Correlational Study between Artificial Lighting and Health of *Trichonephila clavipes* in Isla Colón, Bocas del Toro, Panama

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***Abstract*—Due to the increasing human activities in spiders' habitat, it becomes crucial to examine our impact on spiders' health so that spiders can be better conserved. This study examines many health measurements of female *Trichonephila clavipes* (Golden Orb-Weaver Spiders), such as abdomen size, web size, and numbers of males and kleptoparasites per web, and finds correlations between these measurements and an indicator of human activities: spiders' exposure to artificial lighting. Although no correlation was found between the health of female *T. clavipes* and their exposure to artificial lighting, a two sample t-test found with a high degree of statistical significance that female juveniles contain significantly fewer male spiders in their webs than their adult counterparts, providing evidence to the potential reproductive patterns of *T. clavipes*.**

***Index Terms*—Trichonephila clavipes, Golden Orb-Weaver Spider, Artificial Lighting, Abdomen, Spider Web, Cleptoparasite**

I. Introduction

As a harmless insect, spiders serve important functions such as controlling the population of harmful pests and agriculture [1, 2]. However, human activities over the recent years have decreased the biodiversity and magnitude of the spider population [3]. Therefore, examining the cause of this change within the spider population has become a critical task in order to better protect them.

There are many related experiments that are focused on the causes of spider population decline. For example, [4] proposed that increasing intensity of bird predation is the most significant cause. In [5], the authors suggest that a compound called azadirachtin, which typically appear in neem seeds, caused a reduction of 50% in survival to adult stage. However, both of these study is hinting at a larger causes, namely the increasing human interference in spider's habitat. In fact, [6] confirms this idea by proposing that habitat structure and productivity alteration directly influences spider's abundance and diversity.

With this in mind, we examined the human influence of spiders by focusing on the how artificial light affects the general health of spiders. Many previous papers have demonstrated the effect of artificial light on the characteristics of spiders. As proposed by [7], the prevalence of Artificial Light At Night (ALAN) accelerated the spider juvenile development, subsequently leading to spiders of smaller size. The authors also found that exposure to ALAN led to fewer eggs per female spider. [8] examined the diameters of spider silk fibers accurately and precisely using Polarized Light Microscopy (PLM), and concluded that the thread diameters within the webs of individual spiders can vary by as much as 600%. An artificial light experiment was carried out by [9], which suggested that spiders caught more prey with smaller webs and had higher body conditions in the artificially lit conditions. [10] presented how ALAN has led to insect declines due to its interference with the development, movement, foraging, and reproductive aspects of insects.

Therefore, in an attempt to examine the effect of ALAN on the various aspects of spiders such as development, movement, and reproduction, we studied a mixed population of female *Trichonephila clavipes* (Golden Orb-Weaver Spiders) at ITEC[1] with 11 of them being away from artificial light and 12 of them being exposed to two hours of artificial light per night. More specifically, we recorded the length-to-width ratio of spider abdomen[2], web size, sex ratio, and spider-to-kleptoparasite[3] ratio, and find how these variables are affected by spiders exposure to artificial light.[4] We hypothesized that the female spiders that were exposed to artificial light would be healthier, in terms of abdomen thickness and web size, because of the insects that the light attracts.

II. Materials and Methods

Spiders were found in a variety of locations near and at the ITEC Research Station. Some of the spiders were found in places where there was no artificial light being produced; several were found in areas with artificial lighting. Once a *T. clavipes* was located, the length and width of its web were measured using a tape measure. We define the web length as the tallest part of the viscid spiral[5] perpendicular to the horizon, and the web width as the widest part of the viscid spiral parallel to the horizon. The number of kleptoparasites and male spiders in each web was also noted. Photographs

[1] Institute for Tropical Ecology and Conservation: a biology field station located in Bocas del Toro, Panama

[2] Spider's opisthosoma (belly), which contains the guts, heart, reproductive organs, and silk glands.

[3] Small and silver spiders that feed off the food left in the the female *T. clavipes*'s webs

[4] We used the length-to-width ratio as a determinant variable for overall spider health as suggested by Dr. Leonor Ceballos, and used web size because we believed that healthier spiders have the potential to exert more energy to build their webs.

[5] Catching area of the web.

Fig. 1: Example Measurement for *Trichonephila clavipes* Abdomen Dimensions.

were taken of the spiders from a side on angle at a distance of one meter. Figure 1 shows an example measurement: abdomen length, as shown by the blue line, is the longest dimension of the spider's abdomen; abdomen width, as represented by the red line, is the measure of the spider's abdomen from the leg side to the lop of the abdomen, just behind the cephalothorax. Using Adobe Photoshop to set up a proportion between pixel size and centimeters[6], measurements of the size of the spider's abdomen (length and width) were made. We examine each spider's abdomen size using their abdomen length-to-width ratio.

