PROC. ENTOMOL. SOC. WASH.
124(4), 2022, pp. 749–760

ARADIDAE (HEMIPTERA: HETEROPTERA) EMERGENT FROM COARSE AND FINE WOODY DEBRIS IN LOUISIANA

MICHAEL L. FERRO, DANIEL R. SWANSON, AND MICHAEL D. ULYSHEN

(MLF) Clemson University Arthropod Collection, Department of Plant and Environmental Sciences, 277 Poole Agricultural Center, Clemson University, Clemson, SC 29634-0310, USA (e-mail: spongymesophyll@gmail.com); (DRS) Department of Entomology, University of Illinois at Urbana-Champaign, 320 Morrill Hall, 505 South Goodwin Avenue, Urbana, IL 61801, Illinois Natural History Survey, Prairie Research Institute, University of Illinois at Urbana-Champaign, 1816 South Oak Street, Champaign, IL 61820-6960, USA (e-mail: drswanny@gmail.com, urn:lsid:zoobank.org:author:1F74F4E6-DA35-4A90-8572-EDC8F6660B43, https://orcid.org/0000-0002-0830-2383); (MDU) USDA Forest Service, 320 Green St., Athens, GA, USA (e-mail: michael.d.ulyshen@usda.gov)

Abstract.—Deadwood is a heterogenous, globally important habitat associated with high biodiversity. Surveys and inventories are important to discover which species require what deadwood resources. In the Tunica Hills region of Louisiana an emergence study designed for Coleoptera was conducted using various decay classes of fine and coarse woody debris collected in least-disturbed (Tunica Hills Wildlife Management Area) and secondary (Feliciana Preserve) forests. Aradidae (Hemiptera: Heteroptera) bycatch totaled 258 specimens representing six species. Aradid communities did not differ significantly between the two forests. *Neuroctenus pseudonymus* Bergroth was significantly associated with weathered fine woody debris whereas *Aradus ornatus* Say was significantly associated with both coarse woody debris decay class 2 and weathered fine woody debris. A serendipitous collection of *Aradus duzeei* Bergroth from the exterior of an emergence chamber represents a new state record. Emergence, while time consuming, is a viable way to augment Aradidae surveys and discover habitat preferences.

Key Words: residues, saproxylic, flat bug, subcortical

DOI: 10.4289/0013-8797.124.4.749

Deadwood is a unique, opaque habitat that is increasingly of interest because it is a valuable biotic and abiotic portion of the terrestrial and aquatic landscape, often supports high biodiversity, represents an important portion of the global carbon budget, and has been, and is continuing to be, negatively impacted by human activities (Stokland et al. 2012, Lonsdale 2013, Ulyshen 2018). Organisms that depend on deadwood, or would no longer be present in an area if deadwood were removed, are generally termed saproxylic (Speight 1989). Most members of the flat bug family Aradidae (Hemiptera: Heteroptera) are saproxylic fungivores associated with the subcortical deadwood habitat (Usinger and Matsuda 1959).

An overview of studies specific to saproxylic Aradidae is presented in Gossner and Damken (2018). In general, the following factors have been shown to influence the presence of aradids: fungal species, tree species, wood diameter, decay stage, snags vs. logs vs. stumps, aerial deadwood vs. ground, disturbance history of forest, sun exposure, and presence of fire. Deyrup and Mosely (2004) document the pyrophilic tendencies of *Aradus gracilicornis* Stål in Florida, USA. Most of these factors probably primarily influence preferred fungal species and secondarily influence aradid presence. Basic information on aradid natural history (distribution, phenology, habitat preference, food, mating systems, etc.) is lacking for most species.

Despite having some red-listed species and others that are indicative of old growth forests, few large studies specific to saproxylic aradids have been conducted (Gossner and Damken 2018). In a rare example of aradid-specific research Gossner et al. (2007) surveyed Aradidae at 114 locations within two forests in Germany using time-standardized hand collection and flight intercept traps. They collected four species which were shown to have different habitat requirements.

Aradid bycatch (residues) from emergence studies designed to collect saproxylic Coleoptera have been featured in several publications. Gossner and Damken (2018, Box 9.1, Fig. 9.11) found significant differences in number of specimens of *Aradus conspicuus* Herrich-Schäffer emergent from different tree species. Logs were sampled over five years after they were fresh cut. Ulyshen et al. (2012) reported on Hemiptera bycatch from South Carolina, USA. Logs and snags were collected and placed in emergence chambers about a year after they were cut. Two species of aradids were collected, *Mezira granulata* (Say), which was only collected from logs, and *Calisius contubernalis* Bergroth, which was collected from logs and snags. In both instances sampled wood was relatively fresh (1–5 years old).

During 2007 a large-scale emergence study on saproxylic beetles was initiated in the Tunica Hills region of Louisiana. Ninety emergence chambers were filled with five different types of deadwood resulting in collection of 12,819 adult Coleoptera and 258 Aradidae during the first year. The research was a companion project to a study using the same protocol that was conducted in Great Smoky Mountains National Park (Ferro et al. 2012) which resulted in the collection of 5673 Coleoptera, but no Aradidae (MLF remembers one aradid from the emergence chambers, but the specimen can't be found; needless to say, few aradids were collected).

