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The Joro spider, *Nephila clavata,* in North Georgia

Comparison of the locations and habitat of the introduced species, *Nephila clavata,* to the yellow and black garden spider, *Argiope aurantia,* and the banana spider, *Nephila clavipes*

Mongolia, 2016

Abstract

Invasive spiders can have negative effects on the economy, human health, and the environment. A new spider, the joro (*Nephila clavata*) from Asia, has been discovered in the United States in northeast Georgia. Getting range and abundance information on a species is important to understanding the effects of the new species. This study compares locations of the joro (*N. clavata*) to the locations of two other large orb-weaving spiders in the area, the black and yellow garden spider (*Argiope aurantia*) and the banana spider (*Nephila clavipes*). A citizen science approach was used as well as field observations of spiders found in the north east counties of the state. No sightings of the banana spider were found, but comparisons were made between habitats and locations of the joro and garden spiders. Habitat choice differed between the two species by sunlight, web support, and the presence of other spiders cohabiting with females.

Spiders as Invasive Species

Arthropod predators introduced into new environments can have lasting and unpredictable effects on native ecosystems. An introduced species is considered invasive if the new arthropod causes, or is likely to cause, harm to the environment, economy, or human health (Michigan Invasive Species, 2016). Invasive arthropod predators may cause direct harm to native predators by attacking and killing the competition or by competing for the same resources. For example, laboratory observations of the larvae of the Asian ladybird beetle (*Harmonia axyridis*) revealed that the invasive species is more likely to attack the larvae of two native species of ladybird beetle (Jakob, Porter, Ginsberg, Bednarski, & Houser, 2011). In the Great Lakes, the invasive spiny waterflea (*Bythotrephes longimanus*) preys on zooplankton. This reduces the prey for indigenous zooplankton feeders, diverting energy away from native populations (Jakob, Porter, Ginsberg, Bednarski, & Houser, 2011). Other ways invasive predators may affect the new ecosystem is through disease transmission, toxicity or poisoning of local organisms, or physically changing the structural environment , among others (McGeoch, Lythe, Henriksen, & McGrannachan, 2015). These effects on native populations include a change in species composition and a decrease in biodiversity in the native habitats (Nentwig, 2015).

Spiders are common arthropod predators and can be found in almost every ecosystem on the planet (Jakob et al., 2011). Invasive spiders are usually transported from their place of origin accidentally through international commerce (Hoebeke, Huffmaster, & Freeman, 2015; Jakob et al., 2011). These alien species can have all of the effects listed above, but most especially in competition and predation. Spiders commonly compete for food and web space among themselves, and many prey on their own species as well as other arachnids (Jakob et al., 2011).

Alien species of spiders can reach high densities in urban and natural habitats, which makes the study of invasive spiders important for a variety of reasons. Economically, the cost of the cleaning of structures, application of pesticides, and loss of marketability due to high densities of webs are common issues. There are also the environmental effects of increased pesticide use as well as the loss of biodiversity in the area. Invasive spiders in high densities may also be more likely to come into contact with humans, increasing the probability of spider bites causing human health problems (Nentwig, 2015).

Range and abundance are integral to determining impact in introduced species, and understanding impact is important in separating alien from invasive (Parker et al., 1999). For example, a study by Jakob et al. (2011) was conducted in Maine to help determine the effects of an aggressive alien spider *Linyphia triangularis* on indigenous populations. The authors spent 4 years studying the abundance of *L. triangularis* in various habitats as well as three native species of a similar size (*Frontinella communis*, *Pityohyphantes subarcticus*, and *Neriene radiata*). Their findings suggested that *L. triangularis* may have a negative impact on native species by taking over web support sites as well as actual webs.

Georgia's New Spider

One alien spider recently confirmed in the United States is the joro spider (*Nephila clavata*) from Asia. The first recorded evidence of the joro was reported in a study in Georgia, which used a citizen science approach to help in locating specimens for retrieval and DNA identification (Hoebeke, Huffmaster, & Freeman, 2015). The impact of this spider has yet to be determined, but the area reported by Hoebeke et al. (2015) does have native large orb-weaving spiders of the *Argiope, Nephila, Araneus, Leucauge,* and *Neoscona* genera.

To gain a better understanding of the possible effects of the joro spider (*N. clavata*) in Georgia, I designed this study to compare the locations of the *N. clavata* with the locations of two other large orb-weavers in Georgia, the black and yellow garden spider (*Argiope aurantia*) and the banana spider (*Nephila clavipes*) in the northeast counties. These two orb weavers were chosen because they are most likely to be confused with the joro (*N. clavata*) by size, shape, and coloring, and they occupy a similar niche to the joro. By combining the citizen science approach of Hoebeke et al. (2015) and some elements of other impact studies like Jakob et al. (2011), this study offers insights into the effects *N. clavata* may have on other orb-weaving spiders in Georgia.

Golden Orb Weavers

The golden orb weavers are spiders of the genus *Nephila*. They build large, geometric webs that are usually a distinctive yellow color. These spiders exhibit a pronounced sexual dimorphism, meaning the females are much larger than the males, and they are brightly colored. There are 38 species and subspecies in the genus, and they can be found throughout the world in the tropics and subtropics (Hoebeke et al., 2015; Bakkegard & Davenport, 2012; Su et al., 2011). Prey consists of small to medium flying insects, and *Nephila* spiders subdue prey by biting, rather than immobilization by wrapping as other orb weavers use (Weems & Edwards, 2004).

