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ASSOCIATIONS AMONG GROUND-SURFACE SPIDERS (ARANEAE) AND OTHER ARTHROPODS IN MESIC FLATWOODS

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Abstract

Mesic flatwoods in Florida are increasingly threatened by anthropogenic activities, and although they are known to be important for many species of macrofauna, little is known of the arthropod assemblages that inhabit them. As arthropods can be utilized as indicator taxa, we characterized the assemblages of ground-surface spiders (Araneae) and other arthropods at 2 mesic flatwood sites in Hillsborough County, Florida, and used the Chao 2, ICE (incidence-based coverage estimator), and Michaelis-Menten means species richness estimators to extrapolate the true species richness of ground-surface spiders. Sampling was conducted over a 4-month period at the sites using pitfall traps, with spiders being identified to the level of genus or species, and other arthropods to the level of order. We identified 31 spider species from 27 genera in 12 families, with Lycosidae being the dominant spider family at both sites. However, Collembola and Formicidae were the most abundant arthropod taxa. Ground-surface spiders were not strongly associated with any typical prey groups, indicating that environmental factors might also be important in structuring this community. Our results indicate that more intensive sampling of these habitats would be required to comprehensively sample and identify all of the species present, but from a management perspective, our results appear to be relatively consistent with previous surveys elsewhere.

Key Words: arthropods; biodiversity; Florida; species richness estimators; spiders

Resumen

Los suelos “flatwood” (una serie de suelos de antiplanicie formados de sedimentos marinos con el drenaje deteriorado) mésico en la Florida están cada vez más amenazados por las actividades antropogénicas, y aunque se sabe que son importantes para muchas especies de macrofauna, poco se sabe de los conjuntos de artrópodos que habitan en ellos. Como los artrópodos pueden ser utilizados como taxones indicadores, hemos caracterizado los conjuntos de las arañas de la superficie del suelo y otros artrópodos en dos sitios de “flatwood” mésico en el Condado de Hillsborough de la Florida, y utilizado el Chao 2, ICE (un estimador basado en la incidencia de la cobertura), y Michaelis Menten un estimador del promedio de riqueza de especies usado para extrapolar la verdadera riqueza de especies de arañas de la superficie del suelo. Se realizó el muestreo durante un período de cuatro meses en los sitios usando trampas de caída, y las arañas fueron identificadas a nivel de género o especie, y otros artrópodos al nivel de orden. Se identificaron 31 especies de arañas que pertenecen de 27 géneros de 12 familias, con Lycosidae siendo la familia de arañas más dominantes en ambos sitios. Sin embargo, los Collembola y Formicidae fueron los taxones de artrópodos más abundantes. Las arañas de la superficie del suelo no se asociaron fuertemente con los grupos de presas típicas, lo que indica que los factores ambientales también pueden ser importantes en la estructuración de esta comunidad. Nuestros resultados indican que se requiere un muestreo más intensivo de estos hábitats para realizar un muestreo comprensivo e identificar todas las especies presentes, pero desde una perspectiva de manejo, los resultados parecen ser relativamente consistentes con estudios anteriores en otros lugares.

Mesic (or wet) flatwood habitats are typically dominated by slash pine (*Pinus elliottii* Engelm.; Pinales: Pinaceae) or longleaf pine (*P. palustris* Mill.; Pinales: Pinaceae), and because of the poor drainage of their soils they experience seasonal inundation with water (Harms et al. 1998). Historically these habitats stretched across the Atlantic and Gulf of Mexico coastal plains of the

United States, but increasingly they are threatened by anthropogenic activities and, in recent decades, their range has been greatly reduced (Harms et al. 1998). In addition to their importance economically as a source of timber and fiber, mesic flatwoods are known to support diverse communities of macrofauna (Geneva & Roberts 2009). However, relatively few quantitative data exist on the arthropod assemblages that inhabit mesic flatwoods.

Given that a distinguishing feature of mesic flatwoods is their periodic flooding, the arthropod assemblages found in these habitats could be considerably different from those in nearby xeric or even hydric habitats. Indeed, classical intermediate disturbance theory (Grime 1973; Connell 1978) suggests that such periodic flooding in mesic flatwoods could even lead to higher arthropod diversity than in habitats with more consistent hydrological regimes, and thus they may host a relatively unique arthropod community. Collecting baseline data on the arthropod communities in these habitats is therefore important for several reasons. For example, because many arthropod taxa often are sensitive to changes in environmental conditions they can be utilized as indicators of pollution or other anthropogenic disturbances (Kremen et al. 1993; Schweiger et al. 2005), which could be useful for the management of mesic flatwoods. Furthermore, by determining the associations between different arthropod groups in a community at a coarse taxonomic level, it could also be possible to predict changes in the assemblages based on the loss of certain taxa or the type of disturbance.