Despite being designed for beetles, enough aradids were collected during the study to offer an opportunity for meaningful description and analysis. The purpose of this research is to survey and compare the saproxylic Aradidae within woody debris of different size classes (fine and coarse), different decay stages (defined below), and forest types (least-disturbed and secondary) collected with emergence chambers in the Tunica Hills region of Louisiana.

Materials and Methods

The present study design was meant to compliment similar research that took place in Great Smoky Mountains National Park. See Ferro et al. (2012) for additional considerations and comments.

Study Areas.—The study took place in the Tunica Hills region of Louisiana, at the southern extreme of the Blufflands, a belt of thick loess originally blown from the Mississippi River floodplain (Delcourt and Delcourt 1974, 1975; Ignatov 2001). The resulting hills of easily erodible substrate have since formed a series of deep forested ravines. This area was a major refugium for mixed mesophytic forest species during the Wisconsin glaciation. Many taxa are holdovers from this Pleistocene event and occur nowhere else in Louisiana or meet the southern limit of their range in the Tunica Hills (Delcourt and Delcourt 1974, 1975). This area also contains many subtropical elements not found further north, making this a unique collection of taxa in Louisiana. The area may contain the highest tree diversity in the continental United States (Ignatov 2001).

Tunica Hills Wildlife Management Area: Sites in "least-disturbed forest" were located in Tunica Hills Wildlife Management Area (WMA), which is located in the extreme northwest corner of Louisiana, West Feliciana Parish, 30.95 °N, 91.50 °W. Tunica Hills WMA consists of two tracts, 949 ha adjacent to Louisiana State Penitentiary, and 1682 ha to the southeast (Tunica Hills 2022). Magnolia Glen Preserve, located in Tunica Hills WMA, contains true old-growth forest (Ignatov 2001). However, the area is a mosaic and contains patches of recently cleared uplands (1950s and again in the 1980s) (Ignatov 2001). In general, portions of Tunica Hills WMA are the highest quality, least-disturbed forest available in the Louisiana Blufflands region.

Feliciana Preserve: Sites in "secondary forest" were located in Feliciana Preserve, a 61 ha tract located about 16 km east of St. Francisville, West Feliciana Parish, Louisiana (30.794 °N, 91.254 °W). The area was clear-cut during the late 1950s (~ 70 years ago) and has remained largely undisturbed since. The preserve consists of a secondary mixed mesophytic forest dominated by magnolia (*Magnolia grandiflora* L.), holly (*Ilex opaca* Aiton), beech (*Fagus grandifolia* Ehrhart), pine (*Pinus* spp.), and several species of oak (*Quercus* spp.). Feliciana Preserve is also the location of several studies focused on the Lepidoptera (Landau and Prowell 1999a, b; Landau et al. 1999; Prowell 2001) and the Coleoptera (Gil 2008, Ferro et al. 2009, Ferro and Gimmel 2014) fauna of the area.

Substrate.—At each of the six study sites: 1) basal tree area was measured using a Haglof relascope; and 2) three locations were surveyed using a point relascope sampling technique (Gove et al. 1999, Brissette et al. 2003). Findings were averaged to obtain basal tree area and volume of coarse wood debris per hectare at each study site.

Fine woody debris (FWD) was defined as woody debris 2.5–7 cm diameter originating from trees. Fresh fine woody debris (FWD1) possessed firm bark with intact twigs, showed no visible signs of weathering or fungal intrusion, and was structurally sound. Weathered fine woody debris (FWD2) had loose bark or lacked bark, had lost all small twigs, showed signs of weathering and/or fungal intrusion, and was spongy to the touch, easily broken, or otherwise structurally compromised.

Coarse woody debris (CWD) was defined as deadwood greater than 8 cm diameter but only pieces 8–20 cm diameter were collected. The decay classification of coarse woody debris used for this research is taken from Pyle and Brown (1999). Decay class I (CWD1) is a solid piece of wood with firmly attached bark and small twigs but without weathering stains. Decay class II (CWD2) is a solid piece but shows noticeable decay and lacks firmly attached bark. Decay class III (CWD3) is still solid but shows noticeable signs of decay, possesses little to no bark, and the outer wood surface will flake or shred if thudded perpendicularly. Decay class IV (CWD4) still contains hard chunks of wood, may be oval, and can be easily cleaved into large pieces if kicked. Decay class V (CWD5) is generally flattened, can be easily crushed, and is composed of predominantly powdery wood or separated fibers of cellulosic material.

Sampling.—Woody debris samples were collected during March 2007 at each of the six study sites, three in Tunica Hills WMA, and three in Feliciana Preserve (Table 1). Only samples from hardwood (angiosperm) tree debris were collected and each represented a composite of subsamples taken from numerous pieces of debris available at the site. For this research CWD5 was not collected and CWD3 and CWD4 were combined (CWD3–4). Three samples of each of the following were taken at each study site: FWD1, FWD2, CWD1, CWD2, CWD3–4 (15 samples at each site) resulting in a grand total of 90 samples. Each sample consisted of enough substrate to fill a 68 L emergence chamber three-fourths of its capacity. Emergence chambers consisted of a sealable plastic tote box with ventilation holes and a bottom collection cup (Ferro and Carlton 2011). They were filled and sealed where samples were collected, then taken to a shaded outdoor location at Feliciana Preserve for the duration of the study (Fig. 1).

