where spider and prey density are high (Uetz 1986, Harwood et al. 2003). This increase in population is in response to structure size and the ability to spread out due to high prey density, reducing cannibalism and competition for resources (Rypstra 1986, Glover 2013). This could also be why we found so many orb webs within the building sites but very few in the wet and forest sites. Contradictory to the low number of webs across sites, orb webs had the highest abundance of insects within all three site types during daytime and two site types during nighttime. Similar to this pattern, one study found that in the yellow garden spider, *Argiope aurantia* (Araneidae), foraging success does not depend upon web site type (Enders 1976). Another reason for high insect count is that some orb weavers will risk predation by building their webs in open air to maximize prey capture (Blamires et al. 2007, Glover 2013). Their webs act as a filter for insects, when wind carries prey into the webs if positioned correctly (Riechert and Gillespie 1986). Other studies have found that body size and web size in orb weavers correlates to insect capture ability, with larger webs resulting in a greater abundance of insects (Prokop 2005, Blamires et al. 2007, Pasquet et al. 1999, Lowe et al. 2014), which we also found from our results. However, these findings cannot fully support our hypothesis that orb weavers are more successful at foraging than other spider species due to correlation between web size and insect count.

Cobwebs were the most abundant in building sites, which could be due cob weavers' social nature (Agnarsson 2002). For example, species of the genus *Achaearanea* have the ability to become social when enough food is provided, reducing cannibalism and territorial behaviors, thus increasing population numbers (Rypstra 1986). Another reason for their high abundance could be due to their preference for building webs in sheltered areas such as anthropogenic structures and crevices that naturally occur in forests (Bradley 2012). Their abundance appears to correlate with their average insect counts. Cobwebs had the second highest average daytime and nighttime insect counts in building sites and lowest insect counts in wet and forest sites. One study found that when the western black widow, *Latrodectus hesperus* (Theridiidae), was starved it would spend more time in web construction and vise versa when it was satiated (Blackledge and Zevenbergen 2007). This behavior correlates to our finding that web size and insect counts are dependent through out the site types.

Building sites had the highest diversity of webs and genera. This could be due to the nature of spiders to strategically build webs in sites of high prey density that suits their foraging behavior (Glover 2013). All families observed build their webs at different perimeters within a site (i.e. tree, open air, structure, forest floor), which reduces competition within building sites (Harwood and Obrycki 2005). Spiders abandon webs when a location does not serve as an area of high prey abundance (Harwood et al 2003, Glover 2013). This could explain why not all webs observed had a spider. Overall, we found that spiders prefer a diversity of habitat types, other spider communities, and high insect abundance.

The basis of this study was to understand how web-building spiders and their webs can be used as bioindicators through prey control and habitat quality throughout various site types, with the potential to correlate our results to similar habitats. From our findings, it is certain that body size, web size, and insect count are correlated. This can be applied to future research focusing on prey control. We also found that the more resources a site supplied, the more spiders benefited, contributing to higher spider diversity. This is essential for determining habitat quality and possibly assessing the health of the local environment. In conclusion, spiders can be important bioindicators across all environments.