Spiders (Araneae) in particular have frequently been utilized as indicator taxa because of their abundance and the relative ease with which they can be collected (Wise 1993; Shochat et al. 2004; Buchholz 2010). In addition to being utilized as indicator taxa, spiders can play an important role in many ecosystems because of the top-down effects they exert on their arthropod prey (Riechert & Bishop 1990; Wise 2004), which often includes pest species. Given that exhaustive species surveys of sites often are impractical for taxa such as spiders, using species richness estimators to extrapolate the true species richness for a site could be more useful (Colwell & Coddington 1994). Perhaps most importantly, the species accumulation curves could be useful for informing decisions on sampling effort at other sites with similar habitat.

Accordingly, we surveyed arthropods at 2 relatively undisturbed mesic flatwood sites in Hillsborough County, Florida, with a further focus on ground-surface spiders. Our objectives were as follows: 1) to collect baseline data on the richness and abundance of ground-surface spiders and other arthropods, 2) to examine the associations among arthropod taxa in the community, and 3) to use species richness estimators to extrapolate the true species richness for ground-surface spiders at these sites.

Materials and Methods

Study Sites and Sample Collection

Our 2 study sites were Brooker Creek Headwaters Nature Preserve (BCH) (28° 08.32' N, 82° 33.32' W) and the University of South Florida Ecological Research Area (ERA) (28° 04.24' N, 82° 23.44' W). Common flora at both sites include bald cypress (*Taxodium distichum* (L.) Rich.; Pinales: Cupressaceae) and slash pine, while saw palmetto (*Serenoa repens* [(Bartram) J. K. Small]; Arecales: Arecaceae) and hardwoods such as laurel oak (*Quercus laurifolia* Michx.; Fagales: Fagaceae) are occasionally found in patches. While BCH is open to the public and experiences relatively low-levels of anthropogenic disturbance from hiking, the ERA is closed to the public and therefore experiences virtually no anthropogenic disturbance. To collect arthropod samples from these sites, we deployed 10 pitfall traps filled with 100 ml of soapy-water set 2 m apart along a 10 m transect (2 transects per site). These transects were surveyed approximately once every 2 weeks between July 1st and September 10th 2008 at BCH, and between September 22nd and November 10th 2008 at the ERA, for a total of 16 transect surveys and 160 pitfall trap samples. Pitfall traps were left out for 48-hours before the contents were collected and returned to the lab for identification. Spiders were identified to genus or species, and voucher specimens have been placed in the Florida State Collection of Arthropods. Other arthropods were identified to the order level or below. While it would have been desirable to obtain a higher taxonomic resolution for all arthropods, a coarse, order-level identification could be more useful for management purposes, as there are rarely the funds or expertise to identify many arthropods to genus or species (Rohr et al. 2007).

Statistical analyses

We compared the pooled spider richness and abundance of both sites by generating species accumulation curves and asymptotic richness estimates using the program EstimateS v. 8.0 (Colwell 2005). The species richness estimators we used were: Chao 2, ICE (incidence-coverage based estimator), and Michaelis-Menten means. Frequently there can be considerable variation in the results produced by different estimators, so by using multiple estimators we were able to more effectively evaluate the reliability of their performance (Rohr et al. 2009). The Chao 2 and ICE estimators use the number of uniques and duplicates (species that occur in only 1 or 2 samples respectively) to estimate the number of species that were missed in the sampling procedures (Chao 1987; Chao & Lee 1992; Chazdon et al. 1998), while the Michaelis-Menten means estimator is based on the same equation used in enzyme kinetics (Colwell & Coddington 1994). All curves were generated based on the mean of 1000 randomizations of the sample order.

To determine the relationships between the abundances of all arthropod taxa, we conducted a principal coordinate analysis (PCoA) based on Hellinger's distance (Legendre & Gallagher 2001). The ordination analysis was conducted using CANOCO 4.5 (ter Braak & Šmilauer 2002), and we created the biplot using CanoDraw 4.12 to display the results (ter Braak & Šmilauer 2002). We post-transformed the scores so that the relationships between different arthropod groups could be inferred based on perpendicular projection (Legendre & Gallagher 2001; ter Braak & Šmilauer 2002).