While not part of the initial study, a serendipitous collection of aradids took place at the beginning of the study. During 24 March, as the emergence chambers were being placed in their final position, many Aradidae were collected from the outside of emergence chambers, most were immediately next to the lower vent hole. Presumably they had been attracted to fumes from the chambers and flew in from the surrounding area.

Chambers were serviced six times during the spring, summer, and early fall of 2007 (25 March – 22 April, 22 April – 11 May, 11 May – 16 June, 16 June – 22 July, 22 July – 26 August, 26 August – 29 September), otherwise, the chambers were left unattended. Servicing consisted of removal of specimens and old preservative, then addition of new propylene glycol preservative. Adult Aradidae were pinned or pointed as needed and labeled. Identification to the finest level possible (typically species) was performed with the appropriate taxonomic literature and/or comparison with authoritatively identified reference specimens. Specimens are deposited in: Clemson University Arthropod Collection (CUAC), Clemson University, Clemson, South Carolina; Daniel R. Swanson, personal collection (DRS); and Louisiana State Arthropod Museum (LSAM), Louisiana State University, Baton Rouge, Louisiana.

Table 1. Collection localities and basal tree area and volume of coarse woody debris at each.

Tunica Hills WMA		Basal Tree Area	Volume CWD
1	30.9376 °N, 91.5087 °W	81.3 m^2/ha	37.2 m^3/ha
2	30.9304 °N, 91.5210 °W	24.7 m^2/ha	58.8 m^3/ha
3	30.9950 °N, 91.5452 °W	23.3 m^2/ha	55.6 m^3/ha
	Average	26.8 m^2/ha	50.5 m^3/ha
Feliciana Preserve			
1	30.7934 °N, 91.2545 °W	24.7 m^2/ha	92.9 m^3/ha
2	30.7941 °N, 91.2535 °W	27.3 m^2/ha	44.6 m^3/ha
3	30.7960 °N, 91.2559 °W	28.7 m^2/ha	51.1 m^3/ha
	Average	43.1 m^2/ha	62.9 m^3/ha

Fig. 1. Emergence chambers at Feliciana Preserve, West Feliciana Parish, Louisiana.

Data Analysis.—The total aradid diversity likely to occur within similar substrates in the study area was first estimated using the iNext package in R (Hsieh et al. 2016). iNext also was used to compare aradid diversity estimates between the two locations (Feliciana Preserve and Tunica Hills WMA) based on abundance data. These comparisons were based on the rarefaction and extrapolation sampling curves of Hill numbers, a unified family of diversity indices (Chao et al. 2014). The value of q determines how much weight is given to species based on their rarity, either weighting rare and abundant species equally (q = 0, species richness), weighting species in proportion to their frequency in the sampled assemblage (q = 1, Shannon diversity) or giving abundant species more weight relative to their frequency (q = 2, Simpson diversity). Differences are considered significant when 95% confidence intervals do not overlap at the base sample size.

A multi-response permutation procedure (MRPP) with the Bray-Curtis distance measure in PC-ORD (McCune and Mefford 2011) was used to compare aradid community composition between the Feliciana Preserve and Tunica Hills WMA. After confirming there were no compositional differences between forest types (see below), the same procedure was used to compare communities among substrate types.

To test for particular substrate associations, indicator species analysis in R using the package "indicspecies" was performed. Unlike traditional indicator species analysis (Dufrêne and Legendre 1997), this approach tests for associations with both specific substrates as well as combinations of substrates (De Cáceres et al. 2010). The function multipatt (multilevel pattern analysis) was used to conduct this analysis, using 9999 permutations to calculate P-values for each combination. The resulting indicator values range from 0–1 (no association–complete association).

Results and Discussion

Basal tree area averaged 26.8 m^2/ha in Tunica Hills WMA and 43.1 m^2/ha in Feliciana Preserve (Table 1). Volume of coarse wood debris averaged 50.5 m^3/ha in Tunica Hills WMA and 62.9 m^3/ha in Feliciana Preserve. Neither was significantly different. Tunica Hills WMA has a complicated and dynamic history and accessible locations where samples for this research were taken may have been cut in the past. No systematic survey of deadwood resources in Tunica Hills WMA has been conducted and higher quality habitat (e.g., higher volume of CWD) may exist.

A total of 258 Aradidae representing six species were collected from emergence chambers in this study (Table 2). *Mezira sayi* Kormilev was the most abundant species, accounting for 75% of all specimens, followed by *Aradus ornatus* Say (13%) and *Neuroctenus pseudonymus* Bergroth (8%). The other three species were each represented by 1–4 specimens. Anecdotally, *Mezira sayi* became more common in the samples as the season progressed whereas *A. ornatus* showed the opposite pattern (Fig. 2, Table 3). By contrast, *N. pseudonymus* showed no obvious seasonal pattern of activity.