The webs of the golden orb weavers are large, semi-permanent, and consist of separate types of silk for the frame, radial lines, and sticky, spiral, capture threads (Brunetta & Craig, 2010; Hormiga & Griswold, 2014; Blackledge, 2013). They are vertically oriented to capture fast-flying insects, so they must be strong and elastic (Weems & Edwards, 2004; Agnarsson & Blackledge, 2009). The mesh of the webs is rather fine compared to other orb weavers, allowing *Nephila* species to capture smaller prey than some of their cousins (Weems & Edwards, 2004), and golden orb weavers frequently build guard webbing to either side of the orb for protection (Morse, 2000) (Fig. 1). Males and females both use silk and build webs, but the males usually move into the female's web after sexual maturity. Many golden orb weavers build large conglomerations of multiple webs with common edges, forming groups of males and females that may live in close proximity for certain periods of time, frequently just before mating season (Moore, 1977).

Fig. 1 Orb web with guard webbing

One effect of being able to produce strong, stretchy silk gives orb weavers the ability to climb, drop, or even to "fly". The frame silk used in webs is also used as drag lines, and is strong enough to support the weight of the spider. This allows spiders to avoid predators, leap from tree to tree, and, as spiderlings, "balloon" on air currents to travel great distances. Golden orb silk has been studied extensively for industrial applications because of these characteristics (Agnarsson & Blackledge, 2009; Hoebeke et al., 2015; Brunetta & Craig, 2010; Blackledge, 2013) .

Fig. 2 *Nephila clavipes* Banana spider by Stephanie Morse

Nephila spp. **in Georgia**

The banana spider (*Nephila clavipes*) has been the only member of the genus known in North America until recently. The females have a large, cylindrical body of spotted orange or brown with distinct tufts on the joints of the legs (Fig. 2). These spiders inhabit open areas of high humidity in forests along trails and clearing edges as far south as Argentina and as far north as the United States in the southeast and along the Gulf of Mexico. They construct their webs in trees or bushes beginning in summer and throughout the fall. *N. clavipes* females mature in late summer, and lay one to five egg sacs consisting of several hundred eggs each (Morse, 2000; Hoebeke et al., 2015; Bakkegard & Davenport, 2012; Moore, 1977). In Georgia, the most northern report of *N. clavipes* has been Clarke and Oconee Counties, but there is a concern that climate change will see this spider moving farther north due to increasing temperatures (Bakkegard & Davenport, 2012).

Hoebeke, Huffmaster, and Freeman recently verified a new species of the *Nephila* genus, *N. clavata*, in north Georgia in 2015. In their native range, *N. clavata*, commonly called the Joro spider, can be found throughout Asia, from India all the way to the Japanese islands. The females have a bright yellow striped body with a distinctive red spot on their belly (Fig. 3). In its native habitat, *N. clavata* live in various ecosystems ranging from mountainsides to fields, lowland forests to urban woodlands. They inhabit any structure that gives enough space for the web, even building on power lines, buildings, and fences. The spiders emerge from their egg cocoons in summer and reach sexual maturity in late summer, early fall. Mating produces a single egg sac of 400-1500 eggs, which will over winter until the following summer. Adults die off with the onset of winter (Hoebeke et al., 2015; Miyashita 1986).

Fig. 3 *Nephila clavata* Joro spider

Hoebeke et al. (2015) reported similar observations in their study. Most of the spiders were found in webs attached to the exterior of homes or among bushes or trees near human structures. Females were observed beginning in late September until mid-November, when temperatures began to drop. Most of the specimens were found around the Braselton/Hoschton area, a mixed business, rural, industrial region, and two were found in rural Madison county.

DNA barcoding in the Hoebeke et al. (2015) study suggests the specimens in Georgia are closely related to some in China and Japan, but further sequencing is necessary to confirm the country of origin. The authors report that over 2000 species of insects and arachnids have established themselves on the North American continent in the last 50 years, with most non-native spiders coming in from Europe or Asia. Most attribute this to international travel and shipping. It is probable that the arrival of the joro happened by accidental transport of the spiders, spiderlings, and/or egg masses on cargo, and ballooning can account for some of the dispersal (Hoebeke et al., 2015).

Fig. 4 Other orb weavers found in Georgia - *Araneus* or *Neoscona* genus

There are other large orb weavers in Georgia, but most of them are not usually as brightly colored and have distinctive body shapes with a fat, rounded abdomen that make them easy to differentiate from the *Nephila* species (Fig.4). The only one that may possibly be confused with either the joro or the banana spider is *Argiope aurantia*, the black and yellow garden spider

(Hoebeke et al., 2015; Weems & Edwards, 2004). This spider has a yellow and black body and striped legs (Fig. 5), but there are no tufts on the legs, no red spot on the belly, and the web silk is not yellow. *A. aurantia* also adds a large zigzag pattern to its webs, called stabilimenta (Fig), that makes this spider easier to identify.

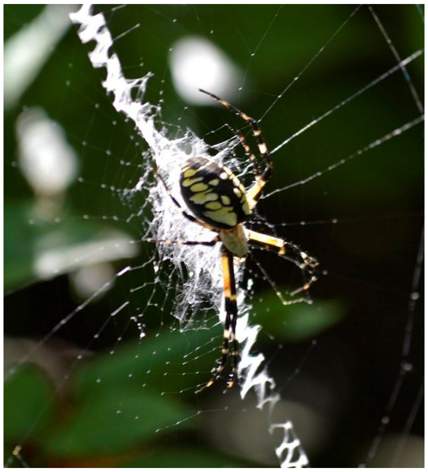

Fig. 5 *Argiope aurantia* Yellow and Black Garden spider

Methods

In discussions with a farm owner and the farm's barn manager in Hoschton, it was suggested a study on the new spiders inhabiting the trails in the area would be beneficial. This farm has seen a marked increase in the joro (*N. clavata*) reported by Hoebeke et al. (2015), and concerns about the possible effects of these spiders were raised by many of the riders and hunters. I designed this study to compare the locations of *N. clavata* with the locations of the two large orb weavers already present in Georgia that could possibly be mistaken for the joro, *N. clavipes* and *A. aurantia,* as a first step in helping determine effects, if any, of the introduced species. *A. aurantia* has been a common sight in the study area for some time and is known as the "writing spider" for the conspicuous zigzag addition it makes to its web. And while *N. clavipes* has not been sighted in most of the counties under observation, its similarity to the joro prompted its inclusion in this study, as well as concerns on climate change. *N. clavipes* lives best in warm, humid environments (Moore, 1977), and as temperatures in north Georgia climb, the spider could expand northward (Bakkegard & Davenport, 2012).

