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Cover Page Footnote

The majority of this study was carried out during my time in the University of Michigan Museum of Zoology, Ann Arbor, Michigan. I thank Mark O'Brien (UMMZ) for his sponsorship regarding loaned material as well as his constant support in my entomological pursuits. I am grateful to Gary Parsons (MSUC) for accommodating several visits to the collection in East Lansing to study the material under his care. I was able to photograph the specimen of Aradus uniannulatus from the American Museum of Natural History, New York, under a Collections Studies Grant awarded to me, and I thank David Grimaldi for sponsoring my visit and Toby Schuh and Ruth Salas for allowing me to study specimens in the Hemiptera Collection. I also thank Robert Zuparko (CAS) for information regarding a Parshley's paratype. I also express my appreciation to two anonymous reviewers, whose comments greatly improved the manuscript.

A Synopsis of the Flat Bugs (Heteroptera: Aradidae) of Michigan

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Abstract

An overview of the 28 species of Aradidae found in Michigan is presented, along with an identification key, distribution maps, and relevant literature. Eleven new state records are presented for the following species: *Aradus approximatus* Parshley, *Aradus duzeei* Bergroth, *Aradus falleni* Stål, *Aradus insolitus* Van Duzee, *Aradus intectus* Parshley, *Aradus montanus* Bergroth, *Aradus proboscideus* Walker, *Aradus shermani* Heidemann, *Aradus uniformis* Heidemann, *Quilnus niger* (Stål) (all Aradinae), and *Neuroctenus simplex* (Uhler) (Mezirinae).

Keywords. true bugs, faunistics, distribution, checklist

Aradidae, commonly called flat bugs or bark bugs, is a family of strongly flattened mycophagous true bugs comprising 126 species in 11 genera in the United States (updated from Froeschner 1988). These insects are cryptic both in habitus and habitat, having a granular integument that adheres bits of substrate and being found most often under the bark of dead or dying trees or logs. They also tend to be slow-moving insects, and this habit, coupled with habitus and habitat, can make them difficult to see, even when (unknowingly) encountered. Thus, despite being a diverse group, aradids are uncommonly found, especially compared to other Heteroptera, and this phenomenon is apparent in the holdings of entomological research collections.

The group has never been treated for Michigan, although O'Brien's (1983, 1988) lists of literature concerning the terrestrial arthropods of Michigan contain sources with a few records of Aradidae. Townsend (1890) and Hussey (1922) contributed to the knowledge of the Aradidae of Michigan, each having catalogued the Heteroptera found in the vicinity of Constantine, Saint Joseph County and Berrien County, respectively. Additionally, Pettit (1901) recorded an *Aradus* sp. from Munising Junction (Alger County), and Adams (1909) recorded a single species of *Aradus* from Isle Royale (Keweenaw County). One species, *Aradus ruficeps* Hussey, 1953, was described based on a single specimen from Michigan.

In an effort to compile the knowledge and expose the diversity of these cryptic insects, I herein present the results of my study of the Aradidae of Michigan, my seventh synoptic family-level contribution studying the heteropteran fauna of the state.

Materials and Methods. Methods parallel previous installments of this series (Swanson 2011, 2012a, b, 2013, 2015, 2016):

The aradid holdings of the two major university collections in southern Michigan were examined. County records were compiled, identification keys were modified, and the existing natural history information, both Michiganian and extralimital, was summarized. Notes on additional species of potential relevance to Michigan follow the primary species accounts.

The identification of the 282 specimens included in this study was rendered or confirmed by the author, and all specimens reside in one of the collections listed below unless otherwise noted. Collection dates indicate the earliest and latest adults examined and refer specifically to specimens collected in Michigan. In the instances where provided, label data are not transcribed verbatim, but complete locality information is included. Any additions, changes, or interpretive

Figure 1. The counties of the State of Michigan.

elements provided by the author are shown in brackets. Locations of Michigan counties from which specimens were collected are depicted in Fig. 1.

The habitus plates (Figs. 2–4) are intended to provide a visual reference for the diversity found in Michigan. Several forms are distinctive in general habitus or particular morphological characters. However, comparison with the plates will not serve as a replacement for keying out specimens.

In the keys, certain characters are occasionally set apart using brackets. These brackets signify that the contrasting character is not in that particular couplet but appears in one of the immediately successive couplets attained through the opposite lead.

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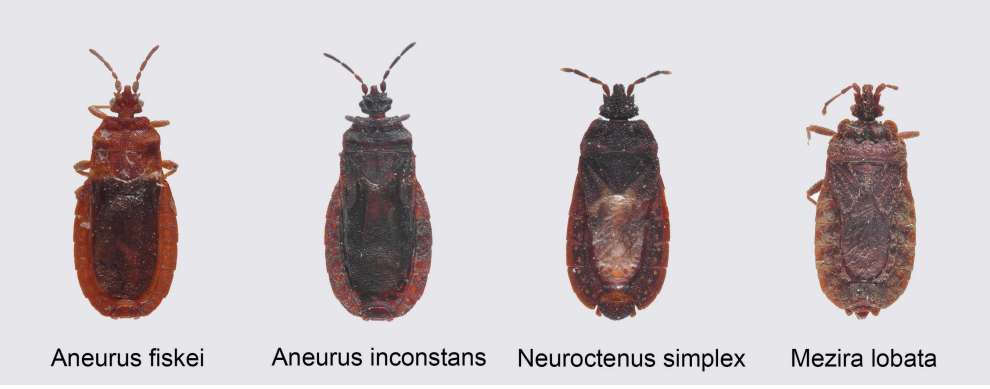

Figure 2. Aneurinae and Mezirinae of Michigan, dorsal habitus.

Regarding host records, I have compiled those previously mentioned in the literature for the aradid species found in Michigan (Table 2), with a few caveats. First, I have reduced records of trees to genus-level only; this means that tree species *might* be listed in the original citation. Second, I have included only tree genera that occur in Michigan. For example, in addition to the five genera listed in the table, *Aneurus fiskei* Heidemann, 1904a also has been recorded from *Oxydendrum* [*arboreum* (L.) DC.] (Blatchley 1926); yet, this record is herein excluded, because sourwood does not occur in Michigan. In the case where an aradid has been recorded from a tree species absent in Michigan but with congeners that are present in the state, I have included the generic level record. For example, *Quilnus niger* (Stål, 1873) has been recorded from longleaf pine (*Pinus palustris* Mill.) (Parshley 1921), and even though longleaf pine does not occur in Michigan, *Pinus* is still marked in the table, regardless of whether records for other *Pinus* spp. exist for *Q. niger* (they do!). Presence of tree genera and species in Michigan was assessed using Barnes and Wagner (2004). The compilation of this table should not be construed as a definitive statement on the hosts of aradids. On the contrary, there is little evidence to suggest that aradids are restricted to particular species of trees, and many of these records represent at best (1) trees that can host fungal species consumed by aradids or (2) incidental captures, especially if occurring during seasonal flights. Lastly, records of fungal hosts, being much more sparse (and perhaps more meaningful) are listed under the species accounts.

Collections are designated as follows: Daniel R. Swanson, personal collection (DRS); Albert J. Cook Arthropod Research Collection, Michigan State University, East Lansing, Michigan (MSUC); and University of Michigan Museum of Zoology Insect Collection, Ann Arbor, Michigan (UMMZ).

Results and Discussion

Family ARADIDAE Spinola, 1837

Flat bugs are generally unmistakable in their oval to rectangular, strongly-flattened habitus. Additionally, members in the Nearctic may be characterized by a short, stout four-segmented rostrum, absence of ocelli, two-segmented tarsi, and a rough or granular integument (Slater and Baranowski 1978, Schuh and Slater 1995). Aradids also possess distinctive coiled mandibular stylets, thereby allowing long structures to be stored in a small head capsule (Spooner 1920, Lee and Pendergrast 1976). Aradids are usually found under the bark or on fungus associated with dead or dying trees or in leaf litter. However, some members of the family are found in the nests of birds and rodents, as well as termites (Kormilev and Froeschner 1987, Schuh and Slater 1995). Some species are gregarious (Cassis and Gross 2002), with many individuals of various life stages found in groups under a single patch of bark. Others go beyond simple gregariousness: McClure (1932), Takahashi (1934), and Taylor (1988a) described parental care in three different aradid species. However, it is not known how widely this phenomenon occurs in the family. Stridulation also is documented in the group (Bergroth 1892, Usinger 1954). Leston (1955) generally described the male and female genitalia. Vásárhelyi (1986) investigated the utility of the pretarsus as a taxonomic character. Schuh and Slater (1995) provided a concise general family-level treatment in a systematic context.