Based on the iNext analysis of the entire dataset, the estimated species richness of aradids (more specifically, aradids collected with emergence chambers) across both locations was 6.5, with a 95% confidence interval of 6.0–14.4 species. There are currently nine species reported from the Parish that would be expected to be collected from emergence chambers (this research combined with Taylor and Gil 2009) (Table 4) which falls neatly within the 95% confidence interval.

Twice as many aradid species were collected at Feliciana Preserve than at Tunica Hills WMA, with the three rarest species (*Aneurus pygmaeus* Kormilev, *Mezira granulata*, and *Notapictinus aurivillii* (Bergroth)) only being captured at Feliciana Preserve (Table 2). Based on iNext analysis, species richness ($q = 0$) was significantly higher at Feliciana Preserve than at Tunica Hills WMA but there were no significant differences in Shannon diversity ($q = 1$) or Simpson diversity ($q = 2$) between the two locations (Fig. 3).

Based on MRPP, aradid communities did not differ significantly between the two forests ($A = 0.016$; $p = 0.19$). This study was not designed for aradids, therefore the inability to find differences between sites is not surprising. However, volume of CWD didn't differ and the amount of disturbance at the specific areas where

Table 2. List of taxa and number of specimens collected (TH/FP). TH = Tunica Hills WMA, FP = Feliciana Preserve. An asterisk (*) indicates significant association, see text for details.

Species	FWD1	FWD2	CWD1	CWD2	CWD3–4	TH	FP	Total
Aneurus pygmaeus Kormilev	0/0	0/4	0/0	0/0	0/0	0	4	4
Aradus ornatus Say	3/0	8/10*	0/1	12/1*	0/0	23	12	35
Mezira granulata (Say)	0/0	0/0	0/0	0/0	0/2	0	2	2
Mezira sayi Kormilev	0/6	24/4	33/58	22/38	3/7	82	113	195
Neuroctenus pseudonymus Bergroth	0/0	3/14*	0/1	3/0	0/0	6	15	21
Notapictinus aurivillii (Bergroth)	0/0	0/0	0/0	0/1	0/0	0	1	1
Total Species	2	4	3	4	2	3	6	6
Total Specimens	9	67	93	77	12	111	147	258

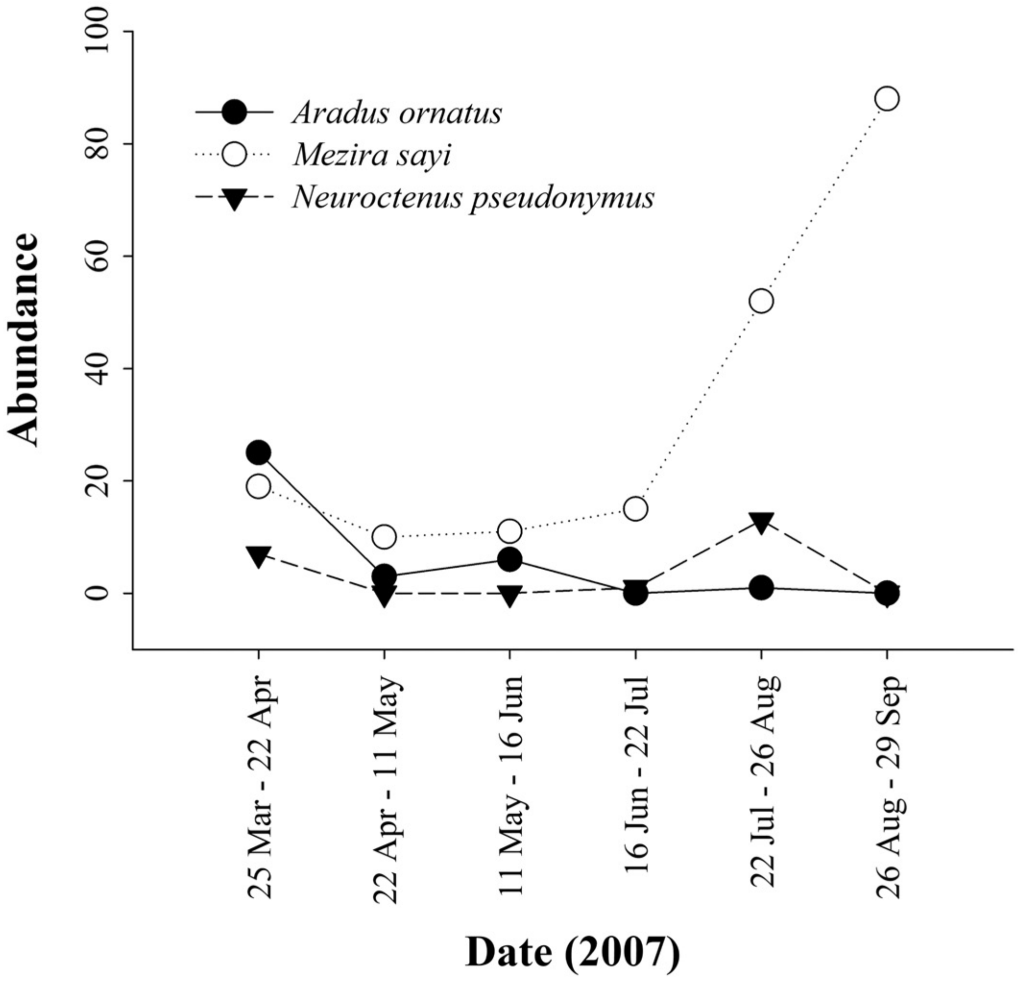

Fig. 2. Seasonal patterns of the three most abundant aradid species collected during this study.

samples were taken within Tunica Hills WMA was unknown. Additional studies may find differences between these locations or show that they are "equally distributed" in relation to saproxylic species.