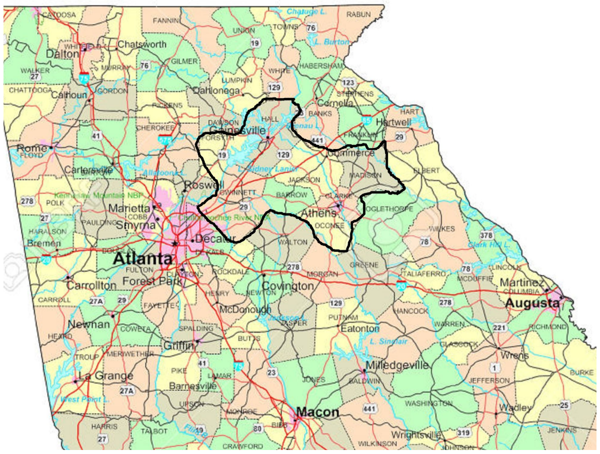

Fig. 6 Study Counties - Base Map by By 123RF

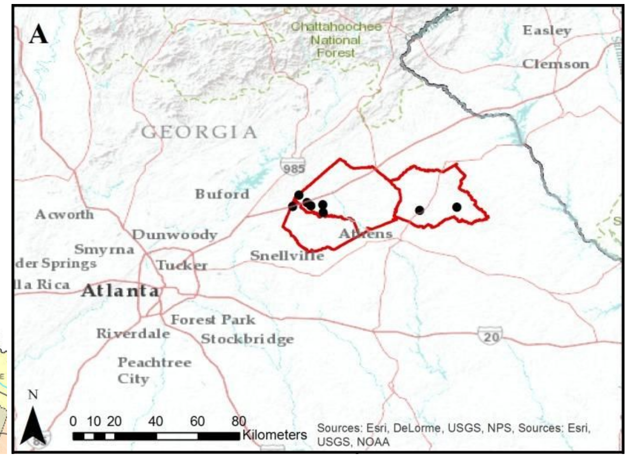

Fig. 7 Study area of Hoebeke et al. (2015) - map used by permission

The citizen science portion of this study started with a call for volunteers to look for the three orb weavers, take photographs and location information (address and/or GPS coordinates), and send them in by email. The volunteers were contacted through a flyer (Flyer) sent out by email (Appendix A), Facebook, and hung in parks (by permission of the park service). Groups contacted were parks, science teachers, scouting clubs, nature centers, equestrian farms, and equestrian organizations in the North Georgia counties of Madison, Clarke, Oconee, Barrow, Jackson, Hall, Gwinnett, and Forsyth (Fig. 6). These counties were chosen by their proximity to the locations of the joro reported in the Hoebeke et al. (2015) study (Fig. 7). The volunteer groups were chosen by their members' inclination to be outside in areas where they might encounter spiders regularly. The photos sent in were placed on a map in Google Earth with the date and time (if given) (see map in Google Earth or Fig. 10).

I also visited public areas, and private areas by permission, surrounding the previous sightings of *N. clavata* in Hoebeke et al. (2015) as well as near the new sightings coming in from the citizen science (CS) team. In these spaces, if one of the species was found, I took data on spider size, web characteristics, location description, and environmental characteristics, such as temperature, pressure, and humidity, in addition to the GPS coordinates (Appendix B). Female spider size and web size/height were taken by placing a translucent ruler close to the web and female spider, rather than direct contact or manipulation of the female, so as to disturb the spider as little as possible. GPS coordinates and elevation were taken by the altimeter and GPS in a Nikon Coolpix (Model AW130; Melville, New York). Pressure, humidity, and temperature were obtained using an Acu-Rite weather station (Model 01033; Chaney Instrument Co. (PFOC), Lake Geneva, Wisconsin). These locations investigated were added to the map, including locations where no spiders of the three species were found (Fig. 8). All locations on the map are color-coded by species (red-joro, orange-garden, pale green-other, bright green line-none found) with bright green lines to denote areas that were checked but showed no signs of study species with the date.