Aradids are predominantly fungus-feeders. Hubbard (1892) provided one

Figure 3. Aradinae of Michigan, dorsal habitus.

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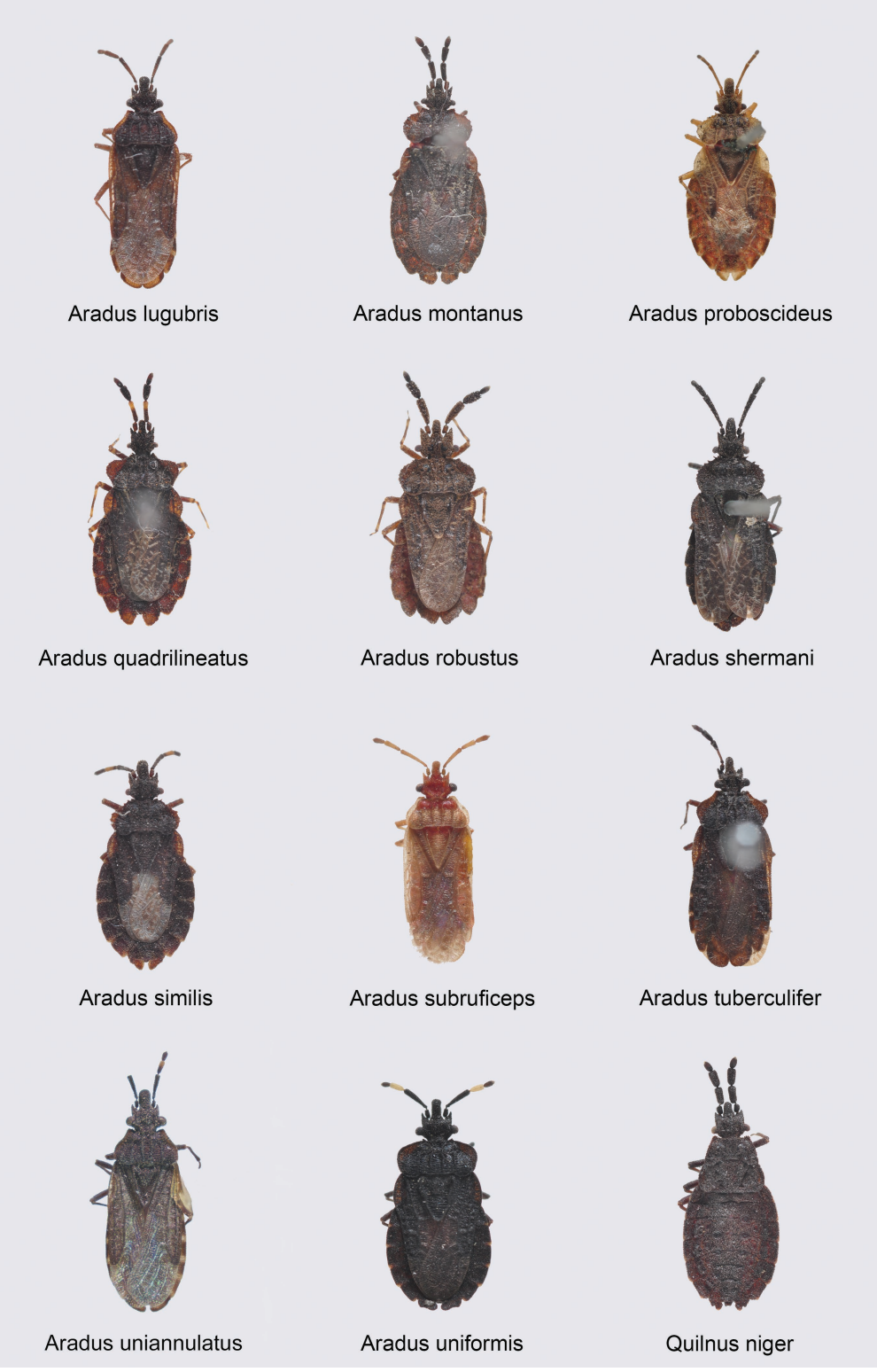

Figure 4. Aradinae of Michigan (cont.), dorsal habitus.

Table 1. Species of Aradidae found in Michigan.

Aneurinae
Aneurus fiskei **Heidemann, 1904a**
Aneurus inconstans **Uhler, 1871**
Aradinae
Aradus abbas **Bergroth, 1889**
Aradus acutus **Say, 1831**
Aradus aequalis **Say, 1831**
Aradus approximatus **Parshley, 1921**
Aradus borealis **Heidemann, 1909**
Aradus crenatus **Say, 1831**
Aradus duzeei **Bergroth, 1892**
Aradus falleni **Stål, 1860**
Aradus implanus **Parshley, 1921**
Aradus inornatus **Uhler, 1876**
Aradus insolitus **Van Duzee, 1916**
Aradus intectus **Parshley, 1921**
Aradus lugubris **Fallén, 1807**
Aradus montanus **Bergroth, 1913**
Aradus proboscideus **Walker, 1873**
Aradus quadrilineatus **Say, 1825**
Aradus robustus **Uhler, 1871**
Aradus shermani **Heidemann, 1906**
Aradus similis **Say, 1831**
Aradus subruficeps **Hussey, 1953**
Aradus tuberculifer **Kirby, 1837**
Aradus uniannulatus **Parshley, 1921**
Aradus uniformis **Heidemann, 1904b**
Quilnus niger **(Stål), 1873**
Mezirinae
Mezira lobata **(Say, 1831)**
Neuroctenus simplex **(Uhler, 1876)**

of the earlier accounts of this behavior, suggesting that the rough surface of these insects provided surfaces for the transport of fungal spores. Schwartz (1901) later split the group between a preference for "feed[ing] upon a blackish mould under the bark" and "liv[ing] outside of the bark of dead trees, upon a whitish fungus". Many subsequent authors (e.g., Parshley 1921, Blatchley 1926, Jordan 1932, Usinger 1936) have corroborated mycophagous behavior. Furthermore, one species, *Aradus kormilevi* Heiss, 1980, has been found in association with the southern pine beetle *Dendroctonus frontalis* Zimmermann, 1868 (Overgaard 1968, Moser et al. 1971; both reported the species as *Aradus cinnamomeus* Panzer, 1806), a bark beetle that often introduces fungal pathogens into the tree (Bramble and Holst 1940, Paine et al. 1997). It also was hypothesized that even those nidicolous species still feed on fungi present in the nests and burrows (Usinger 1936). Nevertheless, a few species may develop on non-tree plants (Tamanini 1955, Heiss 1984), a few subfamilies may subsist on tree sap (Schuh and Slater 1995), and a single Palearctic species is known to feed on phloem, cambium, and xylem of healthy trees (Kormilev and Froeschner 1987). This latter species, *A. cinnamomeus*, is the only aradid known to be pestiferous (Heliövaara 2000).