Based on MRPP, aradid communities did differ among substrate types (A = 0.16; p < 0.01). Indicator species analysis was performed to explore species-specific substrate associations. *Neuroctenus pseudonymus* was significantly associated with weathered fine woody debris (FWD2) (IV = 0.74, p = 0.03), whereas *A. ornatus* was associated with both coarse woody debris decay class 2 (CWD2) and weathered fine woody debris (FWD2) (IV = 0.82, p < 0.01). The most common species, *Mezira sayi*, showed no strong association with any particular substrate or substrate combination.

In total, 13 species of Aradidae have now been reported from West Feliciana Parish, Louisiana (Table 4). Six species were collected during this study using emergence chambers. A seventh species, *Aradus duzeei* Bergroth, was collected

Table 3. Date of species collection.

Species	25 March – 22 April	22 April – 11 May	11 May – 16 June	16 June – 22 July	22 July – 26 Aug.	26 Aug. – 29 Sept.
Aneurus pygmaeus Kormilev	0	0	2	0	2	0
Aradus ornatus Say	25	3	6	0	1	0
Mezira granulata (Say)	0	0	0	0	1	1
Mezira sayi Kormilev	19	10	11	15	52	88
Neuroctenus pseudonymus Bergroth	7	0	0	1	13	0
Notapictinus aurivillii (Bergroth)	1	0	0	0	0	0
Total	52	13	19	16	69	89

off the outside of an emergence chamber and represents a new state record for Louisiana ("USA: Louisiana: W. Feliciana Par. / Feliciana Preserve / N 30.7946, W -91.2537 / 24 March 2007 Outside fresh / emergence chamber – M. Ferro". Deposited in CUAC). Of the remaining species that were not collected in emergence chambers, two—*Acaricoris ignotus* Harris and Drake, and *Neoproxius gypsatus* (Bergroth)—are predominantly in leaf litter. *Notapictinus aurivillii* is also predominantly known from leaf litter, which may explain why only a single specimen was collected from an emergence chamber. *Aradus aequalis* Say has only ever been reported as being collected from flight intercept traps (Taylor and Gil 2009). Three species, *Mezira froescheneri* Davidová-Vilímová, Taylor, and McPherson, *Mezira lobata* (Say), and *Neuroctenus simplex* (Uhler) are known from deadwood and have been reported from West Feliciana Parish but were not collected during this research. Emergence chambers collected five of the nine species (55%) expected from deadwood, and one of the three species (33%) expected from leaf litter.

Total volume of the deadwood collected was not recorded. However, a conservative estimate of number of aradids per volume of deadwood and per hectare can be calculated. Each 68-liter emergence chamber was three fourths filled with material. Those pieces did not fill the entire space, so the actual volume of deadwood probably fell between ¾ (upper bound) and ½ (lower bound) of the emergence chamber volume. Therefore, Tunica Hills WMA had approximately 45–71 aradids per m^3 CWD or 2288–3616 aradids per hectare. Feliciana Preserve had approximately 60–94 aradids per m^3 CWD or 3774–5965 aradids per hectare. However, as aradids tend to be subcortical, surface area, rather than volume of deadwood, may be a more appropriate measure to estimate aradid abundance.

Results of this study differ greatly from the companion study conducted in Great Smoky Mountains National Park (GSMNP) (Ferro et al. 2012). In GSMNP no aradids were collected with emergence chambers, whereas 258 were collected during this study. Differences are probably due to the species available at each location. Thirteen species are reported

Table 4. Aradidae species and number of specimens reported from West Feliciana Parish, Louisiana. Emerg. = specimens collected from emergence chambers (Tunica Hills/Feliciana Preserve); TG = specimens reported in Taylor and Gil 2009; Out. = specimens collected on the outside of emergence chambers at Feliciana Preserve. *Specimens of *Aradus ornatus* reported in Taylor and Gil 2009 were all collected from emergence chambers during this research.