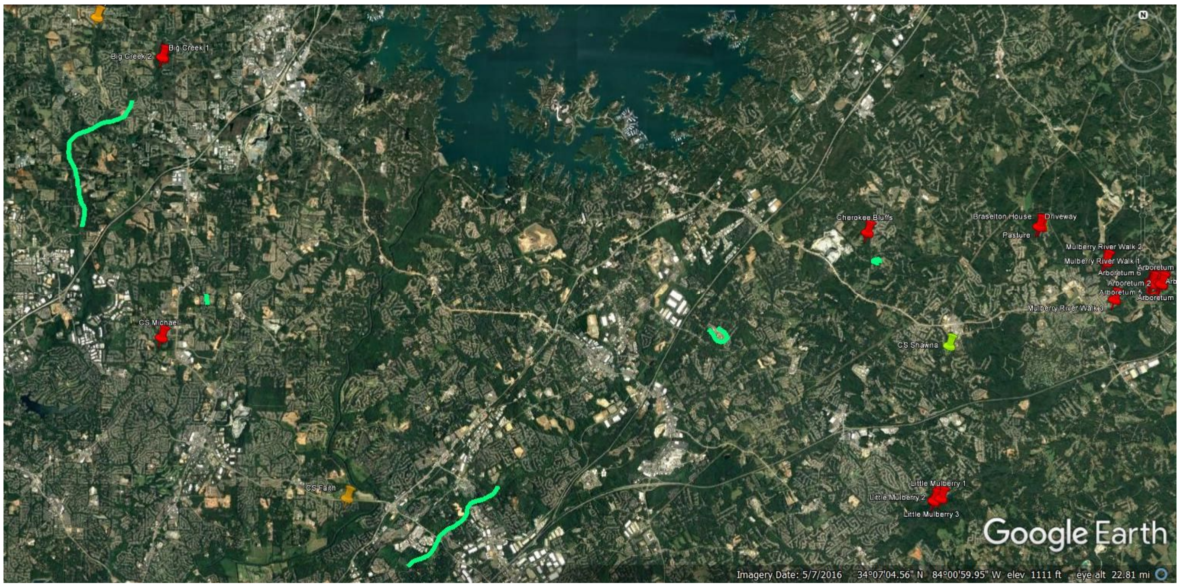

Fig. 8 Sample of Google Earth map with locations of study species.
Red pin-*N. clavata*, Orange pin-*A. aurantia*, Green pin-other species, Bright green path lines-areas where no spiders were found

Data on all spiders in a certain area or trail were collected, unless the density of spiders was too high to make data collection feasible on all specimens. In these cases, counts were taken of the spiders visible down the length of the whole trail with random individuals chosen for data collection. On the Hoschton farm, CS volunteers sent in counts of spiders visible on high-density trails. One CS volunteer gave a high-density count of *A. aurantia* in Powder Springs, and another location of high numbers of *N. clavata* in Braselton was observed. These high-density spots are also included in the Google Earth map with paths color-coded by species, distance of path, and counts taken (Fig. 9). Distances were estimated using Google Earth tools.

Fig. 9 Sample of map showing high density areas; Red-*N. clavata*, Orange-*A. aurantia*

Sixteen photos were sent in by the CS team. Most of the CS volunteers were from email and Facebook contacts, with three from flyers hung in parks. Identification was aided by Dr. Richard Hoebeke at the University of Georgia. Two of the species sent in were not species included in the study. These were included in the map, but their pins were colored with a light green to separate them from the study species. Forty specimens of *N. clavata* were recorded, eight specimens of *A. aurantia*, and zero specimens of the banana spider (*Nephila clavipes*) were found, by the CS team and by personal investigation.

Analysis of the photos and GPS coordinates gave clues to the habitats of the spiders. Comparisons between *N. clavata* and *A. aurantia* were made based on web support, amount of light in habitat, and presence of other spiders in the web. Web support was divided into eight categories (man-made structure, vehicle, bush, tree, fence, bush & fence, bush & tree, fence & tree). Amount of light was divided into three categories (shade, part sun/part shade, full sun). The data on the presence of other spiders in the web with the female included males and females of the same species as well as other species, such as kleptoparasitic spiders that feed on prey caught by the web-building female. Statistical analysis of environmental data, spider size, and web characteristics were attempted, but the small sample size of *A. aurantia* (3 of the eight) gave questionable results.

Results

The locations of the two species can be seen on the map (Fig. 10). The joro (*N. clavata*) were observed in a narrow east-west corridor between latitudes 34º02'58" North and 34º11'20" North. Individuals of the garden spider (*A. aurantia*) were observed in varied locations, but only one specimen was found in the same area as the joro, at the farm in Hoschton (Fig 11). Other species of large orb weaver, from *Araneus* and *Neoscona* genera, were observed in the same areas as the joro (Fig. 12).