Despite their slow-moving ways and cryptic habitat, aradids are surprisingly strong dispersers. There is a high incidence of wing polymorphism in the family (Usinger and Matsuda 1959, Kormilev and Froeschner 1987). In general, polymorphism seems driven by competing needs to maneuver in tight subcorticolous habitats and to disperse to new sites given the ephemeral nature of their food and habitat; indeed, seasonal dispersal flights are well-documented in the group, e.g., McPherson and Weber (1981). Other stimuli seem to draw aradids. Various species are known to be pyrophilous, viz. attracted to forest fires or recently burned trees (e.g., Wyniger et al. 2002, Hjältén et al. 2006, Johansson et al. 2010), and these species often possess specialized sensilla to aid in locating these phenomena (Schmitz et al. 2010). Studies have shown that some aradids engage in scototaxis (Heliövaara and Terho 1981, Taylor 1988b), although some species also are, at least indirectly, attracted to lights at night (Usinger and Matsuda 1959). Still, complete aptery is well-known, independently-derived in several lineages, and concentrated in the Tropics, likely a result of high abundance of food and habitat in these moist ecosystems (Monteith 1982). However, no apterous species have ever been associated with non-apterous morphs (Kormilev and Froeschner 1987). Yet, every other condition, i.e., macroptery, brachyptery, stenoptery, and microptery, is exhibited by some species of aradid, and some species display several of these conditions in a single population (e.g., Heliövaara 1984). Additionally, some macropterous aradids are known to purposefully induce brachyptery "by spontaneous shedding or by self-mutilation" (Kormilev and Froeschner 1987; see also Kenward 1975), a condition termed "ruptobrachyptery" by Kormilev and Froeschner (1987). In another regard to dispersal, aradids may be somewhat pagile, given that several species present in the New World (i.e., *Aradus lugubris* Fallén, 1807; *Aradus signaticornis* Sahlberg, 1848) were described from the Palearctic (Froeschner 1988). However, in contrast to other live-wood-boring insects (e.g., Buprestidae, Cerambycidae, Curculionidae), pagility among Aradidae may be mitigated in that

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Table 2. Host records for species of Aradidae found in Michigan. Records marked with an asterisk (*) are not novel but were reported in earlier references that I have not located.

	Abies	*Juniperus*	*Picea*	*Pinus*	*Taxodium*	*Tsuga*	*Acer*	*Betula*	*Carpinus*	*Carya*	*Crataegus*	*Fagus*	*Fraxinus*	*Liriodendron*	*Platanus*	*Populus*	*Quercus*	*Salix*	*Talia*	*Ulmus*	*Xanthoxylum*
Aneurus fiskei									5			9			4		5				10
An. inconstans	14						13*	1				11									
Aradus abbas				8*	8*																
Ar. acutus																	4,8, 10, 15	15			
Ar. approximatus				8, 10, 16																	
Ar. crenatus	8*						4, 10	8*	13*	4	13*	8*		4, 10	8, 10	16	8*, 10	13*			
Ar. duzeei				8			10					10									
Ar. falleni				7																	
Ar. implanus																				9	
Ar. insolitus																13*, 16		13*			
Ar. lugubris		8*	8*	8*			1, 10												13*		
Ar. proboscideus	12		8	8, 12																	
Ar. quadrilineatus												10, 11				14	8, 10 16			14	
Ar. robustus						11						9,11					8, 10				
Ar. similis				10			4, 10	8, 10					10				10			4, 10	
Ar. uniannulatus				13*																	
Ar. uniformis				8																	
Quilnus niger				2,4, 8, 15		**14**															
Mezira lobata																	10			10	
Neuroctenus simplex				6, 10								3					3-5, 10 15, 16				

[1]Van Duzee (1894)
[2]Heidemann (1901)
[3]Osborn (1903)
[4]Heidemann (1904a)
[5]Torre-Bueno (1908)
[6]Heidemann (1909)
[7]Van Duzee (1916)
[8]Parshley (1921)
[9]Hussey (1922)
[10]Blatchley (1926)
[11]Torre-Bueno (1935)
[12]Usinger (1936)
[13]Usinger and Matsuda (1959, Table 1)
[14]Matsuda (1977)
[15]Taylor and McPherson (1989)
[16]Present study

flat bugs typically require dead or decaying wood, which is generally a product of low commercial or shipping value.

Little is known about the predators of flat bugs. Presumably other subcorticolous arthropods, particularly ants and beetles, prey on aradids, although this has never been recorded in the literature (Usinger and Matsuda 1959). However, Blatchley (1926) noted a female *Aradus similis* Say, 1831 heavily infested under the hemelytra with the mite *Cheyletus clavispinus* Banks, 1902. Furthermore, there are several hymenopterans known to parasitize flat bugs or their eggs, notably platygastrids in the genus *Aradophagus* Ashmead, 1893 (Heidemann 1904a) and *Telenomus aradi* Kozlov, 1967 (Heliövaara et al. 1982).

Flat bugs are strongly affected, often negatively so, by human interactions with trees and/or forests (Osborn 1903, Parshley 1924, Johansson et al. 2010), a conclusion easy to reach given aradids' stenophagy and the increased anthropogenic destruction of virgin habitat over the last several centuries. In one study, Heliövaara and Väisänen (1983) documented that human disturbance caused proliferation in only one aradid species, whereas five others severely declined. From the other side, another study showed that approximating natural disturbances, such as through prescribed burning, increased the diversity and abundance of aradid species in forest stands (Hägglund et al. 2015). Heliövaara et al. (1983) documented positive and negative effects on population growth of one Finnish species correlated with nitrogen fertilization and insecticide use, respectively, in forest plots. Furthermore, it will be important to better elucidate the ranges and host preferences of individual species in order to focus conservation efforts and better preserve aradid diversity.

At the family-level, the taxonomy of the group has remained somewhat stable, at least in the Nearctic. Aradidae, together with Termitaphididae, form the superfamily Aradoidea, although the latter family is not known to occur in the United States or Canada. However, several of the subfamilies had previously been treated as distinct families, i.e., Aneuridae, Meziridae. The most current catalog for the taxa found in America north of Mexico was provided by Froeschner (1988), although Kormilev and Froeschner's (1987) world catalog also contains those species. In Aradidae, three of five subfamilies found in the Nearctic region are represented in Michigan; Calisiinae and Carventinae are known in the U.S. only from the Gulf States. Of taxa in the three present subfamilies, 28 species in 5 genera are found in the state (Table 1).

For the species found north of Mexico, Parshley's (1921, 1929) monograph, a chapter in Blatchley's (1926) tome on eastern Heteroptera, and Torre-Bueno's (1939) synopsis are early but still useful references for the group. Additionally, despite their broader scope, both Usinger and Matsuda's (1959) systematic treatment and Kormilev and Froeschner's (1987) global catalog still provide much useful biological and biogeographical information relevant to the Nearctic taxa. Undoubtedly, Matsuda's (1977) synopsis of the Canadian species remains the most useful work for identification of boreal species in the New World. The following key was synthesized from Parshley (1921), Blatchley (1926), Torre-Bueno (1939), and Matsuda (1977).

Key to the Aradidae of Michigan

1 Postocular area distinctly wider than anteocular area; eyes scarcely or very slightly prominent beyond postocular area; scape with base barely, or less abruptly, narrowed; trochanters freely-articulating with femora; abdominal spiracles remote from basal margins of ventrites 2

1' Postocular area scarcely wider than anteocular area; eyes very prominent beyond postocular area; scape short, stout, base suddenly narrowed into an extremely short, oblique style; trochanters connate with femora; abdominal spiracles placed near basal margins of ventrites (Aradinae) 5

2 (1) Scutellum transverse, obtusely rounded, broad apically; fourth antennomere much longer than third; rostral groove lanceolate (Aneurinae: *Aneurus*).....3

2' Scutellum triangular, hardly transverse; fourth antennomere not, or but slightly, longer than third, generally shorter; rostral groove linear (Mezirinae).....4

3 (2) Pedicel obovate or subobovate, more similar in shape to scape than third antennomere; fourth antennomere twice as long as third; size smaller, 3.5–4 mm .....*Aneurus fiskei*

3' Pedicel elongate, cylindrical, more similar to third antennomere than scape; fourth antennomere one third or less longer than third; size larger, 5.5–6.5 mm .....*Aneurus inconstans*

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4 (2') Anterior margin of fourth, fifth, and sixth abdominal ventrites lacking ventral ridge; third antennomere conspicuously longer than second (*Mezira*) ..... *Mezira lobata*

4' Fourth, fifth, and sixth abdominal ventrites with narrow, sharp, transverse ventral ridge behind anterior margin; third antennomere, at most, only slightly longer than second (*Neuroctenus*) ..... *Neuroctenus simplex*

