Prey Size Preference of the American House Spider *Parasteatoda tepidariorum*

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Abstract

The American House Spider (Parasteatoda tepidariorum) is commonly associated with human populations, and is a major predator of insects such as mosquitos and flies. Little is known about the prey preference of these spiders, for example, whether they prefer larger or smaller insects. This study examined prey size preference in P. tepidariorum, in an effort to both determine whether there is such a preference in these spiders, as well as whether that preference is for larger or smaller prey. Spiders were collected and placed into separate containers, in which they built webs. Prey insects were then collected, and classified as "large" or "small," based on overall body length. Prey species was varied as much as possible, as to limit the effect of species preference on spider prey choice. The prey were kept alive in an attempt to best replicate natural prey choice conditions; as such, they were briefly cooled as to reduce their mobility prior to web placement. One small and one large insect were then simultaneously placed in the web, and prey choice was quantified. 110 trials were run. Through a chi-square analysis, it was determined that the spiders significantly preferred large prey insects over small ones. Several factors could be responsible for this finding, including more web vibrations from larger insects resulting in easier location, or a higher nutrition-to-effort ratio for larger insects. The study has many important implications, such as identifying selective pressures placed on both spiders and prey insects, as well as looking at the choice of spiders in a limited-nutrient environment, relevant to a possible future scenario faced by arachnids due to rapid climate change.

Introduction

Opportunistic predators are generalists that feed on nearly whatever prey that they encounter, and can be highly ecologically impactful. Understanding the prey preferences they may exhibit under resource scarcity or when given a choice can provide insight into their senses and behavior.

The overall role of spiders on global insect regulation is not well understood. However, Nyffeler (2000) posits that, in light of spiders' extensive appetites and heavy population density in favorable environments, overall spider prey kill is 200 kg per hectare per year. This indicates the possibility for spiders to have a wide-ranging impact on insect regulation. Spiders in general give us excellent examples of such opportunistic predators through their predation of many families of arthropods and several varieties of small vertebrates (Menin, 2005).

The spider family, *Theridiidae*, also known as tangle-web, cobweb, or comb-footed spiders, is one of the most diverse and widespread, with more than 124 genera and 2475 species recognized worldwide as of June 2017 (Bern, 2017). Well-known clades include the genera *Anelosimus*, recognized for their sociality and their utility in studies on environmental effects on the development of sociality, group behavior, and inbreeding (Agnarsson, Avilés, & Maddison, 2013) and *Theridion*, whose species *grallator*, famous for the "smiley face" on its abdomen, provide useful data for understanding selective pressures and mechanisms of color polymorphism (Gillespie, 1989). In our study, we aimed to look at the feeding preference of the American House Spider, as a model for opportunistic feeder behavior when given prey choice.

The American House Spider

Perhaps the most ubiquitous member of the cobweb spider family to human society is the American House Spider, *Parasteatoda tepidariorum*. *P. tepidariorum* is a cosmopolitan and synanthropic species which can be found throughout the American continents wherever humans are established (Faúndez & Téllez, 2016). *P. tepidariorum* is so pervasive in human environments that one might consider them the arachnid equivalents of raccoons, rock doves (pigeons), or brown rats, generalists that have found tremendous success in close proximity to and in association with humans.

P. tepidariorum feeds by weaving tangled, patternless webs in corners, preferably sheltered from wind, waiting for prey to wander in and become entangled. Upon sensing the vibrations from the prey's struggles, the spider feels its way towards the movements' source, and quickly enshrouds its prey before it has an opportunity to escape (Nentwig, 1987). Spiders in the family *Theridiidae* are known to throw masses of silk on their victims to entangle and neutralize them from a distance, allowing them to overwhelm dangerous prey, such as ants, bees, and beetles, that comprise a comparatively large portion of their diet (Nentwig, 1987).