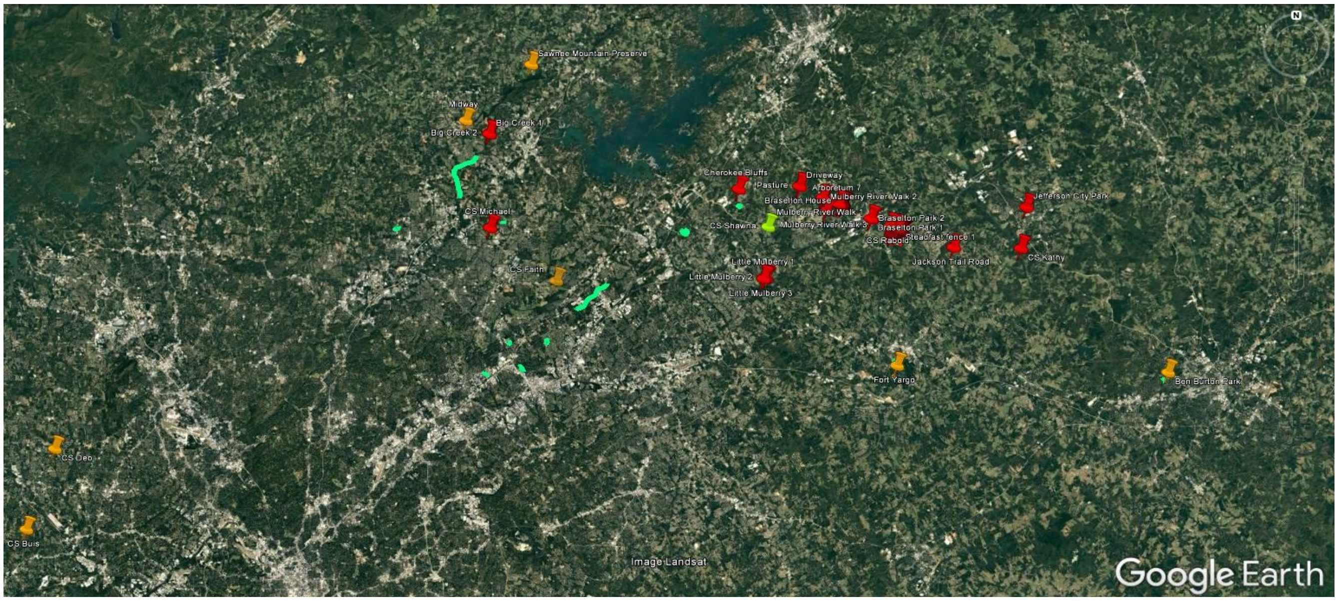

Fig. 10 Map of all spiders found in study

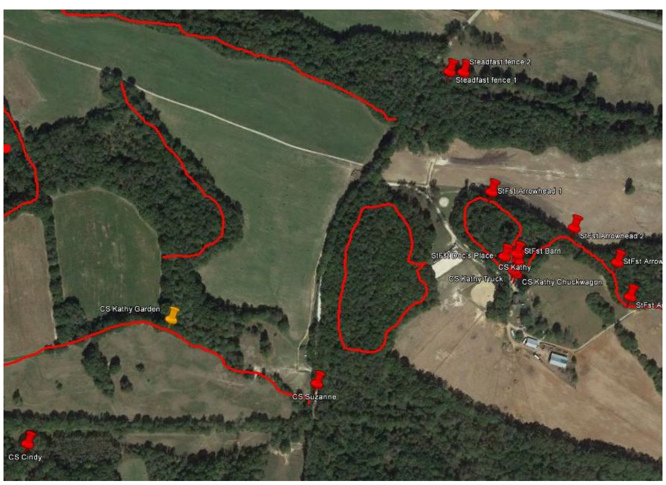

Fig. 11 Sample of map showing *A. aurantia* (orange pin) living in same area with *N. clavata* (red)

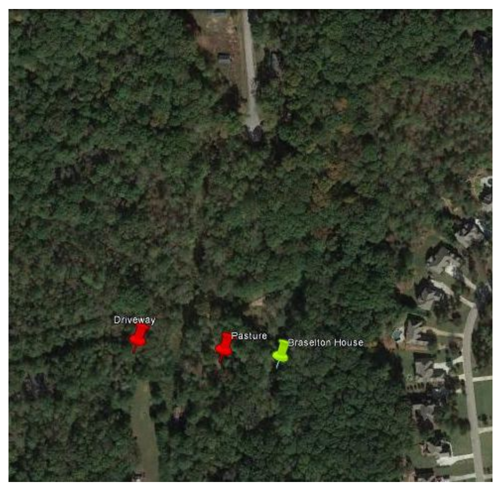

Fig. 12 Sample of map showing other species (green pin) living in same area with *N. clavata* (red)

Web support was compared between the two species (Fig. 13). All eight of the garden spiders (*A. aurantia*) in the study chose either man-made buildings or bushes for their webs. In every case, the webs had one flat side of the web open to the air and the other side protected by either a man-made surface, such as a window or wall, or by dense vegetation (Fig. 14). By comparison, the joro spiders (*N. clavata*) chose a variety of supports, singly or in combination. The common factor in the observed joro webs was open air on both sides of the web, to incorporate the central orb with guard webs on the sides (Fig. 1).

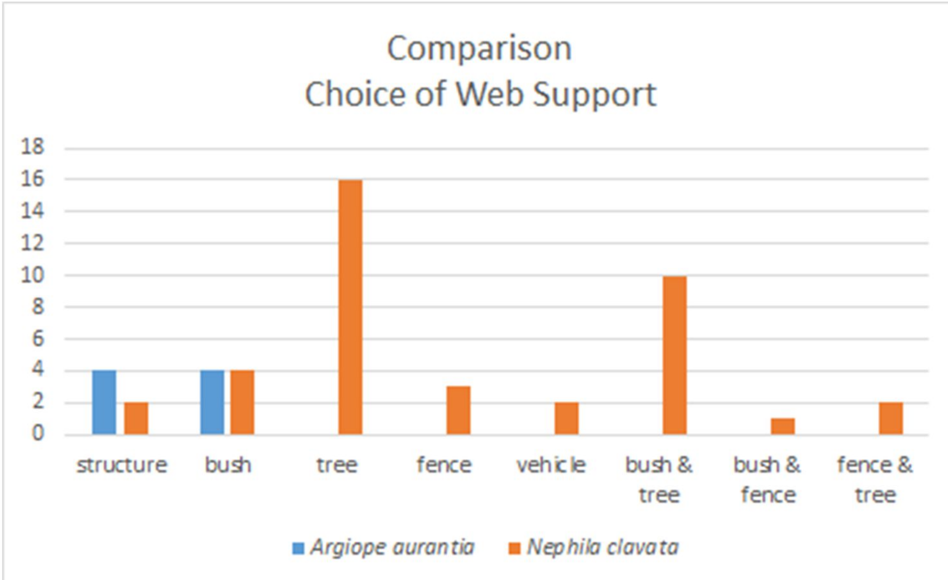

Fig. 13 Comparison of web support between *A. aurantia* and *N. clavata*


Fig. 14 Examples of *A. aurantia* webs with one flat side protected by surface or vegetation

The amount of light in the spiders' habitats showed no spiders choosing to build webs in full sun. 82% of the *N. clavata* specimens chose shaded areas, 18% chose part sun and part shade. In contrast, only 12% of the *A. aurantia* specimens chose shade, 88% built in part sun and part shade (Fig. 15).