5 (1') Rostrum not extending beyond base of head; pronotum trapezoidal, not explanate laterally (*Quilnus*) ..... *Quilnus niger*

5' Rostrum extending beyond base of head; pronotal shape variable but margins more or less explanate laterally (*Aradus*) 6

6 (5') Pedicel as long as or slightly longer than third antennomere 7

6' Pedicel distinctly longer than third 8

7 (6) Pronotum widest behind middle; pronotal margin smooth, untoothed; connexival margin more-or-less entire ..... *Aradus aequalis*

7' Pronotum widest before middle; pronotal margin denticulate in anterior half; connexival margin crenate ..... *Aradus crenatus*

8 (6') Third antennomere one-half thicker than pedicel; pedicel conspicuously bicolorous, blackish in basal half, pale yellowish in apical half ..... *Aradus quadrilineatus*

8' Third antennomere as thick as or only slightly thicker than pedicel; pedicel rarely bicolorous, if so and paler apically, then yellow only at extreme apex 9

9 (8') Lateral margin of pronotum distinctly sinuate in anterior half, distinctly angularly-produced behind middle; rostrum reaching middle of prosternum ..... *Aradus insolitus*

9' Lateral margin of pronotum may be sinuate in anterior half, but not angularly produced behind middle; rostrum usually extending beyond middle of prosternum 10

10 (9') Antennae robust, widest point distinctly thicker than profemur; [pedicel distinctly less than twice as long as third; third antennomere not pale, generally concolorous with other antennomeres] 11

10' Antennae more slender, greatest width subequal to or thinner than profemoral thickness 14

11 (10) Scutellum pentagonal, bases parallel-sided; fourth antennomere small, about half-width of incrassate third ..... *Aradus robustus*

11' Scutellum more-or-less triangular, bases convergent; fourth antennomere subequal to or slightly thinner than third 12

12 (11') Pedicel distinctly shorter than interocular distance; only brachypterous form known ..... *Aradus intectus*

12' Pedicel subequal to or slightly longer than interocular distance; only macropterous form known 13

13 (12') Pronotum unicolorous; scape yellow-brown, contrasting dark-brownish second and third antennomeres ..... *Aradus duzeei*

13' Pronotum with pale spot along anterolateral margin; scape dark-brown, more similar in color to subsequent two antennomeres ..... *Aradus implanus*

14 (10') Corium with lateral margins straight, more-or-less parallel-sided, not distinctly dilated at base; [pronotal margins entire, at most, evenly granulate] (*lugubris* group) 15

14' Corium dilated laterally at base 19

15 (14) Pedicel long, slender, cylindrical, greater than twice length of third antennomere; corium wholly opaque; [third antennomere distinctly bicolorous, basally dark and concolorous with other antennomeres, apically pale yellow-white] 16

15' Pedicel shorter, robust, clavate, little less than twice length of third antennomere; corium with some hyaline cells 17

16 (15) Antennae bifasciate, apex of pedicel and apical half of third antennomere yellow-white; pronotum wide near middle; female with apex of genital segment (=eighth connexival segment) convex, evenly rounded ..... *Aradus abbas*

16' Antennae unifasciate, only apical third of third antennomere yellow-white; pronotum widest distinctly behind middle; female with apex of genital segment (=eighth connexival segment) slightly concave, angulate ..... *Aradus uniannulatus*

17 (15') Pedicel strongly narrowed in basal third; antennae blackish; third antennomere occasionally bicolorous, basally dark and concolorous with pedicel, apically yellow-white ..... *Aradus lugubris*

17' Pedicel gradually thickened from base to apex; antennae pale brownish or reddish; third antennomere concolorous with adjacent segments 18

18 (17') Antennae pale brown; head and pronotum blackish ..... *Aradus falleni*

18' Antennae testaceous; head and anterior pronotal lobe reddish ..... *Aradus subruficeps*

19 (14') Margins of pronotum entire, at most, evenly granulate 20

19' Anterolateral margins of pronotum distinctly serrate, denticulate, or tuberculate; [pronotal margins, excluding teeth, more-or-less convex, never distinctly sinuate] 22

20 (19) Third antennomere wholly pale yellow; lateral pronotal margins evenly convex; [pronotum widest before middle] ..... *Aradus uniformis*

20' Third antennomere dark; lateral pronotal margins more-or-less sinuate in anterior half.....21

21 (20') Pedicel evenly cylindrical; apex of median process of head with width subequal to average width of pedicel; pronotum widest distinctly behind middle ..... *Aradus borealis*

21' Pedicel nearly capitate, distinctly swollen at apex; apex of median process of head with width thicker than average width of pedicel; pronotum widest at middle ..... *Aradus tuberculifer*

22 (19') Pedicel approximately one-third longer than third antennomere; anterolateral angle of pronotum with robust, angular projection .....*Aradus montanus*

22' Pedical at least twice as long as third antennomere; anterolateral angle of pronotum denticulate, but without robust, angular projection.....23

23 (22') Pedicel approximately 2–2.5 times as long as third antennomere 24

23' Pedicel approximately three or more times longer than third antennomere.....26

24 (22") Pedicel shorter, subequal to interocular distance, approximately twice as long as third antennomere; third antennomere often mostly pale yellow, contrasting dark adjacent segments ..... *Aradus similis*

24' Pedicel longer, at least subequal to interocular distance + one eye, approximately 2.2–2.5 times as long as third antennomere; third antennomere concolorous with adjacent segments 25

25 (24') Pedicel slender, evenly cylindrical, not gradually thickening (except sometimes inconspicuously so at extreme apex); apex of median process of head with width easily twice apical width of pedicel; pronotal margins denticulate, teeth smaller, less conspicuous; body, in large part, pale testaceous or rufous ..... *Aradus proboscideus*

25' Pedicel more robust, gradually thickened to apex; apex of median process of head with width less than twice apical width of pedicel; pronotal margins serrate, teeth large, conspicuous; body wholly black, except posterolateral angles of connexival segments and membranous portions of wings .....*Aradus shermani*

26 (23') Abdominal tergites mesad connexiva with distinct silvery granular spots; length of pedicel subequal to three times third anntenomere..... *Aradus acutus*

26' Abdominal tergites mesad connexiva lacking silvery spots; length of pedicel distinctly greater than three times third antennomere 27

27 (26') Pedicel cylindrical from base to middle, strongly and abruptly swollen and black in apical third; lateral pronotal margins less evenly convex, appearing widest slightly behind middle ..... *Aradus approximatus*

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27' Pedicel evenly enlarged from near base to apex, generally unicolorous; lateral pronotal margins more evenly convex, appearing widest at or slightly before middle ..... *Aradus inornatus*

Subfamily ANEURINAE Douglas and Scott, 1865

Genus ANEURUS Curtis, 1825

Subgenus ANEURUS Curtis, 1825

Aneurus fiskei Heidemann, 1904a. (Figs. 2, 5). – This species was reported from Michigan by Hussey (1922); he reported it "[r]ather common under the bark of the dead beeches in the Warren Woods, but found only on fallen trees." Kormilev (1968) and Picchi (1977) keyed the species of *Aneurus* found in the United States. 6 specimens examined. Collection dates from 28 May to 20 July.

Aneurus inconstans Uhler, 1871. (Figs. 2, 6). – This species was reported from Michigan by Picchi (1977); this record apparently was overlooked by Froeschner (1988). This species has been collected from "under bark" in Berrien County, from "under bark of dead limbs" in Clinton County, and from "under bark of fallen tree branch in woods" in Oakland County. It also has been collected from rotary traps both at ground level and at 12 foot height in Saginaw County. Torre-Bueno (1935) discussed the biology of this species in New York. Kormilev (1968) and Picchi (1977) keyed the species of *Aneurus* found in the United States. 54 specimens examined. Collection dates from 1 April to 30 August.