Species	Emerg.	TG	Out.	Habitat / Collection Notes
Acaricoris ignotus Harris and Drake		2		found in leaf litter (Taylor and Gil 2009; Taylor and Lewis 1989)
Aneurus pygmaeus Kormilev	0/4			under bark, dead oak, on cactus (Picchi 1977; Taylor and Gil 2009)
Aradus aequalis Say		1		flight trap (Swanson 2020; Taylor and Gil 2009)
Aradus duzeei Bergroth			1	under bark, on pine, swept from vegetation (Blatchley 1926; Torre-Bueno 1939)
Aradus ornatus Say	23/12	24*	1	deadwood emergence, oak log (Blatchley 1926; Taylor and Gil 2009)
Mezira froescheneri Davidová-Vilímová, Taylor, and McPherson		1		under bark, leaf litter (Davidova-Vilimova et al. 1996; Taylor and Gil 2009)
Mezira granulata (Say)	0/2			under bark of various dead trees and leaf litter (Blatchley 1926; Taylor and McPherson 1989b)
Mezira lobata (Say)		2		under bark, sweeping, flight trap (Blatchley 1926; Taylor and Gil 2009)
Mezira sayi Kormilev	82/113	19	27	under bark, sweeping, leaf litter, flight trap (Taylor and McPherson 1989a; Taylor and Gil 2009)
Neoproxius gypsatus (Bergroth)		7		leaf litter (Taylor and Gil 2009; Taylor and McPherson 1989a)
Neuroctenus pseudonymus Bergroth	6/15	4	1	deadwood, leaf litter (Blatchley 1926; Taylor and Gil 2009)
Neuroctenus simplex (Uhler)		2		under bark of various dead trees (Blatchley 1926; Taylor and Gil 2009; Taylor and McPherson 1989b)
Notapictinus aurivillii (Bergroth)	0/1	1		leaf litter, pitfall, deadwood (Hoffman 2009; Taylor and Gil 2009)

from West Feliciana Parish, Louisiana, whereas only three species have been reported from GSMNP: *A. acutus* Say; *A. aequalis*; and *A. duzeei* (Species Checklist 2022). *Aradus acutus* has been reported from beneath half buried logs, beneath bark of rotten oak, and on stumps (Sherman 1905, Blatchley 1926) and would have been expected in material collected in GSMNP. *Aradus aequalis* is in both GSMNP and Louisiana but was not collected using emergence chambers. Presumably it has been collected from beneath bark or associated with rotting wood, but flight intercept traps are the only collection technique mentioned in the published literature. *Aradus duzeei* is also in Louisiana and was collected at Feliciana Preserve, but not with an emergence chamber.

Any family level survey of Aradidae will require a multitude of collecting techniques and quantification will be difficult. Gossner et al. (2007) surveyed Aradidae in Germany using time-standardized hand collection. They collected four species and 444 specimens, or about one specimen per 12 minutes of searching. They also installed 114 flight intercept traps that were run for two years but only three aradid specimens were collected, concluding that flight intercept traps were of no

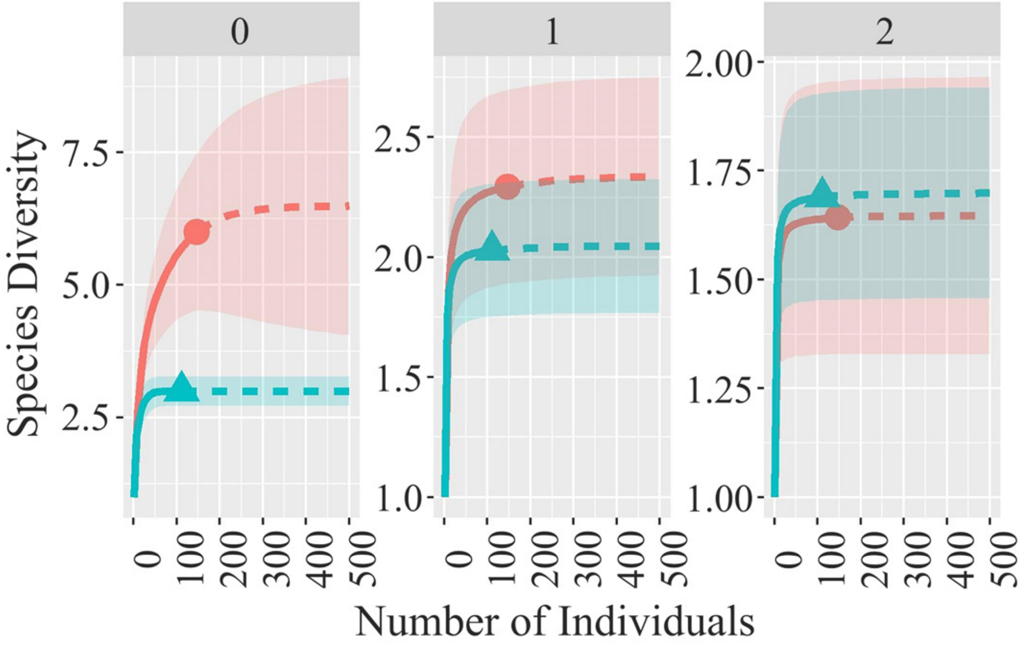

Fig. 3. Rarefaction (solid lines) and extrapolation (dashed lines) of aradid diversity collected with emergence chambers at Feliciana Preserve (circles and pink shading) and Tunica Hills WMA (triangles and blue shading) based on Hill numbers 0, 1 and 2 (species richness, Shannon diversity and Simpson diversity, respectively). Shaded areas represent 95% confidence intervals.

use when surveying aradids. During this research about 42 hours of work was spent setting up and servicing emergence chambers and 258 specimens were collected, which averages about one specimen per 10 minutes of work, comparable to Gossner et al. (2007).

