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Seining watercourses, a new method for collecting flat bugs? (Hemiptera, Heteroptera, Aradidae)

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A b s t r a c t : The known flat bug fauna of continental America North of Mexico comprises 127 species. The genus *Aradus* is represented by 84 species and *Mezira* by 10 species (MATSUDA 1977; KORMILEV & FROESCHNER 1987; VASARHELYI 1994; DAVIDOVÁ-VILIMOVÁ et al. 1996). Eleven species of *Aradus* and one of *Mezira* were collected in the Sierra Nevada of California by the junior author and William Shepard, using an unusual method by which insects were collected from plant debris gathered by seines from an artificial watercourse. From additional material of the first author's collection, *Aradus ampliatus* UHLER, 1876, from Oregon and Washington and *Aradus pannosus* VAN DUZEE, 1920, from Oregon, represent new state records. *Aradus linsleyi* USINGER, 1936, a very rare species only known from two females, was among the examined seined material, as well as *Aradus patibulus* VAN DUZEE which has been reported only twice in the literature since 1936. Photos of the recorded species and figures of male genitalic structures of four taxa are presented, including illustrations of the first known male of *Aradus linsleyi*.

K e y w o r d s : Hemiptera, Heteroptera, Aradidae, new state records, new faunal records, California, USA.

Introduction

The fauna of Aradidae or flat bugs of America North of Mexico was included in the synonymic list of world Aradidae catalogued by KORMILEV & FROESCHNER 1987. Detailed information for species occurring in continental United States with state records was published by FROESCHNER 1988, and for Canada by MATSUDA 1977. They listed 124 Aradidae, of which 84 species belong to the subfamily Aradinae, genus *Aradus*, and nine to the subfamily Mezirinae, genus *Mezira*. Only few additional species have been described since by VASARHELYI 1994 (*Aradus froeschneri* from California, *Neuroctenus unistellatus* from Texas) and by DAVIDOVÁ-VILIMOVÁ et al. 1996 (*Mezira froeschneri* from Florida).

The aradid specimens reported in this paper were collected in an unusual and novel manner by the junior author and her husband, William Shepard, from a canal located in the Sierra Nevada, El Dorado County, California, USA. The El Dorado Canal, also called the El Dorado Ditch, is an artificial watercourse formed by water diverted from the South Fork of the American River near the town of Kyburz at an elevation of 1192 m above MSL. Thirty-five kilometers downstream, the water is discharged into a reservoir to be used for irrigation, drinking water, and hydroelectric power generation.

The collecting site is located 21 km downstream of the canal intake at an elevation of 1180 m above MSL. The area is a mixed conifer forest characterized by ponderosa pine (*Pinus ponderosa* DOUGLAS ex LAWSON & C. LAWSON), sugar pine (*Pinus lambertiana* DOUGLAS), Douglas-fir (*Pseudotsuga menziesii* (MIRBEL) FRANCO), incense-cedar (*Calocedrus decurrens* (TORREY) FLORIN), white fir (*Abies concolor* (GORDON & GLENDINNING) LINDL. ex HILDEBRAND), California black oak (*Quercus kelloggii* NEWBERRY), and big-leaf maple (*Acer macrophyllum* PURSH).

As part of a sampling effort which began in 1991 and continued sporadically through 2016, waterlogged debris, containing insects, was skimmed from the water surface using seines (Photo 1, Fig. 1). Specimens, most of them alive, were hand-picked from the debris on site. The idea to conduct such sampling originated from a paper published by HALSTEAD & HAINES (1987). The overall results of this project will be published in a separate article by Barr and Shepard.

Material and methods

Sampling was accomplished using two homemade seines made of nylon window screen material, 1.3cm diameter PVC pipe and connectors, rope, and lead weights. The rectangular frame and extended net have the following approximate dimensions: 1.22 m wide x 0.3 m tall x 0.5 m deep. Lead weights of 1.4 kg or 2.3 kg were attached to the lower corners to keep the bottom of the frame below the water surface so that debris and insects carried along in the current would be caught in the net bags.

The two seines were secured to a wooden bridge spanning the canal, which is 5-6 m wide, and left in place a variable amount of time until debris carried by the current accumulated in the nets (Photo 1, Fig. 1). The speed of accumulation depended on the amount of wind present and time of year. When full, the seines were pulled from the canal and the contents transferred to enamel pans, from which the debris was then dumped onto a portable table (Photo 1, Fig. 2).

The debris was processed on site by manually removing whatever insects were of interest. No special techniques or equipment (Berlese, Malaise, etc.) were employed in order to extract specimens from the debris, and no debris was taken back to the lab. Particular attention was given to the Coleoptera, the main interest of Barr and Shepard, and groups of insects that were perceived to be especially abundant or species diverse, such as the Aradidae.