III. Results

23 female *T. clavipes* were sampled, including 17 adults and 6 juveniles in 12 different clusters. 12 were subject to artificial lighting and 11 were left in dark.

A. Abdomen Length-to-Width Ratio

The mean and standard deviation for the abdomen length-to-width ratio are shown in Table I. Full data set can be found in Appendix A.

TABLE I: Results Table for Abdomen Length-to-Width Ratio

	Adult	Juvenile	Overall
Mean	2.40	2.67	2.47
Standard Deviation	0.22	0.25	0.27

B. Average Diameter of Spider Web

The average diameter of spider web is calculated by taking the arithmetic mean of the length and width of the spider web. The mean and standard deviation of the data set are shown in Table II. Full results table can be found in Appendix A.

[6]For reference, the proportion is 1669 pixels : 1 centimeter.

TABLE II: Results Table for Spider Web Diameter

	Adult	Juvenile	Overall
Mean	53.55	37.94	49.48
Standard Deviation	13.06	10.63	14.10

C. Number of Males in Spider Web

Table III shows the mean and standard deviation for the number of males in each *T. clavipes*'s web.

TABLE III: Results Table for Number of Males in Web

	Adult	Juvenile	Overall
Mean	5.00	0.83	3.91
Standard Deviation	2.98	0.98	3.19

D. Number of Kleptoparasites in Spider Web

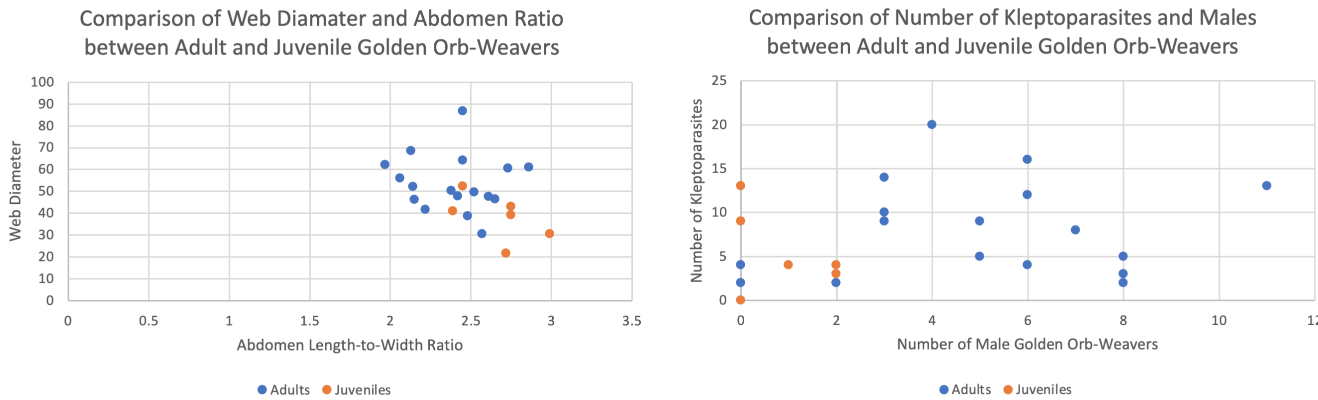
Table IV shows the mean and standard deviation for the number of kleptoparasites in each *T. clavipes*'s web.

TABLE IV: Results Table for Number of Kleptoparasites in Web

	Adult	Juvenile	Overall
Mean	8.12	5.5	7.43
Standard Deviation	5.44	4.68	5.28

E. Cross-Variable Correlation Tests

To examine the correlation between different variables, we selected pairs of variables to calculate the correlation coefficients (R value). Table V shows the pairs of variables along with their respective R Value. All calculations in Table V are based on both adult and juvenile spiders.



(a)

(b)

Fig. 2: Two-sample Scatter Plot Comparisons between Adult and Juvenile *Trichonephila clavipes* on (a) Web Diameter and Abdomen Ratio and (b) Number of Kleptoparasites and Males.

TABLE V: Results Table for Number of Kleptoparasites in Web

Variable 1	Variable 2	R-value
Cluster Size	Male Spiders	0.01
Cluster Size	Kleptoparasites	0.17
Cluster Size	Abdomen Ratio	−0.12
Web Diameter	Kleptoparasites	−0.09
Web Diameter	Male Spiders	−0.08
Light Exposure	Abdomen Ratio	0.25
Abdomen Ratio	Male Spiders	−0.15
Abdomen Ratio	Web Diameter	−0.32

Since the abdomen ratio and web diameter has the strongest correlation, a scatter plot with a line of best fit is presented in Figure 3.

