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A BIOGEOGRAPHIC COMPARISON OF SPIDERS WITHIN ILLINOIS AND INDIANA

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ABSTRACT. In March 2017, the Indiana Academy of Science held a biodiversity symposium prior to their annual meeting. Spiders were among the taxa discussed. Although published data on spider distribution records in both states (Indiana and Illinois) are sparse – especially in Indiana – an online collection network (SCAN) exists that supplements these data. I examined each recorded species from the online collection network that contained the most spider records and attempted to determine each record's validity by comparing the distance from its previously known range to either Indiana or Illinois. In addition, I calculated the numbers of species present in each state and within both states using published records. I also determined the general geographic range of each species based on known distribution data (northern, eastern, mid/eastern, southern, western, and widespread) and used a chi-square analysis with an adjusted residual post-hoc analysis to reveal significant differences from expected values. There were a significantly higher than expected number of spiders found in Indiana only that had eastern distributions and there were a significantly higher than expected number of spiders found in Illinois only that had western and northern distributions. Finally, there were a higher than expected number of spiders found in both states that possessed mid/eastern and widespread distributions. Records from the online database were not used because it became apparent that 10%–21% of the records may be misidentifications. These results emphasize that although the two states are adjacent to each other, the spider composition between the states have significant differences.

Keywords: Illinois, Indiana, biogeography, spider species richness, biodiversity, distribution

INTRODUCTION

The spiders of Illinois (IL) and Indiana (IN) have been documented since the late 1800s. The first published record of a checklist for either of these states was in a talk given by Fox in 1891 to the Washington Entomological Society, which noted 77 spider species known to Indiana (Fox 1891). This list was more than doubled by Banks (1906) to 148. Indiana's fauna list was later updated by Elliot (1932) to 218, Elliot (1953) to 303, Parker (1969) to 378, Beatty (2002) (with a reduction) to 367, Sierwald et al. (2005) to 383, and finally Milne et al. (2016) to 454. Meanwhile, the first published checklist of spiders in Illinois was written by Kaston (1955) in which he documented 350 species. This number was increased by Moulder (1966) to 363, by Beatty & Nelson (1979) to 500, Beatty (2002) to 550, and Sierwald et al. (2005) to 646.

A significant comparison and biogeographic examination of the spider fauna between the two states was not conducted until Beatty (2002) and then Sierwald et al. (2005). Unlike plants and other well-studied organisms, spider distributions are very rarely known at the county level (commonly, they are even poorly known on a state level; "P" in Table 8 in Sierwald et al. (2005)). The exception is medically-important species, such as the brown-widow spider (Brown et al. 2008) and brown recluse spider (Cramer & Maywright 2008). Therefore, it is difficult to answer habitat-specific biogeographic questions using spider distribution data. Alternatively, researchers – such as Beatty (2002) – classified each known species into ten pre-determined range categories and then compared the presence or absence of certain species of different ranges in the combined states (IL and IN together). This large-scale biogeographic analysis, while difficult to relate to specific habitats or environmental features (other than, perhaps, temperature and humidity), can inform us about both states' resemblance to other geographic areas based on their combined spider fauna.

Both IL and IN have physiographic similarities, such as being part of the Central Hardwood Forest, containing largely oak-hickory forest communities that are slowly being succeeded by beech-maple forest communities (Ebinger & McClain 1991; Shotola et al. 1992; Ebinger 1997; Fralish 2004), and having similar above-

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ground biomass density (Brown et al., 1999). However, within both states almost all of these forests have been cleared at least once and much of it is now farmland (Ebinger 1997). Both states also were split north-south by the most recent Wisconsinan glaciation, which retreated approximately 11,000 years before present. However, Illinois was historically primarily prairie (~61% according to early European surveyors) while Indiana only had small sections of prairie (Ebinger 1997).

The main network used for spider distribution records is Symbiota Collections of Arthropod Network (SCAN), which – as of this data analysis – possesses over 10 million records (SCAN 2017). SCAN is a subnetwork of Symbiota, a collection database system built on the internet, and aggregates data from museums, universities, and publicly-fed data aggregators such as the Global Biodiversity Information Facility (GBIF). Therefore, some specimens may have been identified by experts (e.g., museum-employed staff) while others may have been identified by amateurs (e.g., most GBIF submissions are from the public).