During the period from 1991 to 2016 there were a total of 56 collecting events during eight years, most of them in the months of April through July. The events were generally of 5-6 hours duration each, and took place mostly in the afternoon.

Specimens were prepared in the lab for eventual deposition in permanent entomological collections. The aradids were pinned or point mounted and provided with data labels. Some of the specimens collected in the early 1990's were deposited at the California Academy of Sciences (CAS); the remainder has been, or will be, deposited in the Essig Museum of Entomology, University of California, Berkeley (EMEC) and voucher samples in the collection of the first author (CEHI = collection Ernst Heiss, Innsbruck).

Results

A total number of 117 aradid specimens representing twelve species were collected while sampling debris for insects using seines in the El Dorado Canal, an artificial watercourse in California. Of these, 106 specimens belong to eleven species of the genus *Aradus* (about 13% of the North American fauna) and eleven specimens to one species to the genus *Mezira* (10% of the fauna). Although all of these species were previously recorded from California (FROESCHNER 1988), two species are of particular interest. *Aradus patibulus* VAN DUZEE 1927 and *Aradus linsleyi* USINGER, 1936, seem both to be very rare, as only a few additional records have been reported since their description. *Aradus linsleyi*, represented here by seven specimens, has been known only from two females. We are reporting the first known male of this species and are providing a habitus illustration (Photo 5, Fig. 19) and illustrations of the genitalia and antenna (Table II, Figs 16-20). *Aradus patibulus* is represented in the samples by 18 specimens.

The geographic locality as given on the label of each specimen is: CA: El Dorado County / 1 mi. E of Pacific House / 38.7595°, -120.4922° / 1180m. All of the specimens were collected during April through June; specific collection dates are reported below with the species list.

Additional voucher specimens of *Aradus* from the collection of the first author included in this study proved to represent new state records for Oregon (*A. ampliatus*, *A. pannosus*) and Washington (*A. ampliatus*). Distribution data are indicated following FROESCHNER 1988, and MATSUDA 1977.

Family A r a d i d a e BRULLÉ, 1836

Subfamily A r a d i n a e BRULLÉ, 1836

***Aradus ampliatus* UHLER, 1876** (Photo 3, Fig. 5; Table I, Figs 1-5)

M a t e r i a l e x a m i n e d : 2♀♀, 28 V 2015 (2 specimens).

Aradus ampliatus seems to be rare and is recorded only from California and Utah. It is a large, dark colored species and easily recognized by the third antennal segment which has a yellowish apical ring. Its size of about 10mm and the pronotal structure resemble that of *Aradus crenatus* SAY, 1831, from the eastern USA *Aradus crenatus* (Photo 5, Fig. 18) is distinguished by stramineous coloration of body and antennae and also different male genitalic structures which are illustrated for both species (Table II, Figs 11-15; Table I, Figs 1-5).

A d d i t i o n a l m a t e r i a l in CEHI: 1♂ Washington, Boulder Cave, 10 V 1947 (**new state record**); 1♀ Oregon, Klamath Falls, 23 IV 1953 (**new state record**); 1♀ California, Mariposa Co., 6 V 1942.

***Aradus antennalis* PARSHLEY, 1921** (Photo 3, Fig. 8)

M a t e r i a l e x a m i n e d : 1♂, 29.VI.1991; 1♂, 25.IV.1992; 1♂, 22.V.1994; 1♂, 27.V.2016 (4 specimens).

This species is recorded so far only from the western states of California, Idaho, and Washington, the midwestern state of Nebraska, and British Columbia in Canada. It was formerly confused with *Aradus kormilevi* HEISS, 1980, which is widely distributed in eastern USA and Canada.

***Aradus apicalis* VAN DUZEE, 1920** (Photo 3, Figs 6, 7)

Material examined: 2♂♂, 4♀, 25.IV.1992; 12♂♂, 7♀ 30.IV.2015; 1♂, 3♀♀ 28.V.2015; 28.VI.2015; 6♂♂, 5♀♀ 12.V.2016; 6♀♀ 27.V.2016 (48 specimens).

So far this species is only recorded from California. The structure of unicolored dark antennae with very robust antennal segments, the second segment longest, is similar to that of *A. pannosus* VAN DUZEE, 1920, and *A. behrensi* BERGROTH, 1886 (see Photo 4, Figs 12, 13; Photo 3, Figs 9, 10).

***Aradus behrensi* BERGROTH, 1886** (Photo 3, Figs 9, 10)

Material examined: 3♂♂ 25.IV.1992; 1♂ 12.V 2016 (4 specimens).

Aradus behrensi is reported from the western states of California, Oregon and Washington and also from British Columbia in Canada.