Subfamily ARADINAE Spinola, 1837

Genus ARADUS Fabricius, 1803

Aradus abbas Bergroth, 1889. (Figs. 3, 7). – This species was recorded from Michigan by Adams (1909). This species also has been collected on Isle Royale (Keweenaw County). I also examined 2 individuals of *A. abbas* with an "Ag. Coll. Mich." label, although these were excluded from the count (see *Quilnus heidemanni* Bergroth); if Michiganian, the earliest collection date to would be pushed up to 21 April. 4 specimens examined. Collection dates from 21 June to 28 August.

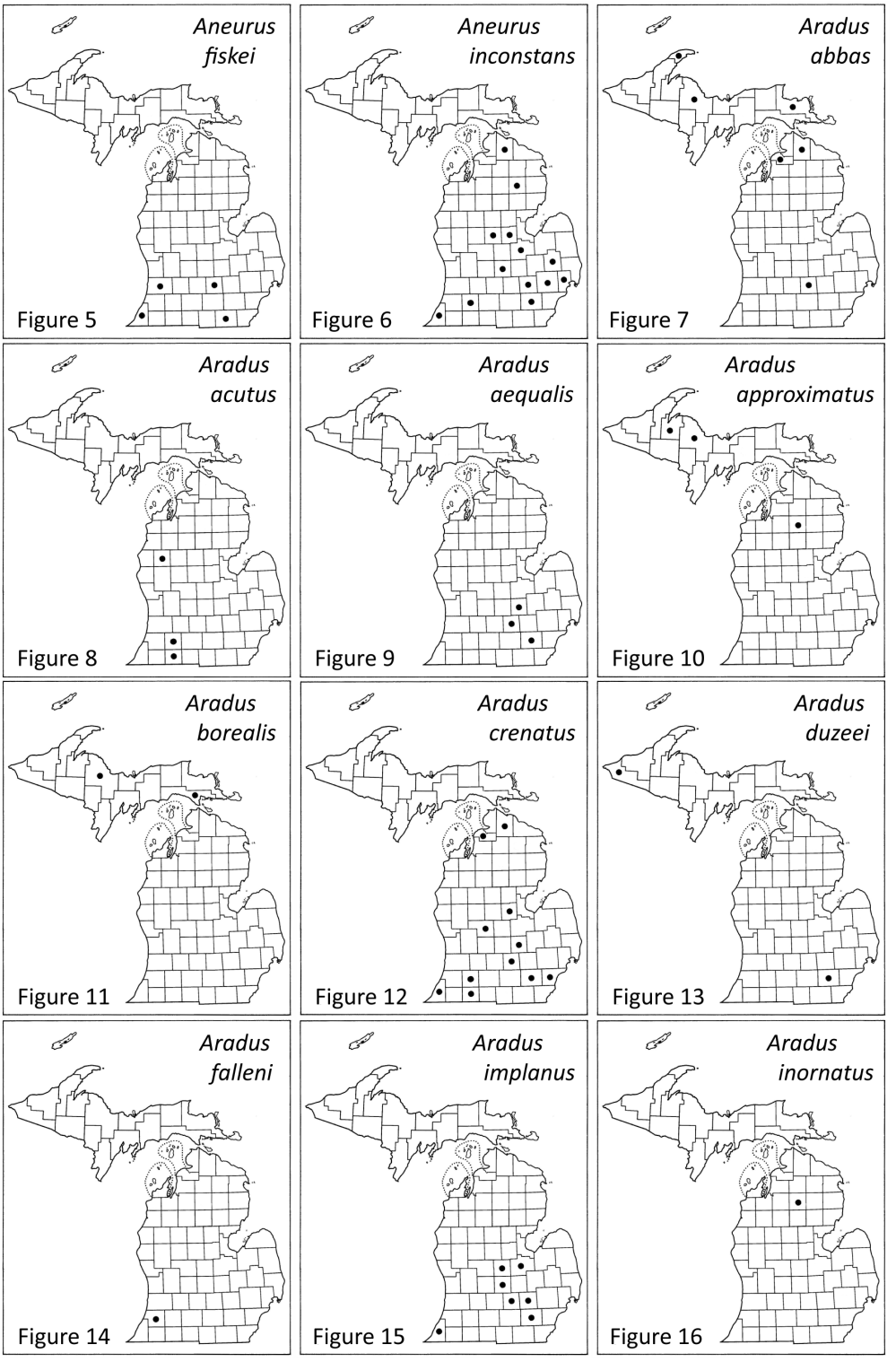
Aradus acutus Say, 1831. (Figs. 3, 8). – This species was reported from Michigan by Townsend (1890); this record apparently was overlooked by Froeschner (1988). This species has been "taken from beneath dead logs" in Kalamazoo County. In the eastern United States, *A. acutus* is easily recognized by the silvery dorsal patches mesad of the connexiva. 5 specimens examined. Collection dates from 12 July to 25 November.

Aradus aequalis Say, 1831. (Figs. 3, 9). – This species was reported only recently from Michigan by Scudder (2012). I have examined the following corroborative material: [Ingham Co.], E. Lansing, 1 May 1951, [no collector], det. D. R. Swanson 2012 [1 ♂] (MSUC); [Ingham Co.], E. Lansing, 3 May 1955, R. L. Fischer, det. D. R. Swanson 2012 [2 ♂] (MSUC); Shiawassee [Co.], 4.5 mi. NW. Perry, ex: Malaise trap, 19 June–4 July 1980, Ralph Gorton, det. D. R. Swanson 2012 [1 ♂] (MSUC); Washtenaw Co., Ann Arbor, Nichols Arboretum, 10 May 2007, 42.2806°N 83.7266°W, 870 ft., D. R. Swanson, #23, det. D. R. Swanson 2009 [1 ♀] (DRS). This species has been collected in a Malaise trap in Shiawassee County. This is one of two species of *Aradus* easily distinguished by the second and third antennomeres being subequal in length. 5 specimens examined. Collection dates from 1 May to 4 July.

Aradus approximatus Parshley, 1921. (Figs. 3, 10). – (**NEW STATE RECORD**). Label data as follows: Baraga Co., 12 July 1966, on jack pine log, W. Mattson, det. D. R. Swanson 2017 [1 ♀] (MSUC); Crawford Co., Frederic, 21 May 1965, collector R. W. Hodges, det. D. R. Swanson 2012 [1 ind., abdomen missing] (MSUC); Marquette Co., Van Riper State Park, 12–14 July 1972, D. K. & D. C. Young, det. D. R. Swanson 2012 [1 ♂] (MSUC). The species was previously known from Georgia, Indiana, Maine, Mississippi, New Jersey, and New York, as well as British Columbia, Manitoba, and Quebec (Froeschner 1988, Maw et al. 2000); thus, it was expected for Michigan. 3 specimens examined. Collection dates from 21 May to 14 July.

Aradus borealis Heidemann, 1909. (Figs. 3, 11). – This species was reported from Michigan in the original description by Heidemann (1909). An additional specimen with the following label data was examined: MICHIGAN: Mackinac Co., St. Helena Is., 26 May 1922, "472", S. Moore, det. R. F. Hussey 1950 [1 ♀] (UMMZ). 1 specimen examined. Collection dates from 26 May to 26 June.

Aradus crenatus Say, 1831. (Figs. 3, 12). – This species was reported from Michigan by Townsend (1890). This species was taken "under loose bark of a dead aspen" in Cheboygan County and "in field grass" in Wayne County, and nymphs have been "taken from rotting wood" in Shiawassee County. Usinger and Matsuda (1959, Table 1) listed several species of polypore mushroom as hosts (i.e., *Trametes versicolor* [L.] Lloyd;



Figures 5–16. Distribution of various aradid species in Michigan.

Trametes gibbosa [Pers.] Fr.; *Spongipellis unicolor* [Schwein.] Murrill). Taylor and McPherson (1989) reported this species taken from two species of fungi (i.e., *Polyporus caesius* (Schrad.) Fr.; *Bjerkandera adusta* (Willd.) P.Karst.) in Arkansas. Jordan (1932) described the morphology and development of this species. This is one of two species of *Aradus* easily distinguished by the second and third antennomeres being subequal in length. 13 specimens examined. Collection dates from 19 March to 1 October.