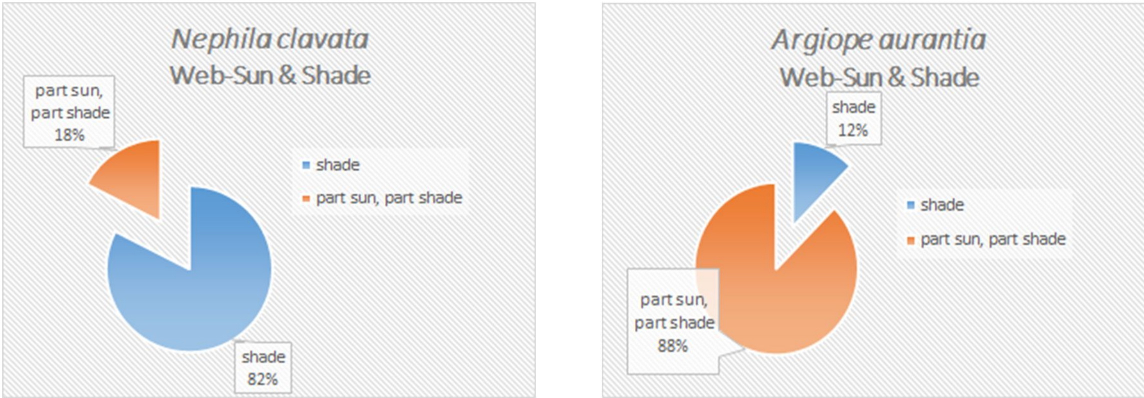

Fig. 15 Comparison of sunlight in habitats of *N. clavata* and *A. aurantia*

Fig. 16 Examples of neighbors in web with female joro

Other spiders in the web with the female were observed only in joro (*N. clavata*) webs. These were males, other females, and other species, such as kleptoparasites (Fig. 16). 37% of the observed joro webs contained a neighbor, while 63% did not (Fig. 17). All males were in webs with females observed before September 12. No webs recorded after the middle of September contained males. Although two CS volunteers reported seeing small spiders in webs with a female in October, no photos were sent in.

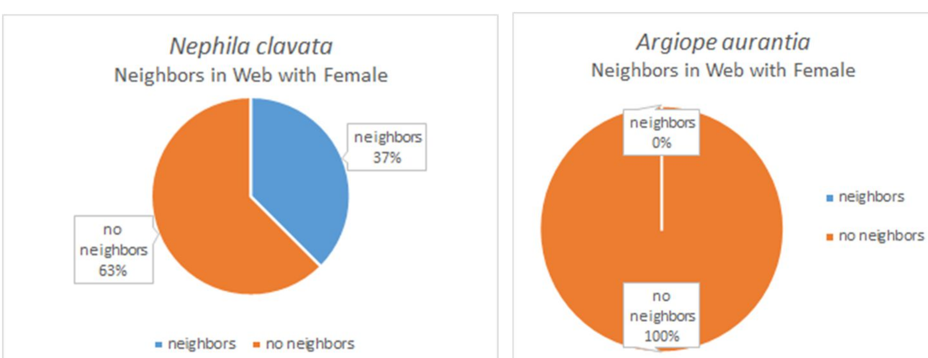

Fig. 17 Comparison of presence of other spiders in web with female

Environmental data, web characteristics, and spider size were recorded on 3 specimens of *A. aurantia* and 31 specimens of *N. clavata*. With the extremely small sample size of the garden spider, statistical analysis was not conclusive. Only web height, web size, and pressure gave Pvalues below 0.05, and these were suspect due to the small sample size and imbalance in numbers between the two species.

High densities of spiders in small areas were recorded by several of the CS volunteers. Eight counts were taken of *N. clavata* and one of *A. aurantia* (Table 1). These densities were recorded by counting the visible females while walking or riding along the path in question. The highest density of *N. clavata* was found in a nine foot area at the farm in Hoschton, an average of two spiders for every linear foot reaching up to 20 feet in the trees.

Table 1 Abundance counts in high-density areas by CS team

	Arboretum *N. clavata*	Stfast Gray field *N. clavata*	Stfast Hay field *N. clavata*	Stfast Driving magic *N. clavata*	Stfast Hog barn 1 *N. clavata*	Stfast Bridlepath *N. clavata*	Stfast Doc's place *N. clavata*	Stfast Bottoms *N. clavata*	Stfast BehindD M pasture	Buis barn *A. aurantia*
Number of spiders	26	97	27	19	49	21	22	141	18	10
Distance in feet	2500	2530	1495	1522	3025	2330	1045	3661	9	200
Linear area per spider in feet	96.15	26.08	55.37	80.11	61.73	110.95	47.5	25.96	0.05	20

The large numbers of *A. aurantia* at the barn in Powder Springs (Table 1) was reported as smaller this year than in past years. The CS volunteer stated that, historically, this area boasted over 30 separate garden spiders every summer. This was corroborated by several other CS volunteers who reported seeing less garden spiders this year than in previous years. Two volunteers stated their intention of joining the study and sending in photos of the spiders they usually get at their homes every summer, but the spiders did not show up this year.

Discussion

Location

The locations of the joro (*N. clavata*) showed an east-west distribution in a narrow band between latitudes 34º02'58" North and 34º11'20" North (Fig. 10). All specimens in the study were within six miles of a major four-lane highway, with the average being two miles (Table 2), and many were close to industrial shipping districts (Fig. 18). This may support the assertion of Hoebeke et al. that suggested the spiders disperse by intra- and inter-state trucking. The distribution along an east-west corridor also supports the suggestion by Hoebeke et al. (2015)

that ballooning of spiderlings plays a role in dispersal, since Georgia winds are usually from the northwest and west (Weber, Buckley, Parker, & Brown, 2001).