***Aradus compressus* HEIDEMANN, 1907** (Photo 4, Fig. 11)

Material examined: 1♀ 4.IV.1991 (1 specimen)

This species shows also a distribution in the western USA and Canada, where it is recorded from California, Oregon, Washington and British Columbia.

***Aradus debilis* UHLER, 1876** (teneral specimen, not figured)

Material examined: 1♀ 30.IV.2016 (1 specimen)

Aradus debilis is known from California, Idaho, Colorado, Montana, Oregon and Washington in the western USA, British Columbia in Canada, and from the eastern states of Massachusetts and New York.

***Aradus linsleyi* USINGER, 1936** (Photo 2, Figs 1, 3; Photo 5, Fig. 19; Table II, Figs 16-20)

Material examined: 1♀ 30.IV.2015; 2♀♀ 2.V.2016; 1♂, 3♀♀ 12.V.2016 (7 specimens).

Aradus linsleyi was described from a single female from Yosemite National Park in California, collected 6 VI 1931 by E.G. Linsley. Another female was reported later from Old Station, Shasta Co. (LINSLEY & USINGER 1942). This species is among the largest Nearctic Aradidae species measuring about 10 mm, and its habitus, antennal structure and coloration are very close to that of *Aradus crenatus* SAY, 1831, which occurs only in the eastern states. *Aradus crenatus* was described from Missouri, but because the types are lost (PARSHLEY 1921), its true identity cannot be verified. A male specimen from Cincinnati, Ohio, 13 VI 1902, which is cited by PARSHLEY 1921, supposedly represents the eastern taxon; the genitalic structures of this specimen are figured (Table II, Figs 11-15).

HEISS 1980, has shown that *A. crenatus*, reported to occur in Europe, is a distinct Nearctic species; the valid name of the European taxon is *A. conspicuus* HERRICH-SCHAEFFER, 1835.

In *A. linsleyi* the genitalic structures of the male, particularly segment IX of the pygophore, are very different from those of *A. crenatus* and resemble more those of *A. ampliatus* of similar habitus, but the latter has antennal segment III bicolored.

This is the second published record of this obviously rare species and the first male reported (Photo 5, Fig. 19).

***Aradus pannosus* VAN DUZEE, 1920** (Photo 4, Figs 12, 13)

Material examined: 3♂♂, 3♀♀ 25.IV.1992; 2♂♂, 1♀ 30.IV.2015; 1♂, 1♀ 28.V.2015; 1♀ 2.V.2016; 1♀ 12.V.2016 (13 specimens).

Specimens of the forma typica of *A. pannosus* show a yellowish apical ring on antennal segment II, but PARSHLEY 1921, described var. *incomtus* lacking this ring. The latter has been treated as a subspecies in the catalogs by KORMILEV & FROESCHNER 1987, and FROESCHNER 1988. However, as PARSHLEY loc.cit. stated, specimens from Marin Co. in California showed both antennal color variations, thus cannot be regarded as subspecies but are merely color variations of antennal segment II without taxonomic value. The specimens collected from El Dorado Canal debris have unicolored antennae. All literature records of this species are from California.

Additional material in CEHI: California: 1♂ Stanford University, 26 V 1957; 1♀ Marin Co., Mill Valley, 28 V 1964; 1♂ Marin Co., Inverness, 27 IV 1957; 1♂ Fort Seward, 20 V 1935; 1♂ Strawberry Cyn., 16 II 1963(all with dark antennal segment II); 1♂ Sta. Clara Co., Los Gatos, 6 V 1961 (with yellowish apical ring). Oregon: 1♀ Benton Co., Dawson, 6 X 19962; 1♀ McMinnville, 29 IV 1957 and 1♀ 19 V 1958; 1♀ Corvallis, 5 V 1953(all with dark antennal segment II) (**new state records for Oregon**).

***Aradus patibulus* VAN DUZEE, 1927** (Photo 2, Figs 2, 4; Photo 5, Fig. 17; Table I, Figs 6-10)

Material examined: 3♂♂, 1♀ 25.IV.1992; 2♂♂, 4♀♀ 30.IV.2015; 1♀ 8.VI.2015; 2♀♀ 2.V.2016; 1♂, 2♀♀ 12.V.2016; 2♂♂ 27.V.2016 (18 specimens).

This striking, large species was described from specimens from Lassen Co, Martin's Springs, and later reported from other localities in California (USINGER 1936, LINSLEY & USINGER 1942, 1944). In the latter paper a male "Neoallotypus" was designated from Miami Ranger Station, Mariposa County, which is deposited in EMEC, however, it has no name-bearing function (ICZN, Recommendation 72A).

The dark coloration, large size and yellowish antennal segment III resemble that of *A. ampliatus*, however the latter never shows a complete yellowish antennal segment III and differs also in the shape of male genitalic structures and female terminal segments (Table I, Figs 3, 8).