Previous Research

Predator prey dynamics in spider/insect systems show many different food acquisition strategies. The Striped Lynx Spider, *Ocyopes salticus,* are thought to possibly imprint a prey preference as a spiderling (Heong et al., 1991). A type of Wolf Spider, *Hogna helluo*, have been shown to preferentially pursue chemical cues from its most recent prey item over those of others (Persons & Rypstra 2000). The Fringed Jumping Spider, *Portia fimbriata,* seems to demonstrate a hierarchy of preferences among several distinct prey items (Li and Jackson 1995). Research exists on prey preferences for many other species of spiders, but none could be found on *P. tepidariorum*. Despite becoming a named species in 1841 and being extremely common, the corpus of research dedicated specifically to *P. tepidariorum* is comparatively minimal. This absence of research provides an opportunity to shed light on such an omnipresent species.

Broader Impacts

Trends in prey size preference of *P. tepidariorum* could point to an ability to choose prey with higher nutritional or caloric value, and may point to a possible adaptation of the species to maximize the ratio of nutritional reward to energy and nutrients expended moving along the web and enshrouding prey. Such mechanisms are known to exist in other groups of spiders (Toft 1997), and our research may indicate similar prey choice capabilities exist in *P. tepidariorum*.

Another important aspect of our research is the potential for there to be an evolutionary pressure placed upon prey insects by this species of spider. For example, if *P. tepidariorum* prefer large prey, this could confer higher fitness upon smaller prey in spider dense environments. Further implications of prey preference could be linked to predator avoidance strategies by spiders and changing resource availability. Additionally, our study results could give insight into future global changes in spider behavior due to altered habitat conditions and resource limitations as a result of global warming and climate change.

Experimental Questions

We seek to establish if *P. tepidariorium* has a significant preference when selecting their prey and whether that choice is based on size. By better establishing our understanding of *P. tepidariorum*'s prey size preferences, we can perhaps gain better insight into their feeding behaviors. Through this research, we hope to identify the role these feeding behaviors have within their greater ecosystem, or how they might change in relation to environmental conditions. We hypothesize that when given a choice, *P. tepidariorum* has a preference for larger prey over smaller.

Methods

Spider Collection

We collected 40 spiders from their webs from the roofs of student cabins located on the shores of Douglas Lake at the University of Michigan Biological Station. We put 20 spiders in their own clear 14”x 8” x 5” plastic containers, and 11 in smaller round plastic containers. Because the spiders tended to build their webs in the corners, we placed the containers upside-down in order to best avoid breaking the webs. In order to better-simulate their natural habitat, the spiders were kept under lamps during daylight hours.

Insect Collection and Storage

We used aspirators to catch various sizes and species of insects for feeding, including midges (*Chironomidae*) gnats (*Sciaridae* and *Anisopodidae)*, mosquitoes (*Culicidae*) and ants (*Formicidae)*. We caught insects during varying times throughout the day and after dusk using a flood-light and cotton sheet, or a black light insect collection bucket. During the day we collected insects from the outside of cabins and buildings around the University of Michigan Biological Station property. In order to slow the activity of the insects for ease of handling, we stored the insects in the aspirator vial in the refrigerator, until we needed to retrieve them to feed to the spiders.

Insect Preparation

To determine what insects we considered small or large, we froze a sample of 40 of the insects collected and measured the length and width of the dead insects. Subsequently, we were able to determine the range and cutoff points of small and large insects: small insects were determined to be less than 3 mm in length with an average of 2.3 mm, and large insects were determined to be all that were greater than 4 mm in length, with an average length of 4.67 mm. Any insects between 3-4 mm were not used.

Spider Feeding

To control for the spiders’ hunger, we fed all 20 spiders on Wednesdays, Saturdays, and Mondays. This ensured that the spiders were starved and fed at regular intervals. This schedule also made it possible to be able to separate our final dataset based on days in case there was an outlier in terms of weather, temperature, or other external factors. If we had noticed a trend in spider preference based on the day of the week, it would be easy to isolate it from the data for further analysis.