In 2017 the Indiana Academy of Science held a two-state biodiversity symposium that examined the similarities and differences in multiple groups of taxa between the two states. Within this symposium, I presented known spider species richness in each state, the shared species between states, and the role of online databases in supplementing traditional formally-published data from journals. Herein, these findings are expanded upon to better understand the similarities and differences in spider fauna between the two states. Moreover, the findings from the symposium are explored, analyzed, and used to build upon Beatty's (2002) biogeographic analysis of spider distributions between the states.

METHODS

The most recent spider distribution records for Illinois were obtained from Sierwald et al. (2005) while the most recent records for Indiana were obtained from the same source but updated with Milne et al. (2016). Distribution records of species were obtained from a combination of the American Arachnological Society's North American species list (Bradley et al. 2017), various manuscripts detailing the original description of the species (or a genus revision), and Sierwald et al. (2005).

Six different geographic distributions were established: northern, eastern, central/eastern, western, southern, and widespread (see Beatty (2002) for example maps of eastern and widespread). These geographic distributions more closely reflect those used by the main identification manual for spiders in North America (Ubick et al. 2017) than Beatty's (2002) geographic distributions. Northern distributions contained Canadian provinces but did not include southern, southwestern, or Gulf coast states. Eastern distributions included eastern Canadian provinces and US states. Eastern distributions also may have included Texas, Midwestern states, and Canadian provinces north of the Midwest. The central/eastern distribution may have included all locations within the eastern distribution in addition to states west of the Mississippi River or Canadian provinces west of Manitoba. However, a central/eastern distribution did not include states or provinces on the west coast or west of the Rocky Mountains. A western distribution mostly includes states west of the Mississippi River and the Canadian provinces north of those states. A southern distribution was constrained to states along the Gulf coast, east coast up to Maryland, and southwestern US but not Canadian provinces (Fig. 1). Finally, a widespread distribution was defined as having records from the east and west coast of the US and Canada and several states in between. Species were placed into one of these six categories based on their known distribution records. As explained in Beatty (2002), the placement of species into these categories can be subjective, but most species fit one of these six categories well. Once placed into a category, species were determined, based on Sierwald et al. (2005) and Milne et al. (2016), to be present in IN only, IL only, or present in both states.

A chi-square test was performed to determine if differences existed between observed and expected values within each category (e.g., the observed number of spiders in Illinois with an Eastern distribution versus the expected number, etc.) using Excel 2016. Expected values were calculated by multiplying the sum of a row by the sum of the column and dividing by the total of all cells (684). A significant p-value of 0.05 was established. Due to the high number of tests (18), a Bonferroni correction was conducted, creating a critical p-value of 0.0028. A two-tailed z-criterion was then created by taking the inverse of this corrected p-value. Using this z-statistic, a post-hoc test was then performed by calculating the adjusted