Aradus duzeei Bergroth, 1892. (Figs. 3, 13). – (**NEW STATE RECORD**). Label data as follows: Washtenaw Co., 6 Mile Woods, 19 May 1931, [no collector], det. R. F. Hussey 1950, det. D. R. Swanson 2012 [1 ♀] (UMMZ); Gogebic Co., 4.8 mi. N. Watersmeet, 22 June 1973, I. J. Cantrall, det. D. R. Swanson 2012 [1 ♀] (UMMZ). The species was previously known from Indiana, Massachusetts, Maryland, Missouri, New Jersey, New York, Ohio, Pennsylvania, and Virginia, as well as Ontario and Quebec (Froeschner 1988, Maw et al. 2000); thus, it was expected for Michigan. 2 specimens examined. Collection dates from 19 May to 22 June.

Aradus falleni Stål, 1860. (Figs. 3, 14). – (**NEW STATE RECORD**). Label data as follows: [Van Buren Co.], S[outh] Haven, 1 June '91, [no collector], det. D. R. Swanson 2012 [1 ind.] (MSUC). The abdomen posterior to the apex of the scutellum is ripped off. Nevertheless, the specimen remains identifiable as the head, antennae, and pronotum remain intact. One of the widest ranging species in the Western Hemisphere, *A. falleni* was previously known from Illinois and Indiana and ranges as far north as British Columbia (Froeschner 1988); thus, it was unsurprising, if not expected, to find *A. falleni* in Michigan. 1 specimen examined. Collection date is 1 June.

Aradus implanus Parshley, 1921. (Figs. 3, 15). – This species was reported from Michigan by Parshley (1921). Hussey (1922) reported it from "under the bark of a dead elm just within the Warren Woods." This species has been collected from a rotary trap in Saginaw County. 11 specimens examined. Collection dates from 23 April to 1 July.

Aradus inornatus Uhler, 1876. (Figs. 3, 16). – This species was recorded from Michigan by Parshley (1921) from "Lake Superior" with no further details. 4 specimens examined. Collection date is 21 May.

Aradus insolitus Van Duzee, 1916. (Figs. 3, 17). – (**NEW STATE RECORD**). Label data as follows: Livingston Co., E. S. George Reserve, "High Heaven", "ex: *Populus grandidentata*; standing, 6" DBH", 12 October 1979, L. Kirkendall, det. D. R. Swanson 2012 [1 ♂] (UMMZ); Oakland Co., Highland, Highland State Rec. Area, on side of wooden shed, 14 May 2011, 42.6427°N 83.5536°W, 870 ft., D. R. Swanson, #11, det. D. R. Swanson 2012 [1 ♂] (DRS). Primarily known from the western North America, i.e., Alberta, British Columbia, California, Idaho, and Oregon (Froeschner 1988), this species was not expected for Michigan. However, Maw et al. (2000) added a citation for Ontario, thereby lending support for the presence of *A. insolitus* in the eastern part of North America. The large temporal separation of the two specimens examined suggest that the species has simply gone undetected in the state. Usinger and Matsuda (1959, Table 1) listed *A. insolitus* from false turkey tail fungus (*Stereum hirsutum* [Willd.] Pers.) on quaking aspen (*Populus tremuloides* Michx.). 2 specimens examined. Collection dates from 14 May to 12 October.

Aradus intectus Parshley, 1921. (Figs. 3, 18). – (**NEW STATE RECORD**). Label data as follows: Mackinac Co., Penny Island, 26 July 1926, S. Moore, det. D. R. Swanson 2012 [1 ♀] (UMMZ); St. Clair Co., Port Huron, 1 June 1924, S. Moore, det. D. R. Swanson 2012 [1 ♀] (UMMZ). Like the previous record, this species is a primarily western element in the North American fauna, being previously known from Alberta, British Columbia, Colorado, Manitoba, Montana, Saskatchewan, Wyoming, and the Yukon Territories (Froeschner 1988, Maw et al. 2000). Thus, it was not expected for Michigan. However, the robustness of the antennae (in relation to the profemora) set it apart from the majority of other species of *Aradus* found in the state. 2 specimens examined. Collection dates from 1 June to 26 July.

Aradus lugubris Fallén, 1807. (Figs. 4, 19). – This species was reported from Michigan by Townsend (1890) (as *Aradus rectus* Say, 1831). This species has been collected on Isle Royale (Keweenaw County). I also examined 8 individuals of this species with an "Ag. Coll. Mich." label, although these were excluded from the count (see *Quilnus heidemanni*). Currently all Michigan records would be assigned to the nominate subspecies; however, *Aradus lugubris nigricornis* Reuter, 1900, might also be found in the state, being known from Alaska, Arizona, California, Colorado, Idaho, Maine, Massachusetts, Nevada, New Mexico, Oregon, Washington, and Wisconsin, as well as British Columbia, Northwest Territories, and Ontario (Froeschner 1988). They are separated by *A. l. nigricornis* possessing wholly black antennae, whereas those in the nominate subspecies have the apex of the third antennomere, and occasionally that of the pedicel, white. However, Parshley

(1921) noted that *A. l. lugubris* "exhibits intergradational variation in the amount of white on the antennae", concluding that "[i]t is not of geographical significance." 6 specimens examined. Collection dates from 21 April to 30 August.

Aradus montanus Bergroth, 1913. (Figs. 4, 20). – (**NEW STATE RECORD**). Label data as follows: Mackinac Co., St. Helena Island, 26 May 1922, S. Moore, det. R. F. Hussey 1950, det. D. R. Swanson 2012 [1 ♀] (UMMZ). This species was previously known from Colorado, Montana, and Quebec; thus, it is plausible, if not expected, to find this species in Michigan. However, as indicated in the key, this species is distinctive among species with serrate pronotal margins in its short pedicel. 1 specimen examined. Collection date is 26 May.

Aradus proboscideus Walker, 1873. (Figs. 4, 21). – (**NEW STATE RECORD**). Label data as follows: Cheboygan Co., Cheboygan, 12 May 1921, "333", S. Moore, det. R. F. Hussey 1921, [1 ♀] (UMMZ); Keweenaw Co., Isle Royale, N.P., 3-mile camp, 2 September 1975, J. K. Liebherr, det. D. R. Swanson 2012 [1 ♂] (MSUC). This species was previously known from Manitoba, Ontario, Quebec, south to Wyoming, Colorado, and New York (Froeschner 1988, Maw et al. 2000); thus, it is plausible for this species to be found in Michigan. Usinger and Matsuda (1959, Table 1) listed *A. proboscideus* from red-belt conk fungus (*Fomitopsis pinicola* [Swartz ex Fries] P.Karst.), and "spruce fungus". 2 specimens examined. Collection dates from 12 May to 2 September.

Aradus quadrilineatus Say, 1825. (Figs. 4, 22). – This species was recorded from Michigan by Parshley (1921). The species has been collected from "under bark of oak stump" in Washtenaw County. This species has been collected on St. Helena Island (Mackinac County). Barber (1923) described the natural history and various life stages, notably the egg, of this species. Torre-Bueno (1935) discussed the biology of this species in New York. This common species is unique and instantly recognizable by the configuration of the antennae. 41 specimens examined. Collection dates from 23 April to 11 August.

Aradus robustus Uhler, 1871. (Figs. 4, 23). – This species was reported from Michigan by Townsend (1890) and Parshley (1921). Hussey (1922) reported it "from the bark of a large fallen beech in the flood-plain forest in the Warren Woods." This species has been collected in a Malaise trap in Dickinson County, in a pitfall trap in Ingham County, from rotaries traps, some at ground level, in Saginaw County, and "sweeping" in Washtenaw County. Leschen and Taylor (1987) and Taylor and McPherson (1989) reported this species taken from the white-rot fungus *Irpex lacteus* (Fr.) Fr. Torre-Bueno (1935) discussed the biology of this species in New York, and Leschen and Taylor (1987) discussed aspects of the biology and distribution in several eastern states. Although I have examined two individuals that could be referred to the subspecies *Aradus robustus insignis* Parshley, 1921, a subspecies recorded from Michigan in the original description, I have declined to include separate divisions for the two subspecies. Parshley (1921) noted that *A. r. insignis* was a color variant of "no geographical significance." The two are separated by portions of the yellowish portions of the pronotum, scutellum and corium, as well as the reddish dorsal coloration of the abdomen, in *A. r. insignis,* as opposed to the uniformly dark coloration in the nominate subspecies. 49 specimens examined. Collection dates from 12 April to 20 July.