Each spider received one small and one large live insect at each feeding. Using forceps, we carefully dropped the two live insects into the web equidistant from the spider in order to control for the spider choosing prey based on proximity. Insects were kept on ice prior to feeding in order to keep activity levels low during the placement process. However, we ensured that both insects were active by the time they were placed in the web. Furthermore, we placed the two insects in the web at the same time in order to avoid the spider choosing one over the other because one landed first in the web. We determined preference of the spider to be based on which insect it wrapped first. We also varied the insect species fed to the spiders to account for potential species specific preferences. Lastly, we measured the length and width of spiders using measuring calipers. We did this to later determine if there was a trend regarding spider size and the size of prey they prefer.

Results

Out of 110 prey choice trials, 22 resulted in the spider choosing no prey option. Because we were looking at prey preference when a choice was made, these trials were not relevant to our research question, and as such were not included in further calculations. Thus, we had 88 valid trials in which a choice was made. 29 (32.95%) of these trials resulted in a spider choosing the smaller insect, whereas the larger insect was chosen during 59 trials (67.04%). A bar graph was created in order to visually show how these values demonstrate the overall proportion of prey choice (Figure 1).

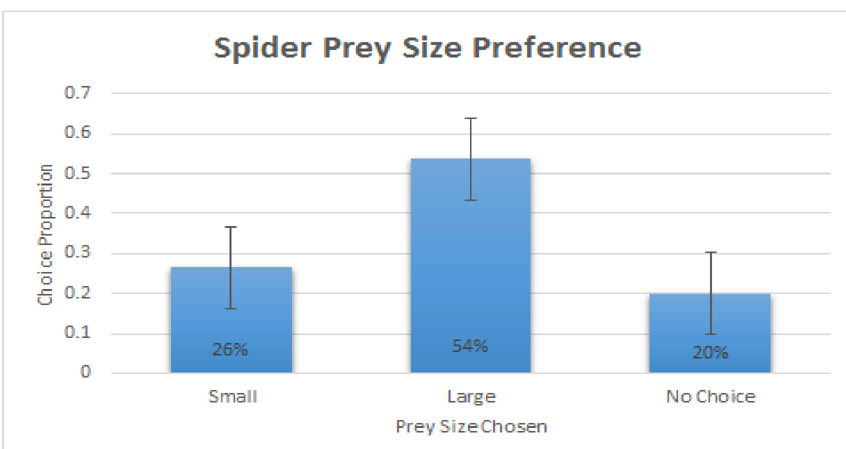

Figure 1. Proportional differences in spider prey choice.

Furthermore, we see that spiders preferred larger insects because, when examining the frequency distribution of large prey choice (Figure 2.), we see a right-skewed distribution, indicating that a higher number of individual spiders chose the larger insect in the majority of their trials. This is especially noticeable considering that the highest frequency of spiders chose the larger insect in 80-100% of their trials.