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FIGURES

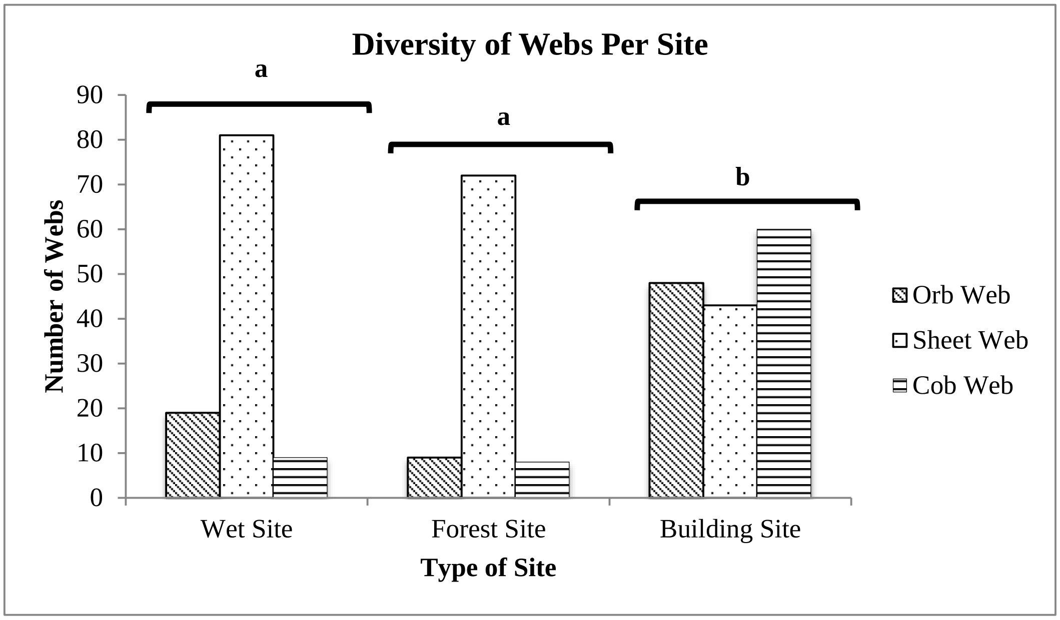
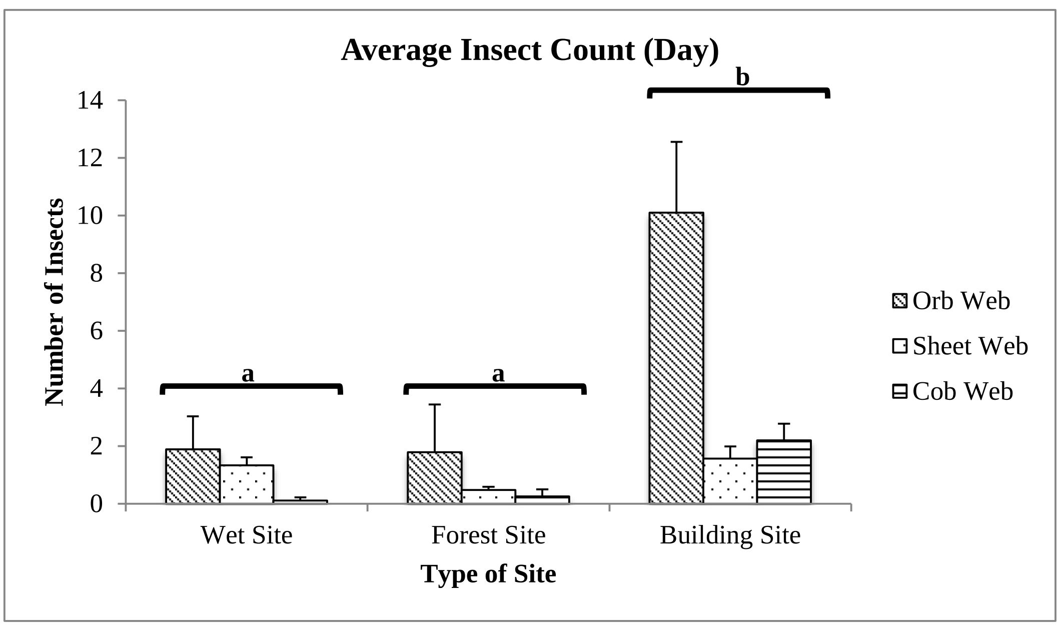
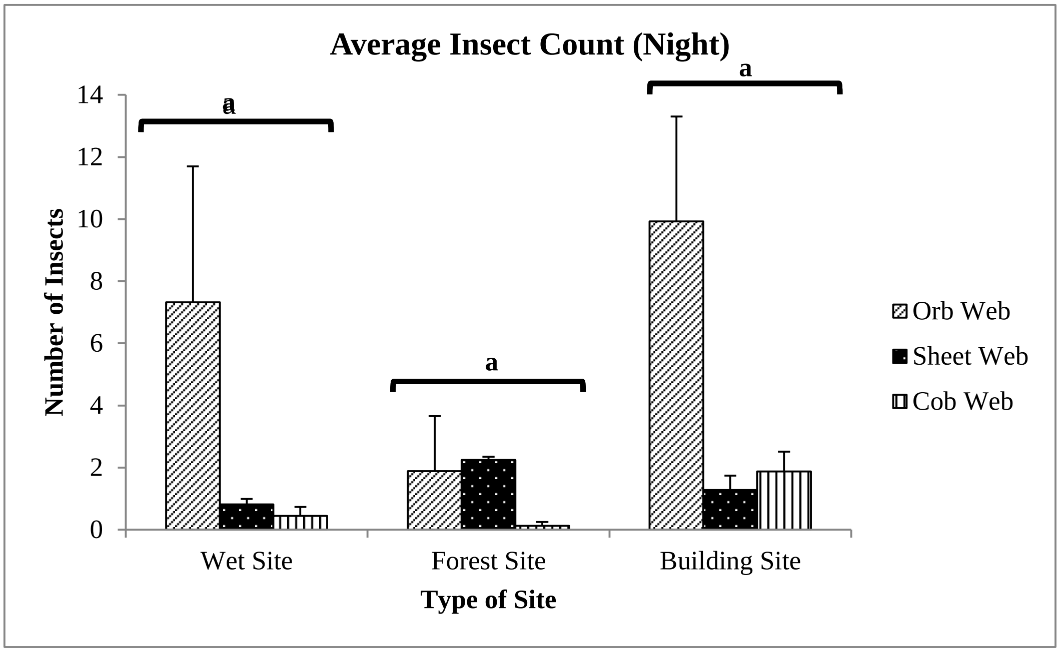


Figure 1. Abundance of different types of webs found within three different habitat types. Groups marked with ‘a’ are not significantly different from each other but differ from ‘b’ ($p < 0.05$).



(a)



(b)

Figure 2. Average insect counts for different web types within wet sites, forest sites, and building sites. (a) Daytime insect counts for each web type across different site types (mean ± SE of insect counts within each web type). Groups ‘a’ are not significantly different but differ from group ‘b’ ($p < 0.0001$). (b) Nighttime insect counts for each web type across different site types (mean ± SE of insect counts within each web type). Groups ‘a’ are not significantly different from each other ($p = 0.062$).