RESULTS

Spider Species Richness and Abundance

We collected a total of 71 spiders, composed of 31 species from 27 genera in 12 families (24 species at BCH, 15 at ERA) (Table 1). Lycosidae was the dominant family at both sites (70.4% of the total spiders at BCH, 56.8% at ERA), followed by Salticidae (6.8% at BCH, 11.1% at ERA) and Tetragnathidae (6.8% at BCH, 3.7% at ERA). Eight species were common to both sites and the most abundant species overall were *Hogna* spp., *Pirata suwaneus* Gertsch, *Schizocosa humilis* (Banks), and *Sosippus floridanus* Simon, all of which are lycosids. To determine guild composition, we followed the general classification of Young & Edwards (1990), who proposed 5 guilds of spiders based on hunting behaviors: wandering-active, wandering-ambush, web-matrix, web-orb, and web-sheet. The guild of wandering-active spiders was by far the most abundant, comprising 75% and 92.6% of spiders at BCH and the ERA respectively. We found representatives from only 2 other guilds present: web-sheet spiders (13.6% of spiders at BCH and 3.7% at ERA), and web-orb spiders (11.4% of spiders at BCH and 3.7% at ERA).

TABLE 1. TOTAL NUMBERS OF SPIDERS COLLECTED AT BROOKER CREEK HEADWATERS PRESERVE (BCH) AND THE UNIVERSITY OF SOUTH FLORIDA ECOLOGICAL RESEARCH AREA (ERA) IN 2008.

Family/Species	BCH	ERA	Total
Agelenidae			
Barronopsis sp.	1		1
Araneidae			
Gea heptagon	2		2
Corinnidae			
Phrurotimpus alarius		1	1
Ctenidae			
Ctenus captiosus		1	1
Gnaphosidae			
Gnaphosa sericata	1		1
Zelotes sp.	1	1	2
Hahniidae			
Neoantistea magna	2	1	3
Linyphiidae			
Ceratinella sp.	1		1
Ceratinops crenatus	1		1
Meioneta sp.	1		1
Lycosidae			
Allocosa mulaiki	1	2	3
Hogna lenta		1	1
Hogna sp.	6	5	11
Pirata insularis		4	4
Pirata suwaneus	2	5	7
Rabidosa rabida	3		3
Schizocosa humilis	6		6
Schizocosa sp.	2	1	3
Sosippus floridanus	5	1	6
Oonopidae			
Heteroonops spinimanus	1		1
Pisauridae			
Dolomedes sp.	1		1
Pisaurina sp.	1		1
Salticidae			
Habronattus sp.		1	1
Naphrys bufoides		1	1
Neon sp.	1		1
Phidippus sp.	1		1
Zygoballus sexpunctatus	1		1
Zygoballus rufipes		1	1
Tetragnathidae			
Glenognatha foxi	1		1
Leucauge sp.	1		1
Pachygnatha autumnalis	1	1	2

Arthropod Richness and Abundance

Including spiders, we collected a total of 3,101 arthropods (1,591 at BCH, 1,510 at ERA) from 11 taxonomic groups (Actindedida, Araneae, Coleoptera, Collembola, Diptera, Formicidae, Hemiptera, Homoptera, Hymenoptera (excluding Formicidae), Lepidoptera, and Orthoptera) (Fig. 1). Collembola was the most abundant taxa at both sites (58.5% of the total arthropods at BCH, 60.3% at ERA), followed by Formicidae (29.5% at BCH, 21.6% at ERA). With the exception of Diptera at ERA (9.3%), all other taxa comprised < 3% of the total number of arthropods each for both sites.

Spider Species Richness Estimators

None of the species richness estimators we used reached a clear asymptote, however the curve generated using Michaelis-Menten means appeared to be closest to approaching this (Fig. 2).

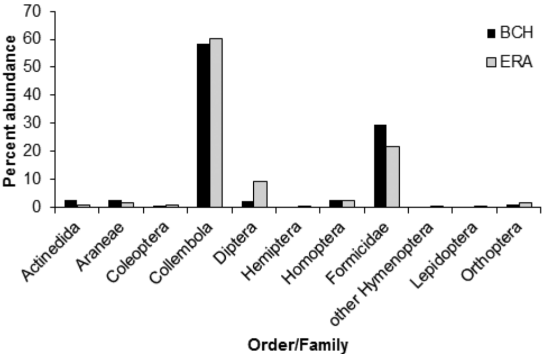

Fig. 1. Percent abundance of different arthropod taxa at Brooker Creek Headwaters Preserve (BCH) and the University of South Florida Ecological Research Area (ERA).