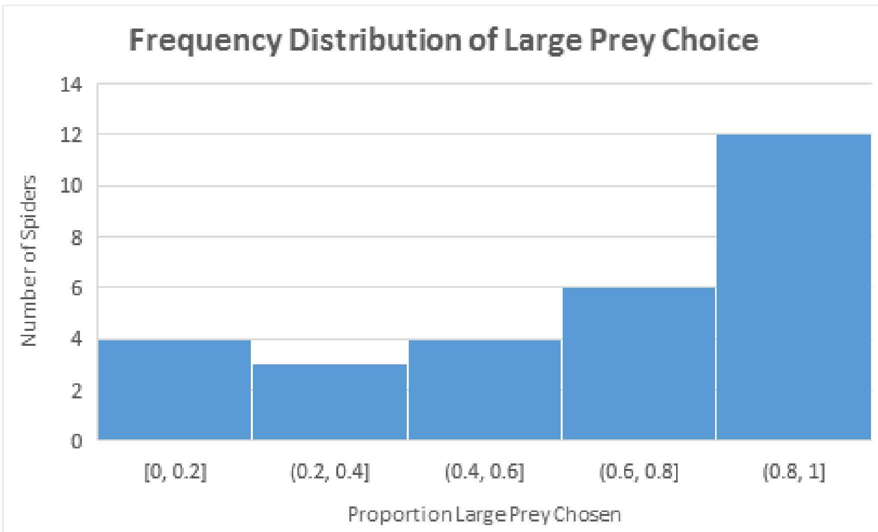

Figure 2. Frequency of the spiders choosing the large insect.

In order to determine whether spider size was associated with the size of prey chosen, size choice was put into categories of 1 for small and 2 for large, and then these numbers were averaged to create a continuum of prey preference for each spider. A regression was then run to plot average prey choice against spider length (see Figure 3). Our R^2 value of <0.001 indicates that there was no significant relationship between the size of spider and prey size choice.

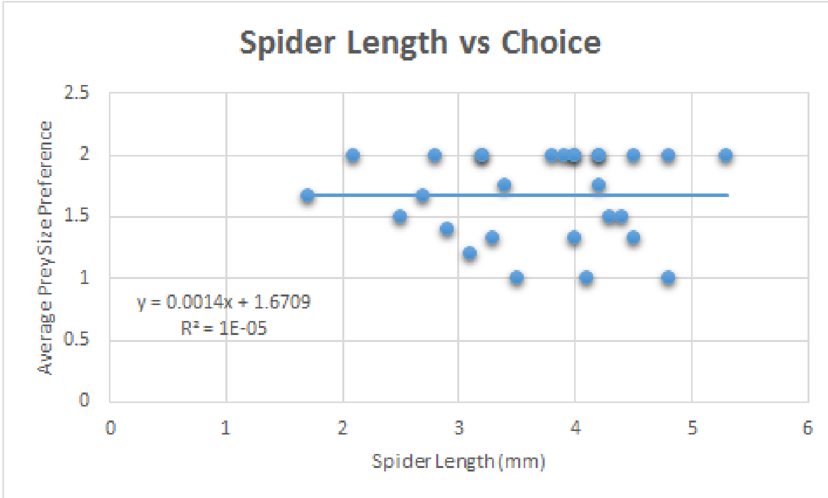

Figure 3. Relationship between *P. tepidariorum* length and prey choice (R^2=<0.001)

We used a chi-square goodness of fit test to determine if our *P. tepidariorum* showed a significant preference in prey size. We calculated a chi-square value of 49.37 (29 degrees of freedom), which gave us a p-value between .025 and .01. We also ran the chi-square test with our totaled values, which gave us a chi-square value of 10.23 with 1 degree of freedom. This corresponded to a very low p-value below .01. Given that our p-value in both cases was below .05, we had sufficient evidence to reject our null hypothesis and conclude that there is a significant difference in prey size preference of the *P. tepidariorum*. Additionally, using our trial data of prey preference proportions, we could determine that *P. tepidariorum* prefer larger insects.

Discussion

Possible Explanations

The reduced fitness caused by nutritional deficiency on every aspect of an organism's life induces a powerful selective pressure for a creature to self-select food items by nutritional value (Toft, 2013). We observed that our spiders had a significant preference for larger insects. A possible reason for this could be that they choose prey based on nutrition if larger prey correlates with a higher nutritional value. For example, there exists research indicating that at least one group of spiders, wolf spiders, preferentially seek proteinaceous and amino-acid-rich food over calories alone, which could be indicative that web-weaving spiders may have similar nutritional/dietary requirements (Greenstone, 1979). Furthermore, it has been shown that some spiders have the ability to actively regulate and control macronutrient intake (Mayntz et al. 2005), partially compensating for an imbalance of either protein or lipids (Toft, 2013). These results that can be linked to our study when determining why spiders under nutrient intake restrictions may make specific choices of which prey to focus on, specifically larger rather than smaller prey.