In Louisiana at least eight techniques have been used to collect Aradidae: pitfall (1 species); yellow sticky trap (2); sweeping vegetation (2); black light (4); flight intercept trap (5); litter sifting (6); emergence (6); and hand collection from deadwood (9) (Taylor and Gil 2009). Of the 13 Aradidae species known from the West Feliciana Parish, nine would be expected from deadwood and five of those were collected with emergence chambers. Emergence chambers were not efficient; less than three specimens were collected per chamber, but one species, *Aradus ornatus*, has only ever been collected using emergence chambers in Louisiana. A survey of only wood-inhabiting aradids would probably best be conducted through hand collecting, although other techniques would certainly augment the results. Clearly a variety of techniques are required to survey Aradidae and the value of those techniques varies from place to place.

Acknowledgments

MLF thanks Matthew L. Gimmel (Santa Barbara Museum of Natural History) and Heather Bird Jackson (University of Tennessee) for help in the field and Victoria Bayless (Louisiana State University) for loan of the specimens. The project would have been greatly diminished without Biodiversity Heritage Library (https://www.biodiversitylibrary.org/) and Resource Sharing (Interlibrary Loan and Scan & Deliver) at Clemson Libraries. This material is based upon work supported by NIFA/USDA, under project number SC-1700596. Technical Contribution No. 7103 of the Clemson University Experiment Station.

Literature Cited

Blatchley, W. S. 1926. Heteroptera or True Bugs of Eastern North America With Especial Reference to the Faunas of Indiana and Florida. The Nature Publishing Company, Indianapolis, Indiana. 1116 pp.

Brissette, J. C., M. J. Ducey, and J. H. Gove. 2003. A field test of point relascope sampling of down coarse woody material in managed stands in the Acadian Forest. Journal of the Torrey Botanical Society 130: 79–88.

Chao, A., N. J. Gotelli, T. C. Hsieh, E. L. Sander, K. H. Ma, R. K. Colwell, and A. M. Ellison. 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. Ecological Monographs 84(1): 45–67.

Davidová-Vilímová, J., S. J. Taylor, and J. E. McPherson. 1996. A new species of *Mezira* Amyot and Serville (Heteroptera: Aradidae) from Florida, with a key to the small *Mezira* species of America north of Mexico. Proceedings of the Entomological Society of Washington 98(4): 630–639.

De Cáceres, M., P. Legendre, and M. Moretti. 2010. Improving indicator species analysis by combining groups of sites. Oikos 119(10): 1674–1684.

Delcourt, H. R. and P. A. Delcourt. 1974. Primeval magnolia-holly-beach climax in Louisiana. Ecology 55: 638–644.

Delcourt, H. R. and P. A. Delcourt. 1975. The Blufflands: Pleistocene pathway into the Tunica Hills. American Midland Naturalist 94(2): 385–400.

Deyrup, M. and J. G. Mosley. 2004. Natural history of the flat bug *Aradus gracilicornis* in fire-killed pines (Heteroptera: Aradidae). Florida Entomologist 87(1): 79–81.

Dufrêne, M. and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67: 345–366.

Ferro, M. L. and C. E. Carlton. 2011. A practical emergence chamber for collecting Coleoptera from rotting wood, with a review of emergence chamber designs to collect saproxylic insects. The Coleopterists Bulletin 65(2): 115–124.

Ferro, M. L. and M. L. Gimmel. 2014. Season of fine woody debris death affects colonization of saproxylic Coleoptera. The Coleopterists Bulletin 68(4): 681–685.

Ferro, M. L., M. L. Gimmel, K. E. Harms, and C. E. Carlton. 2009. The beetle community of small oak twigs in Louisiana, with a literature review of Coleoptera from fine woody debris. The Coleopterists Bulletin 63(3): 239–263.

Ferro, M. L., M. L. Gimmel, K. E. Harms, and C. E. Carlton. 2012. Comparison of Coleoptera emergent from various decay classes of downed coarse woody debris in Great Smoky Mountains National Park, USA. Insecta Mundi 0260: 1–80.

Gil, S. 2008. Succession of Coleoptera on freshly killed loblolly pine (*Pinus taeda* L.) and southern red oak (*Quercus falcata* Michaux) in Louisiana. LSU Master's Thesis. 1067. 92 pp.

Gossner, M. M. and C. Damken. 2018. Diversity and ecology of saproxylic Hemiptera, pp. 263–317. *In* Ulyshen, M. D., ed. Saproxylic Insects: Diversity, Ecology and Conservation. Springer, Switzerland. 904 pp.

Gossner, M., H. Engel, and M. Blaschke. 2007. Factors determining the occurrence of flat bugs (Aradidae) in beech dominated forests. Waldoekologie online 4: 59–89.

Gove, J. H., A. Ringvall, G. Stahl, and M. J. Ducey. 1999. Point relascope sampling of downed coarse woody debris. Canadian Journal of Forest Research 29: 1718–1726.

Hoffman, R. L. 2009. First records of *Notapictinus aurivillii* (Bergroth), a little-known flatbug, for Virginia and the Carolinas (Heteroptera: Aradidae). Banisteria 33: 50–52.