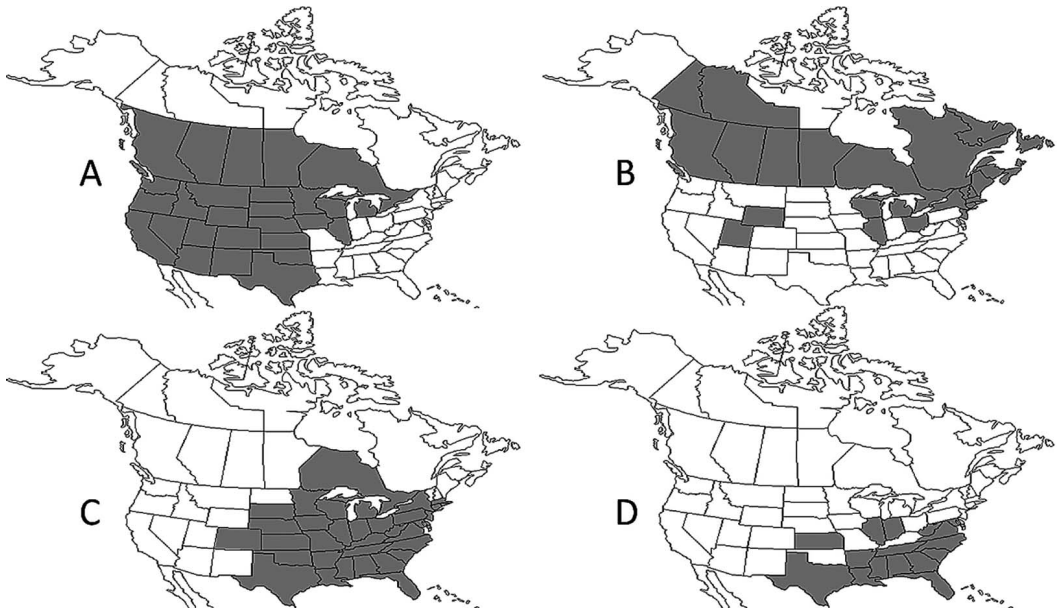

Figure 1.—Known range of four species. A. Western distribution exemplified by *Schizocosa mccooki* (based on Dondale & Redner 1978; Sierwald et al. 2005). B. Northern distribution exemplified by *Walckenaeria castanea* (based on Millidge 1983; Sierwald et al. 2005). C. Central/eastern distribution exemplified by *Schizocosa ocreata* (based on Dondale & Redner 1978; Sierwald et al. 2005; Milne et al. 2016; Bradley et al. 2017). D. Southern distribution exemplified by *Tigrosa georgicola* (based on Brady 2012; Bradley et al. 2017).

residuals for each category using the formula: {[observed value - expected value]/$\sqrt{}$[expected value $\times$ (1-row total/sum) $\times$ (1-column total/sum)]}.

Finally, all records of spiders (5,842 records) were examined within Indiana and Illinois on SCAN and cross-referenced against the most recent peer-reviewed publications. Since most of these records were not accompanied by any photographs nor were most of them available for examination, I attempted to determine the validity of all new state records by determining either the distance from the closest known distribution range or the country of the species' known range. Records that represented 1000+ mile range extensions were rejected as unlikely to be correct.

RESULTS

Of the 684 species documented, 405 were found in both states (59%). Illinois was found to possess far more unique species (236) than Indiana (43; Table 1). As presented in Table 1, most species documented had a central/eastern distribution (170; 24.9%). In descending order, the next most common were widespread species (166; 24.3%), eastern species (147; 21.5%), northern species (114; 16.7%), southern species (64; 9.4%), and finally western species (23; 3.4%).

The chi-square analysis of these data was highly significant ($p < 0.0001$). The z-criterion was 2.99 or -2.99, so all values greater than 2.99 and less than -2.99 were determined to be significant (bolded values in Table 1). The adjusted residuals indicated that the occurrence of species with an eastern distribution was significantly higher in Indiana than expected and significantly lower in both states than expected (Table 1). The adjusted residuals also indicated that the occurrence of spiders in Illinois was significantly higher than expected for northern and western species. Moreover, the occurrence of species in both states was significantly lower than expected for northern, southern, and western species. The occurrence of spiders with a central/eastern distribution within both states was significantly higher than expected, but significantly lower than expected in each state alone. This pattern also was present for spiders with a widespread distribution, except that it was non-significant for Indiana only (Table 1).

Table 1.—A comparison of the number of species found in each state by geographic range. Numbers in parenthesis represent adjusted residuals from chi-square post-hoc analysis. A residual of > 2.99 and < -2.99 indicates a value significantly different than expected. Significant adjusted residuals are bolded.