The Chao 2 estimator yielded the highest number of species (91), almost double the number generated by Michaelis-Menten means (53). The ICE estimator produced a species number that was slightly above the Michaelis-Menten means (67). We also found that there was always a greater number of uniques than duplicates, with uniques steadily increasing while the number of duplicates eventually started to decrease.

Principle Coordinate Analysis

PCoA revealed that arthropod assemblages differed at both sites, particularly driven by variation in abundance of Diptera and to a lesser extent Orthoptera (Fig. 3). Ground-surface spiders were strongly negatively associated with Diptera, and only weakly associated with other common prey taxa such as Collembola and Homoptera. Formicidae also appeared to be negatively associated with Collembola and Homoptera.

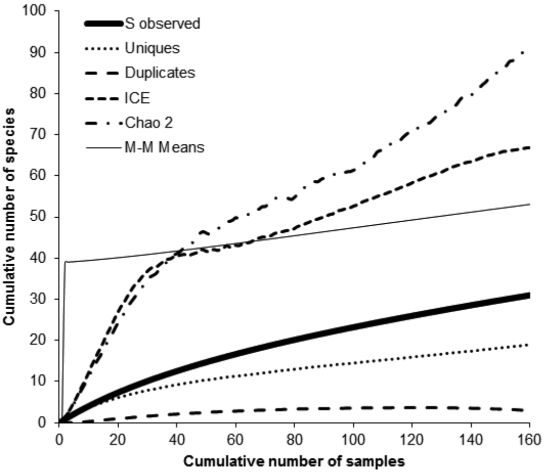

Fig. 2. Individual-based spider species rarefaction (S observed), estimated true richness (Chao 2, ICE [incidence-based coverage estimator], and Michaelis-Menten means), and uniques and duplicates.

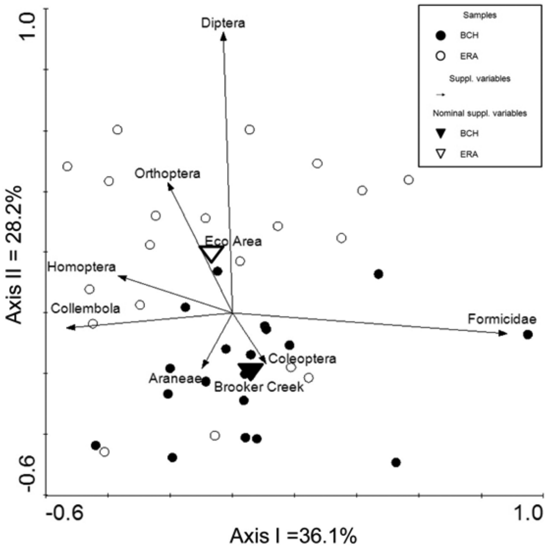

Fig. 3. Results of a principal coordinate analysis (based on Hellinger's distance) of the relationships among arthropods at Brooker Creek Headwaters Preserve (BCH) and the University of South Florida Ecological Research Area (ERA).

Discussion

At the family level, ground-surface spider diversity and relative abundance were fairly similar to sandhill and xeric or hydric flatwood habitats elsewhere in Florida (Muma 1973; Corey & Taylor 1988; Corey et al. 1998). For example, Muma (1973) found Lycosidae to be the most dominant ground-surface spider family at a hydric pine flatwoods site in central Florida, comprising 64% of the total number of spiders. At another site in central Florida, Corey & Taylor (1988) examined more mesic flatwoods, and found that lycosids also dominated the habitat (47.2%), although not quite to the same extent as found by Muma (1973). Our results at the family level are even fairly similar to those of Corey et al. (1998), who examined ground-surface spider assemblages at several sandhill sites and found Lycosidae to be the most dominant family (75.2%). However, at the species level some differences become apparent between the communities we examined and those from previously published work by Muma (1973) and Corey & Taylor (1988). For instance, we identified 9 species of lycosids compared to 13 by Muma (1973), with only 3 species common to both studies (*Hogna lenta* [Hentz], *Pirata suwaneus* and *Sosippus floridanus*). Furthermore, of the 15 most common species found in mesic flatwoods by Corey & Taylor (1988), only 2 were present at our sites (*Ctenus captiosus* and *S. floridanus*). These observed patterns could represent true differences between the communities, but perhaps more likely result from the less intensive sampling we conducted compared to the previous studies of Muma (1973) and Corey & Taylor (1988).