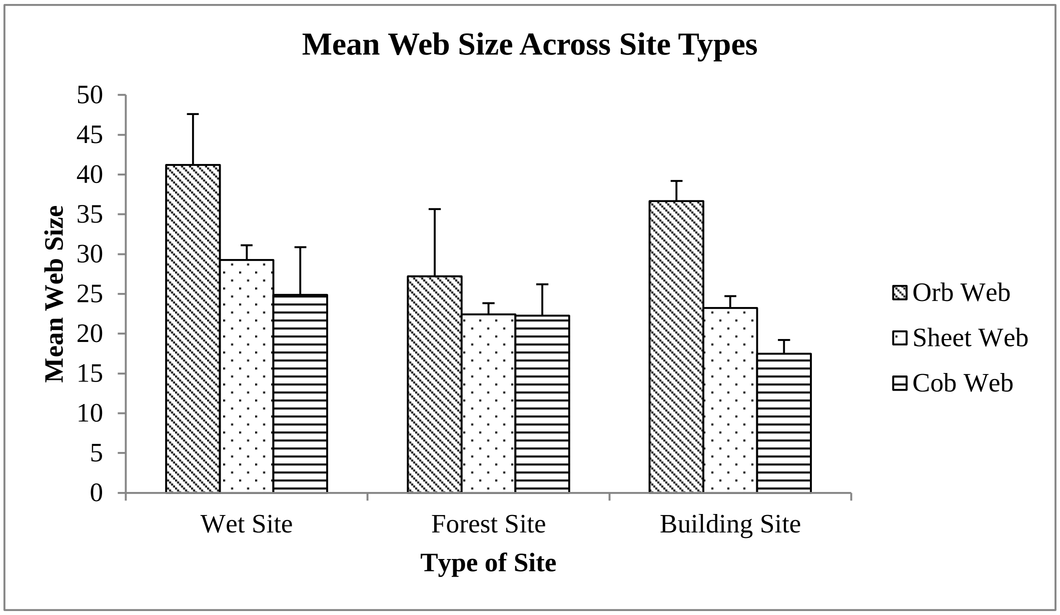


Figure 3. Mean size of web through out the different site types (mean ± SE).

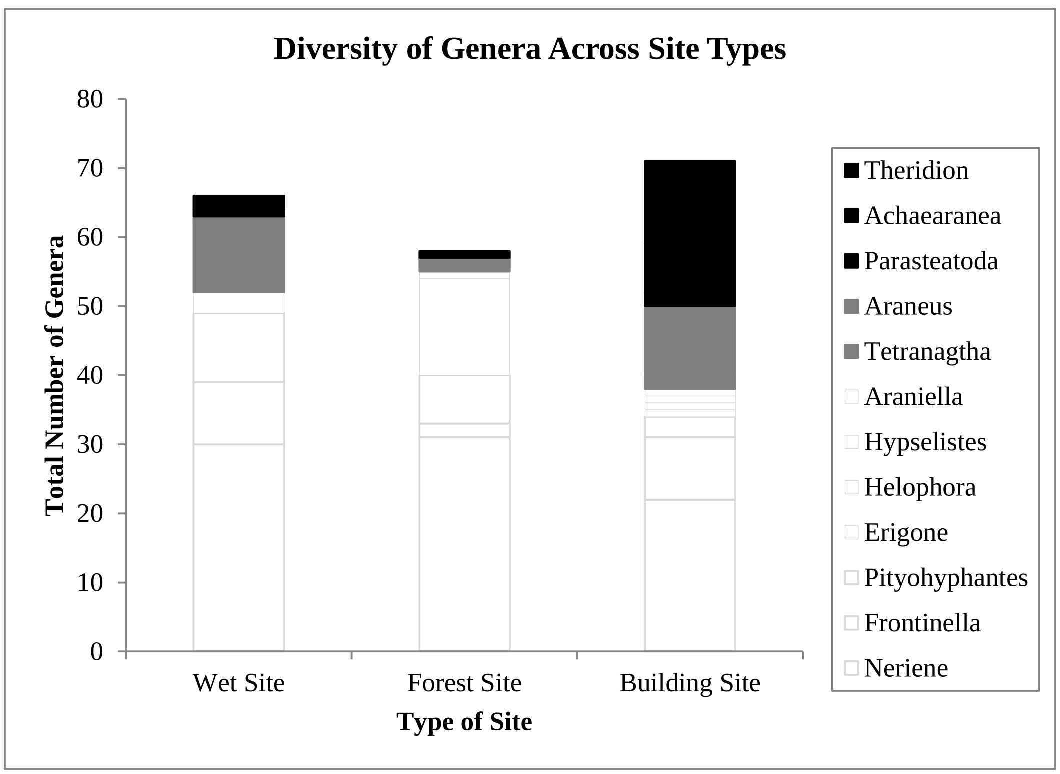


Figure 4. Richness of spider family recorded at all three site types. The black areas represent cob weavers, gray areas represent orb weavers, and the white areas represent sheet weavers.