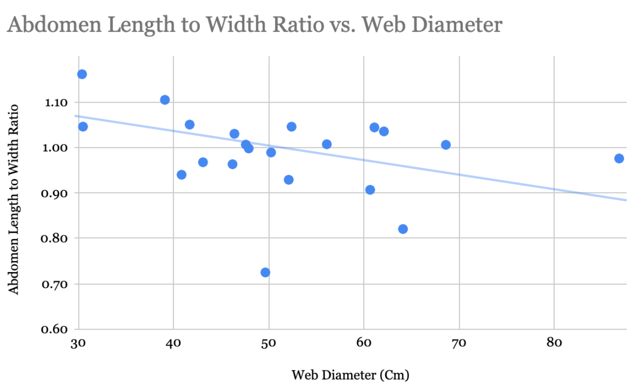


Fig. 3: Scatter Plot and Line of Best Fit for Abdomen Ratio and Web Diameter.

Comparisons between adults and juveniles are also made using two-sample t tests and scatter plots. The scatter plots are shown in Figures 2(a) and 2(b). For the two-sample t tests, we found that the p-value when comparing adult and juvenile web size is 0.0302 and the p-value when comparing males present in adult and juvenile webs is 0.0062.

IV. Discussions

A. Results Interpretation

Table I shows that the juvenile female *T. clavipes* tend to have a greater abdomen length-to-width ratio, indicating skinnier abdomens than their adult counterparts, which is expected during these early stages of development. Another significant finding at an $\alpha = 0.10$ significance level, as indicated by a p-value of 0.0675, was that juvenile spiders created a web that was on average 29% smaller than the adults.

This study also examined the number of both *Argyrodes Elevatus* (a type of kleptoparasitic spider) and male *T. clavipes* found inside the spider webs. There is not a significant difference in the kleptoparasite count from juveniles to adult orb weavers, as given by the p-value 0.3075. However, as shown by Table III and Figure 2(b), there is a significant lack of male spiders in the webs of the juveniles. Only 11% of adult female webs were without male *T. clavipes* whereas 50% of juvenile females had no males in their web. On average the adult *T. clavipes* had 6 times more males in their webs (5 males on average) than the juveniles (0.833 males on average). The relationship between the juvenile and adult web male population was proven to be statistically significant at an $\alpha = 0.05$ significance level with a two tailed t-test reporting a p-value of 0.0124.

B. Limitations and Potential Sources of Error

The methods presented a few issues with accuracy in both the measurements for the abdomen and the diameters of the web. Since the spiders were measured using photographs, a few degrees off of a straight on angle would skew both the abdomen length and width. Taking multiple photographs with slightly different angles, we can find the most direct angle from the spider to make an accurate measurement.

Another source of error in the data was measuring the webs with a tape measure. Due to the fragile nature of spider webs there were a few instances in which the tape measure could not completely touch the web. To combat this, a photo technique similar to the one used in the abdomen measurements could be employed.

Lastly, it is important to acknowledge that in all calculations including web dimensions one specific spider (spider number 24) was excluded due to its web being largely destroyed.

C. Future Research

In conducting these experiments the question was raised of why spiders incline towards artificial light in such large clusters if they are not benefiting from it. Are there better measurements of overall health? In the future exploring how other human behaviors influence the health of spiders may be beneficial for their conservation.

V. Conclusion

We did not find any statistically significant difference in length-to-width ratio between spiders exposed to artificial light and those that were not. We suspect that there was either no difference between spiders with and without artificial light or the length-to-width ratio was not a reflective measurement of overall spider health.

Web size showed statistical significance difference between the juvenile and adult *T. clavipes*. Similarly, juveniles displayed significantly fewer male spiders in their webs than their adult counterparts.

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References

[1] Britannica. Importance of spiders.

[2] Peng-Yu Jin, Lu Tian, Lei Chen, and Xiao-Yue Hong. Spider mites of agricultural importance in china, with focus on species composition during the last decade (2008–2017). *Systematic and Applied Acarology*, 23(11):2087–2098, 2018.

[3] Samrat Chatterjee, Marco Isaia, and Ezio Venturino. Spiders as biological controllers in the agroecosystem. *Journal of Theoretical Biology*, 258(3):352–362, 2009.

[4] Bengt Gunnarsson. Vegetation structure and the abundance and size distribution of spruce-living spiders. *The Journal of Animal Ecology*, pages 743–752, 1990.