None of our species accumulation curves reached an asymptote, which further suggests that we did not sample all of the ground-surface spider species present at our study sites. Additionally, there was considerable variation in the results produced by the different estimators, with the total number of species projected to be approximately 2 to 3 times greater than the number of species observed. Some of the curves also generated seemingly unrealistic results. For example, 39 species were projected to be collected after just 2 samples using the Michaelis-Menten means estimator. The overall performance of the estimators used was similar to the results of Toti et al. (2000), who examined the species richness of spider assemblages in Appalachian balds and found that the Michaelis-Menten means estimator performed best when judged by their indirect criteria (that the curve was close to reaching an asymptote with fewer samples than the observed species curve, and that the estimates were close to a visual extrapolation of the asymptote of the observed species curve). Based on the performance of the 3 estimators, it appears as though the true spider species richness is at least 50-70 species (where the ICE and Michaelis-Menten means curves were more closely grouped together). This number seems to be consistent with the more extensive previous surveys in flatwoods by Muma (1973) and Corey & Taylor (1988), who found 55 and 48 species respectively.

Our objective in the present study was to survey ground-surface spiders and other arthropods, and accordingly we deployed pitfall traps. Pitfall traps generally are effective at catching arthropods inhabiting the ground-surface, and this method has previously been used numerous times (e.g., Corey & Taylor 1988; Corey et al. 1998; Stiling et al. 2010). However, spiders from the wandering-active guild (particularly lycosids) tend to be overrepresented in samples from pitfall traps, while those from web-building guilds are often underrepresented because they spend less time on the ground (Uetz & Unzicker 1975; Green 1999; Hövemeyer & Stippich 2000). Consequently, it is likely that some occasional ground-foraging species were missed by our sampling procedure. There is also evidence suggesting that the use of pitfall traps can result in samples with biased sex and age ratios, which could further limit any inferences made from our survey (Topping & Sunderland 1992). To reduce the possibility of such biases, any future sampling in mesic flatwoods should incorporate other methods such as visual species counts in quadrats, or the use of a suction sampling device (Rohr et al. 2007). Further limiting factors in any sampling procedure are the duration of the survey and seasonality, which can strongly influence the spider species captured (Hatley & MacMahon 1980). Our sampling period covered the most active time of year for ground-surface spiders in Florida (Corey & Taylor 1988), which is also the wet season. Because of the seasonal changes in water levels in mesic flatwoods however, more extensive sampling in the dry season would likely yield a more accurate estimate of the total spider species diversity.

We found that ground-surface spiders were not strongly associated with typical prey groups, supporting the idea that environmental factors can have an important influence on spider distribution (Greenstone 1984). However, many other studies have found strong associations between spiders and their prey (Harwood et al. 2001), somewhat contrary to our results. Indeed, even within the same study sites, we have previously found 1 species of spider (*S. floridanus*) to track the abundance of their common prey (Jennings et al. 2010). Our findings could therefore potentially be attributed to the relatively low number of spiders collected, which could have limited our ability to detect such associations between spiders and their prey.

The associations between other groups of arthropods were not particularly surprising. Collembola and Formicidae were clearly the 2 most abundant taxa, as found in ground-surface habitats elsewhere in Florida (Stiling et al. 2010; Gill et al. 2011), and both are known to be mobile foragers in the soil and leaf litter. They were negatively associated with each other, which could have been a result of microhabitat differences. For example, standing water was found at our sites on several occasions during our sampling period and certain groups of Collembola have a high affinity for these types of conditions, which conversely could have been prohibitive to many Formicidae. Diptera was responsible for most of the difference in the arthropod assemblages between our study sites, and the most parsimonious explanation for this is because of seasonal differences. Both study sites are close to lentic waterbodies and they have a similar habitat structure, but the sampling at the ERA was conducted after BCH and therefore may have coincided with increased abundance for certain species, perhaps for breeding events.

Conclusions

Our study provides baseline data on the ground-surface spider and other arthropod assemblages of mesic flatwoods. The guild structure of spiders at the study sites was similar to previous work in other flatwood habitats, being dominated by wandering-active spiders (primarily Lycosidae). The ground-surface spider species accumulation curves indicated that more intensive sampling of these habitats would be required to comprehensively sample and identify all of the species present, but from a management perspective, our results appear to be relatively consistent with previous surveys elsewhere.

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