Aradus shermani Heidemann, 1906. (Figs. 4, 24). – (**NEW STATE RECORD**). Label data as follows: Oakland Co., Milford, 22 June 1921, "35", T. H. Hubbell, det. R. F. Hussey 1921 [1 ♂] (UMMZ). This species was previously known from Alabama, Florida, Georgia, Maine, New Jersey, North Carolina, Ontario, Pennsylvania, Quebec, Saskatchewan, and the Yukon Territories (Froeschner 1988, Maw et al. 2000); thus, it is plausible for this species to be found in Michigan. 1 specimen examined. Collection date is 22 June.

Aradus similis Say, 1831. (Figs. 4, 25). – This species was recorded from Michigan by Parshley (1921). I also examined 1 individual of this species with an "Ag. Coll. Mich." label, although this was excluded from the count (see *Quilnus heidemanni*); if Michiganian, the earliest collection date to would be pushed up to 6 May. Usinger and Matsuda (1959, Table 1) listed this species from *Polyporus* fungus on birch (*Betula* sp.). 9 specimens examined. Collection dates from 12 May to 18 August.

Aradus subruficeps Hussey, 1953. (Figs. 4, 26). – This species was described from Michigan by Hussey (1953) based on a single individual. It remains possible that *A. subruficeps* is merely a teneral individual of *A. falleni*, and Hussey (1953) noted that it runs to that species in various keys. However, he stated "It agrees in size with smaller individuals of that species, but is at once distinct by reason of its color, the very different proportions of head and pronotum, the nonfenestrate ventral genital segment of the male, and so forth." Thus, it is retained here as a valid species. 1 specimen (holotype) examined. Collection date is 31 July.

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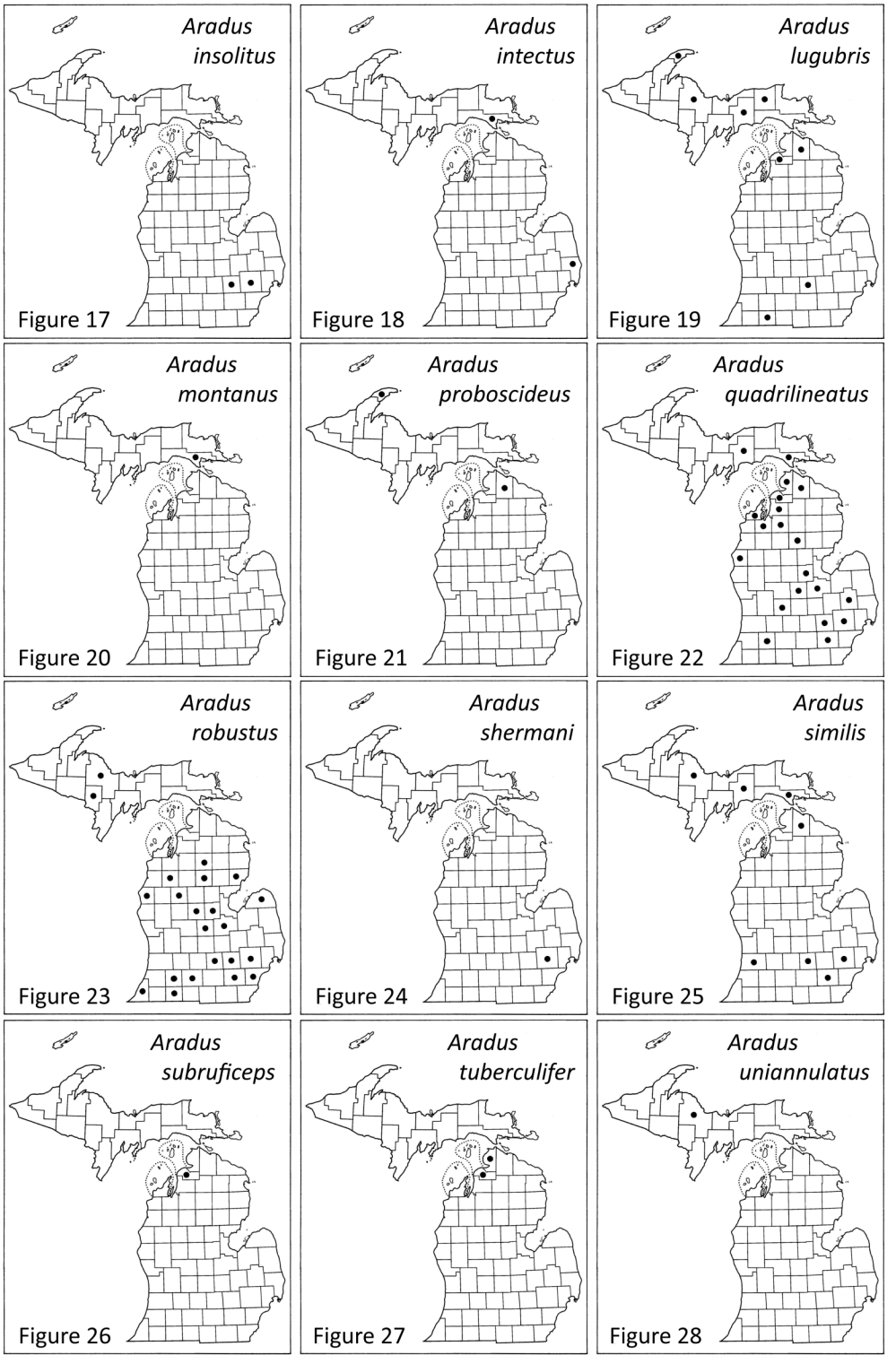
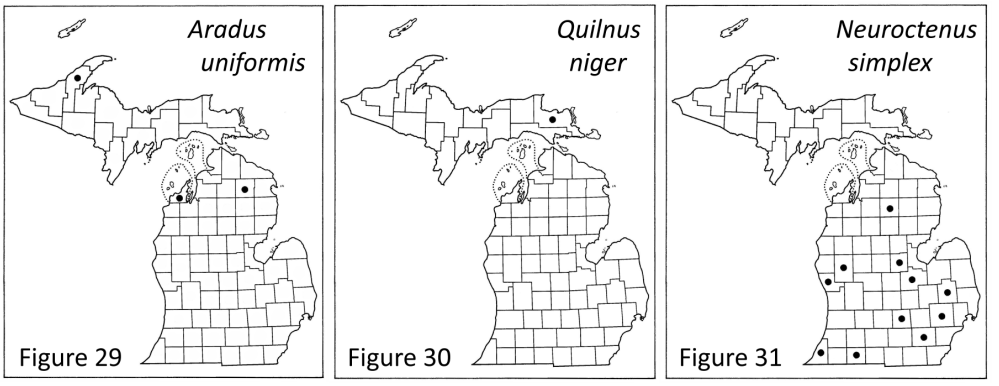


Figures 17–28. Distribution of various aradid species in Michigan.



Figures 29–31. Distribution of various aradid species in Michigan.

Aradus tuberculifer Kirby, 1837. (Figs. 4, 27). – This species was recorded from Michigan (without any locality information) by Parshley (1921). I examined the following two corroborative specimens: Charlevoix Co., Whiskey Is., 9 June 1923, "589", S. Moore, det. R. F. Hussey 1950 [1 ♂] (UMMZ); Emmet Co., Waugoshance Pt., 22 May 1922, "470", S. Moore, det. R. F. Hussey 1950 [1 ♂] (UMMZ). 2 specimens examined. Collection dates from 22 May to 9 June.