[5] Elena Martínez-Villar, Francisco J Sáenz-De-Cabezón, Fernando Moreno-Grijalba, Vicente Marco, and Ignacio Pérez-Moreno. Effects of azadirachtin on the two-spotted spider mite, tetranychus urticae (acari: Tetranychidae). *Experimental & applied acarology*, 35(3):215–222, 2005.

[6] Eyal Shochat, WL Stefanov, MEA Whitehouse, and Stanley H Faeth. Urbanization and spider diversity: influences of human modification of habitat structure and productivity. In *Urban Ecology*, pages 455–472. Springer, 2008.

[7] Nikolas J Willmott, Jessica Henneken, Caitlin J Selleck, and Therésa M Jones. Artificial light at night alters life history in a nocturnal orb-web spider. *PeerJ*, 6:e5599, 2018.

[8] Todd A Blackledge, Richard A Cardullo, and Cheryl Y Hayashi. Polarized light microscopy, variability in spider silk diameters, and the mechanical characterization of spider silk. *Invertebrate Biology*, 124(2):165–173, 2005.

[9] Dylan GE Gomes. Orb-weaving spiders are fewer but larger and catch more prey in lit bridge panels from a natural artificial light experiment. *PeerJ*, 8:e8808, 2020.

[10] Avalon CS Owens, Précillia Cochard, Joanna Durrant, Bridgette Farnworth, Elizabeth K Perkin, and Brett Seymoure. Light pollution is a driver of insect declines. *Biological Conservation*, 241:108259, 2020.

Appendix A - Full Results Table

Spider ID	Cluster ID	Number In Cluster	Age	Kleptoparasites	Number of Male Spiders	Abdomen Length (Cm)	Abdomen Width (Cm)	Abdomen L/W Ratio	Web Length	Web Width	Average Diameter	Location	Hours of Artificial Lighting
1	1	6	Adult	9	3	2.49	1.17	2.14	55.8	48.4	52.1	Left of Cafeteria	8-10pm
2	1	6	Adult	2	8	2.22	0.92	2.42	48	47.8	47.9	Left of Cafeteria	8-10pm
3	1	6	Adult	4	6	2.14	0.96	2.22	39.6	43.8	41.7	Left of Cafeteria	8-10pm
4	2	1	Adult	2	2	2.13	0.74	2.86	58.4	63.8	61.1	Left of Cafeteria	8-10pm
5	3	2	Adult	8	7	2.16	0.88	2.45	88.9	84.7	86.8	Open Tree Stand	none
6	4	2	Adult	14	3	1.82	0.88	2.06	55.7	56.5	56.1	Under Reasearch Station	none
7	1	6	Adult	20	4	2.49	1.16	2.15	47.9	44.5	46.2	Left of Cafeteria	8-10pm
8	5	1	Adult	12	6	2.14	0.88	2.45	75.6	52.6	64.1	Under Dorm	none
9	6	1	Adult	5	8	2.16	0.84	2.57	25.5	35.3	30.4	Under Dorm	none
10	7	2	Adult	3	8	2.06	0.79	2.61	47.3	47.9	47.6	Outside Cafeteria Windows	8-10pm
11	7	2	Adult	4	0	2.02	0.74	2.73	66.3	55	60.65	Outside Cafeteria Windows	8-10pm
12	8	5	Adult	16	6	1.92	0.72	2.65	45	47.8	46.4	Outside Office	8-10pm
13	8	5	Adult	10	3	1.95	0.82	2.38	50.8	49.7	50.25	Outside Office	8-10pm
14	8	5	Adult	9	5	1.84	0.73	2.52	63.3	36	49.65	Outside Office	8-10pm
15	9	1	Adult	13	11	1.91	0.77	2.48	27.4	49.9	38.65	Edge of Jungle	none
16	10	1	Adult	2	0	2.08	0.98	2.13	68.2	69	68.6	Behind the Lab	none
17	11	3	Adult	5	5	1.79	0.91	1.97	59.9	64.3	62.1	Tree in Field	none
18	4	2	Juvenile	3	2	0.78	0.28	2.75	44.5	41.7	43.1	Under Reasearch Station	none
19	11	3	Juvenile	4	1	1.94	0.79	2.45	50	54.8	52.4	Tree in Field	none
21	12	1	Juvenile	13	0	1.39	0.58	2.39	43.3	38.4	40.85	By Generator	none
22	8	5	Juvenile	4	2	1.16	0.39	2.99	29.1	31.9	30.5	Outside Office	8-10pm
23	8	5	Juvenile	9	0	1.28	0.47	2.75	35	43.2	39.1	Outside Office	8-10pm
20	11	3	Juvenile	0	0	1.66	0.61	2.72	34.9	8.5	21.7	Tree in Field	none