	IL only	IN only	Both	Total
North	64 (**5.32**)	7 (-0.07)	43 (**-5.11**)	114
East	58 (1.43)	20 (**4.13**)	69 (**-3.42**)	147
Central/East	32 (**-4.96**)	2 (**-3.17**)	136 (**6.36**)	170
West	16 (**3.60**)	3 (1.36)	4 (**-4.15**)	23
South	31 (2.46)	8 (2.15)	25 (**-3.44**)	64
Widespread	35 (**-4.18**)	3 (-2.73)	128 (**5.39**)	166
Total	236	43	405	684

After cross-referencing the SCAN records against both Sierwald et al. (2005) and Milne et al. (2016), there were 84 new state records for Indiana and 131 new state records for Illinois. However, the new Indiana records included six species that were rejected due to unlikely ranges, i.e., two Palearctic species, and one European species (10.7% of the total number of new distribution records). Similarly, the Illinois records included twenty-five 1000+ mile range extensions, i.e., one Chinese species, one Japanese species, and one Palearctic species (21.4% of the total number of new distribution records).

DISCUSSION

In his analysis, Beatty (2002) found that most spider species in IL and IN possessed an eastern distribution (37%), while the remaining species possessed (in descending order of occurrence) a northeastern (18.4%), northern (15.9%), southeastern (13.6%), widespread (10.6%), western (1.7%), central (1.5%), and southern distributions (1.3%). Because this study used different geographic regions than Beatty (2002), it is difficult to directly compare the two analyses. However, when the eastern and central/eastern categories of this analysis were compared to Beatty's (2002) eastern and northeastern categories – a similar categorization – they make up approximately half of the species found in both analyses (this analysis is ~46% while Beatty's is ~55%). Moreover, both analyses found that species with northern distributions make up approximately 16% of the species and western species are quite rare in IL and IN (Table 1). The most notable difference was that Beatty (2002) found that only 11% of the species were considered widespread while the current analysis put that value at 24.3%. This may be due to how each author categorized distributions as "widespread." The higher value in this analysis may be attributed, in part, to an increased number of distribution records throughout the US and Canada added within the last 15 years, thereby giving a more recent analysis of any particular species a higher likelihood of being considered "widespread."

As expected, species with eastern distributions had a significantly higher occurrence than expected in the more eastern state (IN) while species with western distributions had a significantly higher occurrence than expected in the more western state (IL). Spiders that possessed a widespread or central/eastern distribution had significantly higher occurrences in both states than was expected. This may be because spiders that have a widespread occurrence will likely occur in both IL and IN as well as many other Midwestern states. What was interesting to note was that species with a northern occurrence were significantly more prominent in Illinois than would be expected. This may be due to the presence of the northern part of Illinois in higher latitudes, to the west of Lake Michigan – latitudes not present in Indiana. This is undoubtedly also due to the makeup of the taxa. Many spiders with northern distributions are in the family Linyphiidae, sheetweb weaving spiders. Many of these spiders are small, rare, and have not been found in Indiana, likely due to a lack of searching (Sierwald et al. 2005).

These conclusions are dependent on reliable distribution record data, but the data used to come to these conclusions are incomplete. Sierwald et al. (2005) predicted the presence of hundreds of species in Indiana that have not yet been found. Moreover, the greatest predictor of knowing the distribution of species within a state was found not to be geographic area or time since state founding, but human population size. This

suggests that as human population increases, sampling effort increases due to the higher likelihood of the presence of arachnologists within that state actually looking for spiders (Sierwald et al. 2005). Indeed, very recent studies (e.g., Milne et al. 2016) represent the ongoing faunistic work that is occurring within Indiana.

Reliability of these data is also an important aspect when considering faunistics, the study of species lists and distributions. The peer-review of species lists is critical in ensuring correct distribution maps for species. Spider identification is notoriously difficult and is therefore a slow process, so much so that computer algorithms and programs have been developed in attempts to bolster identification speed and accuracy (Do et al. 1999). This difficulty hampers identification by amateurs and specialists alike. While it is likely that most of the species I found in SCAN were legitimate new records that have yet to be recorded in the published literature, the fact that they were interspersed with 10%–21% likely incorrect species identifications "muddies the water." With this hindrance to accuracy, the only way to determine if these specimens were legitimate would be to examine them in person or to view detailed pictures of the specimens, neither of which were readily available. Due to this unreliability, I would recommend not using SCAN data without examining specimens first. To improve the quality of SCAN data, I recommend that these specimens' identity be comfirmed by an arachnologist prior to being added to the database.

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