Furthermore, another possible explanation for our results is that *P. tepidariorum* pursues prey with the highest caloric value instead of highest nutritional value. This is possible because spiders lack a well balanced diet consisting of a sufficient ratio of proteins and lipids. Some scientific research has supported this notion because for generations, the scholarly consensus on predators was that their diet is inherently balanced and rich in nutrient quality (Slanksky & Scriber, 1985). However, this notion has been largely overturned for generalist predators of several vertebrate and invertebrate clades, including spiders (Toft, 2013). Because of this assumption, imbalanced spider diet may not be relevant when assessing why the spiders in our study chose certain sizes of insects. Instead, the overall caloric value of prey may be regarded, which would lead to larger insects being preferred. Another indicator of this is that our study attempted to account for the chance for specific species to be preferred based on potentially variable nutritional values of insects. We did this by using multiple different insect species for both the large and small categories, reducing the effects of species-specific preferences.

Another variable that may explain why we saw that *P. tepidariorum* prefers large over small prey is that they were able to better sense the presence of larger insects. Their eyesight, like those of many web-building spiders, is very weak, and they don’t respond to visual stimuli from greater than 3-4 inches away (Fiedler, 2000). Their sensory apparatus is further complemented by olfaction (Pollard et al., 1987). Therefore, spiders find prey based on the vibrations sent through the strands of their web from their struggling prey. Specifically, *P. tepidariorum* have vibratory receptors on their legs that are sensitive to both vibrations and sounds (Walcott & Van der Kloot 1959, Walcott 1963). Considering these studies, it is logical that movements produced by larger insects would indicate to the spider the size of the prey, which would lead the spiders to be able to exhibit a preference for larger insects. However, a possible counterpoint for this idea is indicated by unique spider behavior observations seen during our trials. In a few trials, after the spider noticed the prey caught in its web, it would inspect the smaller insect with its front legs without wrapping it, and then later divert its attention to the larger insect and wrap it. In these cases, since wrapping an insect was our measure of preference, the spider was noted to prefer the large insect, but it was also noted when the spider would clearly inspect both. This result may show that the spiders did not automatically choose the insect making the most vibrations. However, as this was observed in less than 10 of the trials, web vibrations as an indicator of insect size should still be considered a possible explanation of our results.

We noted that the smallest insects occasionally went untouched, possibly even undetected, regardless if they were alive or not. Many web-weaving spiders are known to regularly consume and rebuild their webs, and any undiscovered prey items are consumed with the old silk that entrapped them (Peakall, 1971). At least one species of spider's diet is composed of up to 23% of such prey items by weight (Nentwig, The Diet of Spiders, 1987). This could be an indicator that small prey is not seen as an immediate priority when larger prey is also present, leading to a preference for wrapping larger insects.

The ecological consequences of spider prey preference become more apparent in the context of predator avoidance and resource scarcity. Spider predator avoidance could have implications on the risk assessment strategy of the spider. For example, a spider may make a choice of prey based on the status of their own predators in a given season or year. The time spent out on a web may be a factor in safety for spiders, which would influence whether they would choose to go out onto the web multiple times for small prey, or fewer times for large prey in order to get a similar caloric or nutritional value of food. This situation is a tradeoff between nutrition gain and vulnerability experienced by spiders when they are exposed out on the web. Due to our finding that the spiders significantly preferred large prey over smaller prey, this could point to the importance of risk aversion in prey choice of House Spiders.