Hsieh, T. C., K. H. Ma, and Anne Chao. 2016. iNEXT: an R package for rarefaction and extrapolation of species diversity (Hill numbers). Methods in Ecology and Evolution 7: 1451–1456.

Ignatov, I. I. 2001. Natural history and phytogeography of the loess hills and ravines, lower Mississippi embayment. LSU Historical Dissertations and Theses. 347. 650 pp.

Landau, D. and D. Prowell. 1999a. A partial checklist of moths from longleaf pine savannas in Louisiana (Insecta: Lepidoptera).

Transactions of the American Entomological Society 125: 127–138.

Landau, D. and D. Prowell. 1999b. A partial checklist of moths collected from mixed mesophytic hardwood forests in Louisiana (Insecta: Lepidoptera). Transactions of the American Entomological Society 125: 139–150.

Landau, D., D. Prowell, and C. E. Carlton. 1999. Intensive versus long-term sampling to assess lepidopteran diversity in a southern mixed mesophytic forest. Conservation Biology and Biodiversity 92: 435–441.

Lonsdale, D., ed. 2013. Ancient and Other Veteran Trees: Further Guidance on Management. The Tree Council, London. 202 pp.

McCune, B. and M. J. Mefford. 2011. PC-ORD. Multivariate analysis of ecological data. Version 6. MjM Software, Gleneden Beach, Oregon, USA.

Picchi, V. D. 1977. A systematic review of the genus *Aneurus* of North and Middle America and the West Indies (Hemiptera: Aradidae). Quaestiones Entomologicae 13: 255–308.

Prowell, D. 2001. Additions and corrections to Macrolepidoptera in Landau and Prowell 1999 (a & b), partial checklists of moths from longleaf pine savannas and mesophytic hardwood forests in Louisiana. Transactions of the American Entomological Society 127: 239–244.

Pyle, C. and M. M. Brown. 1999. Heterogeneity of wood decay classes within hardwood logs. Forest Ecology and Management 114: 253–259.

Sherman, F., Jr. 1905. The flat-bugs (Aradidae) of North Carolina. Entomological News 16: 7–9.

Species Checklist. 2022. Species Checklist for Great Smoky Mountains National Park (GRSM). (https://irma.nps.gov/NPSpecies/Reports/SpeciesList/Species%20Checklist/GRSM/8/false) [Last accessed 1 February 2022.].

Speight, M. C. D. 1989. Saproxylic invertebrates and their conservation. Nature and environment series, Strasbourg, No. 42: 1–82.

Stokland, J. N., J. Siitonen, and B. G. Jonsson, eds. 2012. Biodiversity in Deadwood. Cambridge University Press, New York, NY. 509 pp.

Swanson, D. R. 2020. A synopsis of the flat bugs (Heteroptera: Aradidae) of Michigan. The Great Lakes Entomologist 53(3–4): 83–104.

Taylor, S. J. and S. A. Gil. 2009. State records, confirmations, and habitats of Aradidae (Hemiptera: Heteroptera) from Louisiana, U.S.A. Florida Entomologist 92(2): 199–207.

Taylor, S. J. and S. P. Lewis. 1989. Notes on the habitat and distribution of *Acaricoris ignotus* Harris and Drake (Heteroptera: Aradidae). The Southwestern Naturalist 34(1): 154–155.

Taylor, S. J. and J. E. McPherson. 1989a. Distributional records of some Florida Aradidae (Heteroptera). Florida Entomologist 72(2): 265–267.

Taylor, S. J. and J. E. McPherson. 1989b. State records and confirmations of Arkansas flat bugs (Heteroptera: Aradidae). The Great Lakes Entomologist 22(1): 19–23.

de la Torre-Bueno, J. R. 1939. A synopsis of the Hemiptera—Heteroptera of America north of Mexico. Part I: Families Scutelleridae, Cydnidae, Pentatomidae, Aradidae, Dysodiidae and Temitaphididae. Entomologica Americana 19(3): 141–206.

Tunica Hills. 2022. Louisiana Wildlife and Fisheries Tunica Hills. (https://www.wlf.louisiana.gov/page/tunica-hills) [Last accessed 1 February 2022.].

Ulyshen, M. D., ed. 2018. Saproxylic Insects: Diversity, Ecology and Conservation. Springer, Switzerland. 904 pp.

Ulyshen M. D., J. L. Hanula, R. L. Blinn, and G. Kritsky. 2012. Saproxylic Hemiptera habitat associations. Southeastern Naturalist 11(1): 135–140.

Usinger, R. L. and R. Matsuda. 1959. Classification of the Aradidae (Hemiptera-Heteroptera). Trustees of the British Museum, London. 410 pp.

Aradidae (Hemiptera: Heteroptera) Emergent from Coarse and Fine Woody Debris in Louisiana

Authors: Ferro, Michael L., Swanson, Daniel R., and Ulyshen, Michael D.

Source: Proceedings of the Entomological Society of Washington, 124(4) : 749-760

Published By: Entomological Society of Washington

URL: https://doi.org/10.4289/0013-8797.124.4.749