Aradus uniannulatus Parshley, 1921. (Figs. 4, 28). – This species was recorded from Michigan by Parshley (1921). At the time, the single Michiganian paratype was retained in Parshley's collection, and it currently resides in the California Academy of Sciences (CAS) (Zuparko, pers. comm., 2016). No specimens examined. Collection date is 28 August.

Aradus uniformis Heidemann, 1904b. (Figs. 4, 29). – (**NEW STATE RECORD**). Label data as follows: Leelanau Co., South Fox Island, 27 May 1925, S. Moore, det. R. F. Hussey 1950, det. D. R. Swanson 2012 [2 ♀] (UMMZ); Montmorency Co., 6 mi. N. Atlanta, Jackson Lake Forest Campground, 22 June 1995, M. A. & M. O'Brien, det. D. R. Swanson 2012 [1 ♀] (UMMZ). This aradid also has been collected from Isle Royale (Keweenaw County). This species was previously known from Florida, Massachusetts, Maryland, New Jersey, New York, North Carolina, Pennsylvania, and Virginia, as well as Ontario (Froeschner 1988); thus, it was expected for Michigan. 4 specimens examined. Collection dates from 27 May to 22 June.

Genus QUILNUS Stål, 1873

Quilnus heidemanni (Bergroth, 1906). – I have examined a single female of *Q. heidemanni* in MSUC. It bears the following label data: "Ag. Coll. Mich., 3-21-'90, 14, det. D. R. Swanson 2012". This specimen, however, is excluded, because labels of this type typically denote ownership rather than a collecting locality (O'Brien 1998). It is primarily a western species, being known from California, Colorado, Montana, New Mexico, Oregon, and Washington, as well as Alberta and British Columbia (Froeschner 1988). Given these factors, it seems prudent to exclude this species from Michigan's faunal list at this time.

Quilnus niger (Stål, 1873). (Fig. 4, 30). – (**NEW STATE RECORD**). Label data as follows: Chippewa Co., 27 August 1941, R. R. Dreisbach, det. D. R. Swanson 2012 [1 micropterous ♀] (MSUC). This species, being known from Missouri, New York, Ontario, and Quebec, among other states and provinces (Froeschner 1988), was expected for Michigan. Heidemann (1901) discussed the habitats of this species. 1 specimen examined. Collection date is 27 August.

Subfamily MEZIRINAE Oshanin, 1910

Genus MEZIRA Amyot and Audinet-Serville, 1843

Mezira lobata (Say, 1831). (Fig. 2). – This species was recorded from Michigan by Uhler (1876) and Blatchley (1926), although neither provided specific localities in the state. Froeschner (1988) listed "Canada", in addition to Midwestern states, such as Illinois, Indiana, and Ohio; thus, it seems plausible for the species to be found in Michigan, assuming records from Canada are valid. Furthermore, being one of the "large" species of *Mezira*, it should be easily distinguished from the other mezirine species known from the state. Usinger (1936) and Kormilev

(1962, 1971) keyed the genus. No specimens examined. Collection date unknown.

Genus NEUROCTENUS Fieber, 1860

Neuroctenus simplex (Uhler, 1876). (Fig. 2, 31). – (**NEW STATE RECORD**). Given the number of specimens examined, it remains surprising that this species was heretofore unreported from Michigan. Certainly, its presence in Michigan was plausible, as it was previously known from Illinois, Maine, Montana, and Ohio, among other states (Froeschner 1988), and this dearth of records might come from the occasional difficulty in separating *N. simplex* from its congeners, as well as similar-sized, i.e., "small", species of *Mezira*. This species has been taken "under hickory or oak bark" and "taken on *Quercus velutina*" in Washtenaw County. I also examined 25 individuals of this species with an "Ag. Coll. Mich." label, although these were excluded from the count (see *Quilnus heidemanni*). Kormilev (1982a) keyed the genus. 52 specimens examined. Collection dates from 13 February to 14 November.

NOTES ON ADDITIONAL SPECIES

The cryptic characteristics of aradids likely contribute to an underestimation of the biodiversity in the state. These cryptic facets of aradids also suggest that the distribution of many aradid species is poorly-understood. As highlighted above, the presence of several predominantly western elements in Michigan contributes further evidence toward this incomplete understanding regarding aradid ranges. Therefore, mention of species that might eventually be found in Michigan is warranted. In this context, there are three tiers of species' ranges to consider. First, four species are known from across portions of Canada but also in the northern corners of the United States, thereby including Michigan in the potential range on strictly latitudinal criteria: *Aneurus borealis* Picchi, 1977; *Aradus debilis* Uhler, 1876; *Aradus funestus* Bergroth, 1913; and *Aradus persimilis* Van Duzee, 1916. The sole member of the second tier is *Aradus paganicus* Parshley, 1929, being known from both eastern and western Canada, specifically British Columbia and Ontario, but not yet known from the United States. The third tier encompasses six species, all but one being mezirines, that are present in adjacent states to the south, and therefore might be found in southern Michigan: *Aradus ornatus* Say, 1831; *Mezira granulata* (Say, 1831); *Mezira sayi* Kormilev, 1982b; *Nannium pusio* Heidemann, 1909; *Neuroctenus elongatus* Osborn, 1903; and *Neuroctenus pseudonymus* Bergroth, 1898. It is important to keep these potential additions in mind when keying out specimens. These species are not included in the key, and more inclusive treatments, particularly those of more boreal species such as Matsuda's (1977) *Aradidae of Canada*, should be consulted. Two species bear special consideration:

Aneurus simplex Uhler, 1871. – Although the currently known range is similar to that of "tier 1 species" mentioned above, *A. simplex* is found farther south in several portions of its range. Distributed widely across Canada (Alberta, British Columbia, Manitoba, Newfoundland and Labrador, Northwest Territories, Nova Scotia, Ontario, Quebec, and Yukon Territories), this species also occurs in Alaska, Colorado, Idaho, Maine, Massachusetts, Montana, New Hampshire, New Jersey, New York, North Carolina, Oregon, Vermont, Washington, and Wyoming (Froeschner 1988, Maw et al. 2000). Usinger and Matsuda (1959, Table 1) listed Sitka spruce (*Picea sitchensis* [Bong.] Carr.) as a host record for this species, although this species of spruce is not found in Michigan (Barnes and Wagner 2004). Like *A. inconstans*, the pedicel is more similar to the third antennomere than the scape; however, *A. simplex* is unique from all species of *Aneurus* known from the United States in the lateral (visible in dorsal view), rather than ventral, spiracle of the fifth abdominal tergite.

Aradus kormilevi Heiss, 1980. – Previously confounded with the pestiferous *Aradus cinnamomeus*, *A. kormilevi* will surely be found in Michigan. Having been recorded from Alabama, California, Colorado, Florida, Georgia, Kansas, Maryland, Massachusetts, Mississippi, Missouri, Montana, Nebraska, New Jersey, Pennsylvania, Texas, Virginia, West Virginia and Wyoming, as well as Washington, D.C. and Alberta, British Columbia, Manitoba, New Brunswick, Nova Scotia, Ontario, Quebec, and Saskatchewan (Froeschner 1988, Maw et al. 2000), the current known range of this species encloses Michigan. Despite belonging to the same complex as *A. cinnamomeus*, this species is not known to be economically impactful (Heliövaara 2000). Usinger and Matsuda (1959, Table 1) listed many host records for *A. cinnamomeus*, of which the following trees are found in Michigan (Barnes and Wagner 2004): Scots pine (*Pinus sylvestris* L.), black pine (*Pinus nigra* Arnold), jack pine (*Pinus banksiana* Lamb.), white fur (*Abies concolor* [Gordon and Glend.] Lindley ex Hildebrand), Norway spruce (*Picea abies* [L. H.Karst.]), common alder (*Alnus glutinosa* [L.] Gaertn.), juniper (*Juniperus* sp.), and willow (*Salix* sp.). However, these records might be either shared or confounded with *A. kormilevi*. The species is easily recognized from other

aradines by the obliterated pronotal carinae, the short moniliform antennae, the wide "snout", small body size (less than 4 mm), and reddish-brown coloration. This is the only species in the United States known to have stenopterous morphs.

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