Climate Change Implications

Another important implication of our research is spider resource availability. Changing seasonal patterns, temperature, and climate change are important factors when considering spider reliance on insects. Changing temperatures could lead to insects emerging from diapause earlier, even prematurely (Bale & Hayward, 2009). The former could lead to a selective pressure to hatch or mature more quickly in *P. tepidariorum*, and the latter could lead to mass die-offs from starvation or exposure, potentially leading to severely limited prey options for spiders. In this case, spiders would be living in a resource scarce environment, which may increase the imperative nature of choosing the most rewarding prey when it did become available. Finding that our spiders significantly preferred large over small prey favors the idea that our spiders are already choosing the more rewarding prey if, in fact, larger insects do have higher nutritional value. Considering the changing climate and possible alterations of insect cycles, opportunistic spiders may need to become more selective about which food options are the most valuable in the future.

Noisy Variables

In order to avoid the noisy variable regarding insect size variation, we set size ranges that eliminated intermediate insects from lengths 3-4mm. This made our “small” and “large” categories discrete. In addition, it has been noted that researchers have been known to disproportionately favor collecting large insects for spider feed (Nentwig, 1985). To preemptively counter a potentially confounding variable, we collected insects we deemed both “large” and “small”. A way to improve upon this aspect of our methodology would have been to measure each insect before using it in a trial. This would have created a continuum of insect size in order to run a regression analysis for preference, but because of our set standard sizes, this was not possible in our study.

One noisy variable that we could not completely eliminate is that of insect species preference. We accounted for this as much as possible by varying the insect species for both large and small, but this could not totally eliminate the chance of spiders exhibiting species preference in each trial. Limiting the effect of species preference helped reduce but did not remove this noise in our results.

Future Research Directions

Our study sets up a good base for further experiments to expand upon the topic of spider prey preference. One way to improve our experiment would be to test spider prey preference with large insects known to have relatively low nitrogen, to determine if preference would hold for large insects based on large size (content) rather than nutrition levels. Spider choice based on nitrogen level per unit mass of an insect could mean a spider would prefer multiple small insects over one large insect. Natural conditions may provide this opportunity, where a spider wraps multiple small insects that have greater nitrogen per unit mass each than a large insect. Thus, another aspect of spider prey preference that could then be improved upon is the natural conditions of insect catching of webs.

Additionally, we were not able to account for web placement, size, or production. An additional aspect for a further experiment may be to better chart web making, as there could be a connection with the type of prey chosen in webs of different sizes or locations in the container. An issue with this appeared to be leftover content in the web interfering with fresh prey choices. On several occasions, a spider with two new prey choices would return back to old wrapped prey from a previous day, resulting in a "no preference" mark. To combat against this result and force a choice between small and large, 11 of the containers were cleared of their webs partway through the experiment. Since the spiders rebuild webs within a day, we did not expect to see a large effect because of this, and eliminating old insects from the webs increased clarity of our results. However, the process of keeping webs clean that are normally taken down and rebuilt in natural habitats could be better standardized to reduce effects in a future study.

We did not test the overall nutritional value of the insects we fed to our spiders i.e. caloric density and nutrient richness. Toft (2013) maintains that for a spider, food quality can't be determined by any means except "performance experiments", i.e. observe growth rates, predation, and reproductive success for spiders reared on specific species of prey. From them, he has noted that prey with high protein or lipid contents could theoretically possess toxins or other deterrents that could render them ineffective or outright-dangerous to consume, despite being apparently nutritious (Toft & Wise, 1999). Future research on the quality of different prey for *P. tepidariorum* could determine through experiments like our own if *P. tepidariorum* is capable of selecting prey for nutritional value.

Conclusion

Our findings on prey preference in the American House Spider indicate interesting behavioral patterns in an opportunistic predator. Our results indicate that American House Spiders significantly choose larger prey when given a choice, and this has many implications on predator behavior in future and changing conditions. Some of these are risk aversion tactics and predator avoidance, while altered resource availability due to climate change could accelerate behavioral changes. By expanding upon our study and regulating more variables such as insect size, web placement, and nutrient makeup in prey, further insight could be found about the behavioral variation of opportunistic predators such as the American House Spider.

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