Table 2 Distances of *N. clavata* specimens to major highways

Location	Distance to Highway in feet	Location	Distance to Highway in feet
Hoschton, Driving Magic	8,320	Jefferson, house	30,000
Hoschton, Arrowhead Trail	10,780	Mulberry River Walk, Braselton	10,825
Hoschton, Arrowhead Trail	11,300	Mulberry River Walk, Braselton	10,840
Hoschton, Arrowhead Trail	11,660	Mulberry River Walk, Braselton	6,200
Hoschton, Arrowhead Trail	11,870	Caney Creek Preserve, Cumming	12,650
Hoschton, Doc's Place Trail	11,170	Hoschton, various trails	11,400
Hoschton, Fence	10,075	Hoschton, various trails	11,360
Hoschton, Fence	10,065	Big Creek Trail, Cumming	10,250
Braselton, driveway	17,030	Big Creek Trail, Cumming	10,300
Hoschton, Hog Barn	10,960	Arboretum	5,490
Little Mulberry Park, Dacula/Auburn	10,200	Arboretum	5,580
Little Mulberry Park, Dacula/Auburn	10,040	Arboretum	5,715
Little Mulberry Park, Dacula/Auburn	10,270	Arboretum	5,870
Braselton Park, Braselton	3,500	Arboretum	6,185
Braselton Park, Braselton	3,750	Arboretum	6,360
Braselton, pasture	16,960	Arboretum	6,610
Hoschton, Barn	11,200	Side of Jackson Trail road	19,650
Cherokee Bluffs Park, Flowery Branch	9,670	Jefferson City Park	20,050
Hoschton, Barn round pen	11,150		

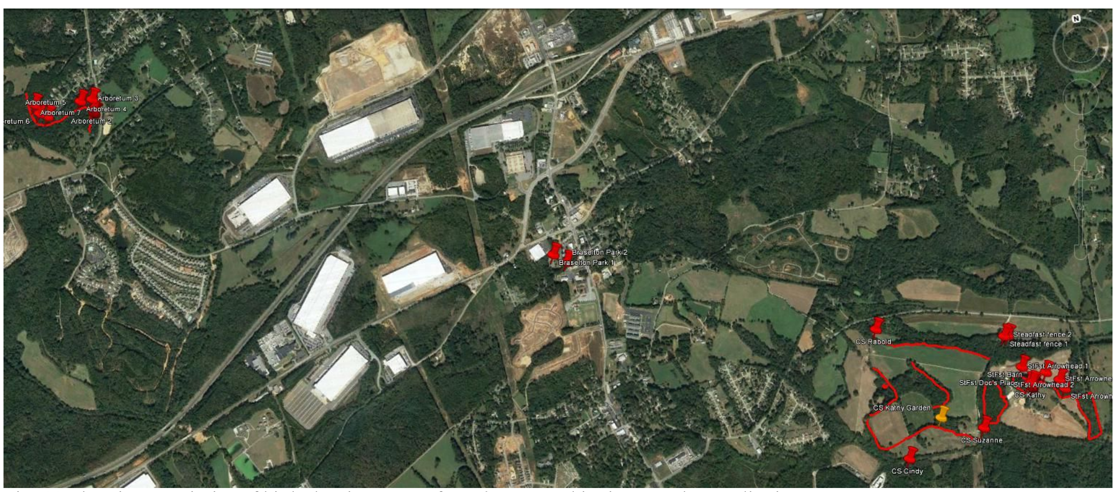

Fig. 18 Showing proximity of high-density areas of *N. clavata* to shipping warehouse district

The locations of the garden spider (*A. aurantia*) were more varied (Fig. 10), but only one occurred in the area inhabited by the joro (Fig. 11). The CS team all reported seeing garden spiders throughout the study area historically for many years, but most also reported a declining number of sightings in the past year. It is unclear whether there is a correlation between the increase in the abundance of joro spiders and a decrease in the abundance of garden spiders. It would take a study of several years to determine if the decrease in *A. aurantia* is a pattern or is a single phenomenon limited to this past season. It is suggestive, though, that the two species were found together only once, when *Araneus spp*. and *Neoscona spp.* were found in close proximity several times (Fig. 12 and Google Earth map).

Since no reports came in of the banana spider (*N. clavipes*), no comparisons of location can be drawn between it and the other two species. The farthest north the banana spider has been documented was in the Clarke/Oconee counties in the study by Bakkegard & Davenport (2012). These counties were included in this present study, but none were reported by CS volunteers or by personal investigation. This gives no support to Bakkegard & Davenport's (2012) theory that the *N. clavipes* is moving north, at least not yet. It would be interesting to follow the spread of the joro and the banana spiders over several years to see what interactions occur.

Web Habitat

The choice of habitat for building webs gives some insight into the differences between the garden (*A. aurantia*) and the joro (*N. clavata*) spiders (Fig. 13). The joro seemed to choose open shaded areas, building on a variety of supports that provide enough space for the orb web and guard webs. This agrees with reports from their native environments as well as reports of other *Nephila* species (Hoebeke et al., 2015; Bakkegard & Davenport, 2012; Su et al., 2011; Morse, 2000; Moore, 1977). The abundance of joro webs found in trees, fences, and combinations of natural and unnatural supports differed from that reported by Hoebeke et al. (2015), who found most specimens on or near human structures. Only two of the 39 webs in this study were found on buildings, but two were found on vehicles. CS volunteers reported taking these spiders for rides daily, sometimes as far as 15 miles away. The only limitation on web support suggested in the results is the need for shade (Fig. 15). The flexibility of *N. clavata* in choosing a habitat may give the joro an advantage in its new environment as well as add to their ability to travel.

Neighbors

The number of males or other spiders observed in joro (*N. clavata*) webs cohabiting with the female was higher than expected, 37% (Fig. 17), since Hoebeke et al. (2015) reported seeing males in only one web (1 in 9, 11%). No males or other spiders were observed in *A. aurantia* webs, raising questions of whether the males of the joro are more abundant and/or more aggressive than those of the garden spider. A study of the male/female interactions would be helpful in understanding how this relates to breeding fitness and abundance of the joro in the United States.

Fig. 19 Many sightings of *N. clavata* occurred within a few hundred feet

High Densities

Eight of the nine reports of high densities of spiders in small areas were of *N. clavata* (Table 1). And many of the observed specimens of the joro were within a few hundred feet of each other, such as the Braselton park, Big Creek Trail, Braselton house, and Mulberry River Walk groups (Fig. 19). Only the one case of high numbers of *A. aurantia* in Powder Springs was reported. All others reports of *A. aurantia* were single specimens with no close neighbors of the same species. This may suggest a larger territory or a smaller number of offspring for *A. aurantia* than *N. clavata*. Whether this is a genetic difference or may be due to species preferences, predator choice or abundance, prey choice, or other considerations is unclear. A future study on territory sizes would be beneficial in understanding fitness in the two species.

Fig. 20 Ability of *N. clavata* to live in close proximity-red circles show females-stop sign is normal sign size

Similar to *N. clavipes* as discussed by Moore (1977), females of *N. clavata* were observed living in close proximity to each other, frequently sharing guard web and web support (Fig. 20). This was seen throughout the study, regardless of female size, presence of males, or time of year.

The abundance of spiders at the farm in Hoschton prompted the request to study these spiders, causing concern in riders and hunters on the property. The ability to live close to each other, the abundance of spiders, and the presence of males reported in August and September suggest a breeding facility which may lend the joro a step up in fitness in their new environment, as discussed in Nentwig (2015).

Action

My first action is to continue this study to track how the locations of the spiders change in the coming years, especially as the numbers of the garden spider seem to be low this year and no banana spiders were sighted. So far, we have only one instance of the joro and the garden existing in the same area. The joro does seem to coexist with other large orb weavers from the *Neoscona* or *Araneus* genera. I intend to contact schools, teachers, scouts, and barns to develop several groups of volunteers in the areas where the joro was found. I will meet with those interested to discuss the study and go over the protocols of data gathering. Having a trained team will make the data collection easier and should generate more numbers for analysis.

Dr. Hoebeke has also spoken of the need to do a year-long observation of the new species to track basic life-cycle data. I have a couple of volunteers that may be interested in doing something with this. The teams developed for the observation data could also be looking for spiderlings, ballooning, prey choice, etc., depending on age, ability, and interest level.

I intend to also develop a website for the tracking of these spiders and other orb weavers in the southeast United States. I hope to contact other websites that track invasive species, too, to discuss the issues. The joro is not a conclusive invasive yet, so I'm not sure how this will fit in with what they are doing. I will just be starting a dialogue and developing contacts for the future.

Conclusion

In conclusion, the locations and habitat characteristics of the joro spider (*Nephila clavata*) compared to the black and yellow garden spider (*Argiope aurantia*) has yielded some interesting insights, such as the light requirements and the choice of web support. Reports of the garden spider numbers declining is disturbing, but may or may not be related to the introduction of the joro to the area. More study is needed to determine if the trends observed in this study are indicative of true patterns. A continued effort to record locations as well as habitat characteristics is needed.

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Photos

All photos by author unless otherwise noted

1. County Map. 123RF USA States Series: Georgia http://previews.123rf.com/images/fourseasons/fourseasons0709/fourseasons070900010/1565661-USA-states-series-Georgia-Political-map-with-counties-roads-state-s-contour-bird-and-flower-Stock-Photo.jpg
2. *Nephila clavipes* Banana spider by Stephanie Morse http://animaldiversity.org/collections/contributors/jo_okeefe/Golden_Silk_Spider_100_7257/large.jpg
3. Map of study area in Hoebeke et al. article - Hoebeke, E. R., Huffmaster, W., & Freeman, B. J. (2015). Nephila clavata L. Koch, the Joro Spider of East Asia, newly recorded from North America (Araneae: Nephilidae). PeerJ 3:e763. DOI 10.7717/peerj.763

<u>**Appendix A**</u>

Email Texts

1. My name is Angela Harvey, and I am conducting a study on orb-weaver spiders in North Georgia. The purpose of this research is to determine locations of the common yellow and black garden spider, Argiope aurantia, and the golden orb-weavers, the banana spider, Nephila clavipes, and the Joro spider, N. clavata. Hoebeke, Huffmaster, and Freeman established the presence of the Joro spider, which has been introduced into Georgia from Asia, in an article in 2015. To further the study of this species and help determine its impact, I will be asking for volunteers to take pictures and send them to us with location data on the three species. I would like to have your permission to post a flyer about the study at parks in your county and to investigate the sightings reported. This research is being conducted as part of my graduate degree program at Miami University of Ohio. If you have any questions, you can contact me at harveyal@miamioh.edu. Thank you for your time.

2. My name is Angela Harvey, and I am conducting a study on orb-weaver spiders in North Georgia, part of a graduate degree program at Miami University Ohio in coordination with entomologists at UGA. The purpose of this research is to determine locations of the newly introduced Joro spider, Nephila clavata, from Asia and compare its range to the common yellow and black garden spider, Argiope aurantia, and the banana spider, Nephila clavipes. The Joro has been confirmed in the United States for the first time in Northeast Georgia, and its impact has yet to be determined. I am looking for volunteers to spot these spiders, take photos and location information, and send them to me via email to map the spiders' locations. I would appreciate your help by using this information and passing it on to other appropriate leaders who might have children or parents interested in joining us by seeking out these spiders in their respective areas. The more people we have looking, the better our information will be. I have attached the .pdf of our flyer for your use. If you have any questions, please feel free to contact me at harveyal@miamioh.edu.

Thank you

Appendix B

Data Sheet

Date:____________________ Time:___________

Spider

Species:___________________________

Size:______________________________

Males:____________________________

Neighbors:________________________

Web

Width:___________________________

Height:__________________________

Support:____

Location

Address:____

GPS:____

Elevation:_______________________________

Temperature:_____________________________

Pressure:________________________________

Humidity:_______________________________

Description of area:

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