Additional material in CEHI: 1♀ California, Calaveras Co., NE Arnold, 1500m, 3 VIII 2013.

***Aradus persimilis* VAN DUZEE, 1916** (Photo 4, Fig. 14)

Material examined: 1♂ 28.V.2015 (1 specimen)

Recorded from the western United States: California, Colorado, Montana, Washington and the Canadian provinces of Alberta, British Columbia, and Newfoundland, – which seems a doubtful record not mentioned by PARSHLEY 1921 and USINGER 1936.

***Aradus proboscideus* WALKER, 1873** (Photo 4, Figs 15, 16)

Material examined: 1♀ 25.IV.1992; 1♂, 1♀ 28.V.2015; 2♀♀ 8.VI.2015; 2♀♀ 12.V.2016 (7 specimens).

This species shows a widespread distribution throughout the United States and is recorded from 23 states. It seems to be associated with coniferous trees.

Subfamily Mezirinae OSHANIN, 1908

***Mezira pacifica* USINGER, 1936** (Photo 5, Figs 20,21)

Material examined: 1♀ 25.IV.1992; 1♂ 12.VI.1994; 1♀ 30.IV.2015; 2♀♀ 28.V.2015; 3♂♂, 1♀ 8.VI.2015; 1♂, 1♀ 12.V.2016 (11 specimens).

Recorded from Arizona and the western United States: California, Idaho, Oregon, Washington, and Wyoming, and British Columbia in Canada.

Discussion

Aradidae are commonly associated with their preferred food source, fungi, which develop and grow on decaying wood of coniferous or deciduous trees. They are usually found under or on the bark sucking fungal hyphae. Only few species suck sap of living plants, such as *Aradus cinnamomeus* PANZER, 1806, on *Pinus* sp., and *Aradus pallescens frigidus* KIRITSHENKO, 1913, on roots of *Helianthemum* sp. (Cistaceae); both are Palaearctic taxa.

Therefore, the record of 12 flat bug species and large numbers of individuals, among debris collected from seines in a watercourse, was unexpected as this is a very unusual "habitat." Most Nearctic Aradidae are macropterous and good flyers, however, and are known to engage in spring dispersal and migration flights (USINGER 1936; LINSLEY & USINGER 1942, 1944). It can be assumed that they migrated in search of a new food source and were attracted by the water surface. In addition, Aradidae are also caught using pitfall- or other traps and the canal is, functionally, a giant pitfall trap. Insects that fall or fly into the steep-sided structure are stunned by the cold water and carried along by the swift current, making escape nearly impossible. Their natural habitat is certainly the mixed coniferous forest surrounding the El Dorado Canal.

Acknowledgments

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Zusammenfassung

Die bisher bekannte Aradidenfauna der kontinentalen USA und Canada umfasst 127 Arten. Davon sind 84 Arten der Gattung *Aradus* und 10 Arten der Gattung *Mezira* zugeordnet (MATSUDA 1977; KORMILEV & FROESCHNER 1987; VASARHELYI 1994 DAVIDOVÁ-VILIMOVÁ et al. 1996). Eine recht ungewöhnliche Sammelmethode der Zweitautorin und deren Ehegatten William Shepard, Debris aus Schleppnetzen in einem künstlichen Wasserlauf in Californien nach Insekten zu durchsuchen, brachte den überraschenden Nachweis von elf *Aradus*-Arten und einer Art der Gattung *Mezira*. Alle waren bereits von Californien gemeldet, jedoch zwei *Aradus*-Arten (*A. ampliatus*, *A. pannosus*) aus dem Vergleichsmaterial der Sammlung des Erstautors sind Erstnachweise für die Bundesstaaten Oregon bzw. Washington. Vom sehr seltenen und nur vom weiblichen Holotypus bekannten *Aradus linsleyi* USINGER, 1936 stellen die nun vorliegenden Belege den Drittfund dar und von *Aradus patibulus* VAN DUZEE sind seit 1936 nur zwei weitere Literaturangaben erfolgt. Fotos von zehn der festgestellten Arten, einschließlich der Holotypen von *A. linsleyi* und *A. patibulus*, als auch Abbildungen der Genitalstrukturen der Männchen von vier Arten, darunter jene des ersten Männchens von *Aradus linsleyi*, werden vorgelegt.

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Photo 1: (**1**) Seine equipment installed in the El Dorado Canal in California; (**2**) Retrieving a seine containing debris and insects by the co-author (left) and her husband William Shepard. Photos courtesy of Joyce Gross.

Photo 2: **Figs 1-4**. (**1**) Holotype female of *Aradus linsleyi* USINGER, 1936; (**2**) Holotype female of *Aradus patibulus* VAN DUZEE, 1927; (**3**, **4**) labels attached to holotypes, deposited in the CAS. Photos courtesy of the CAS.

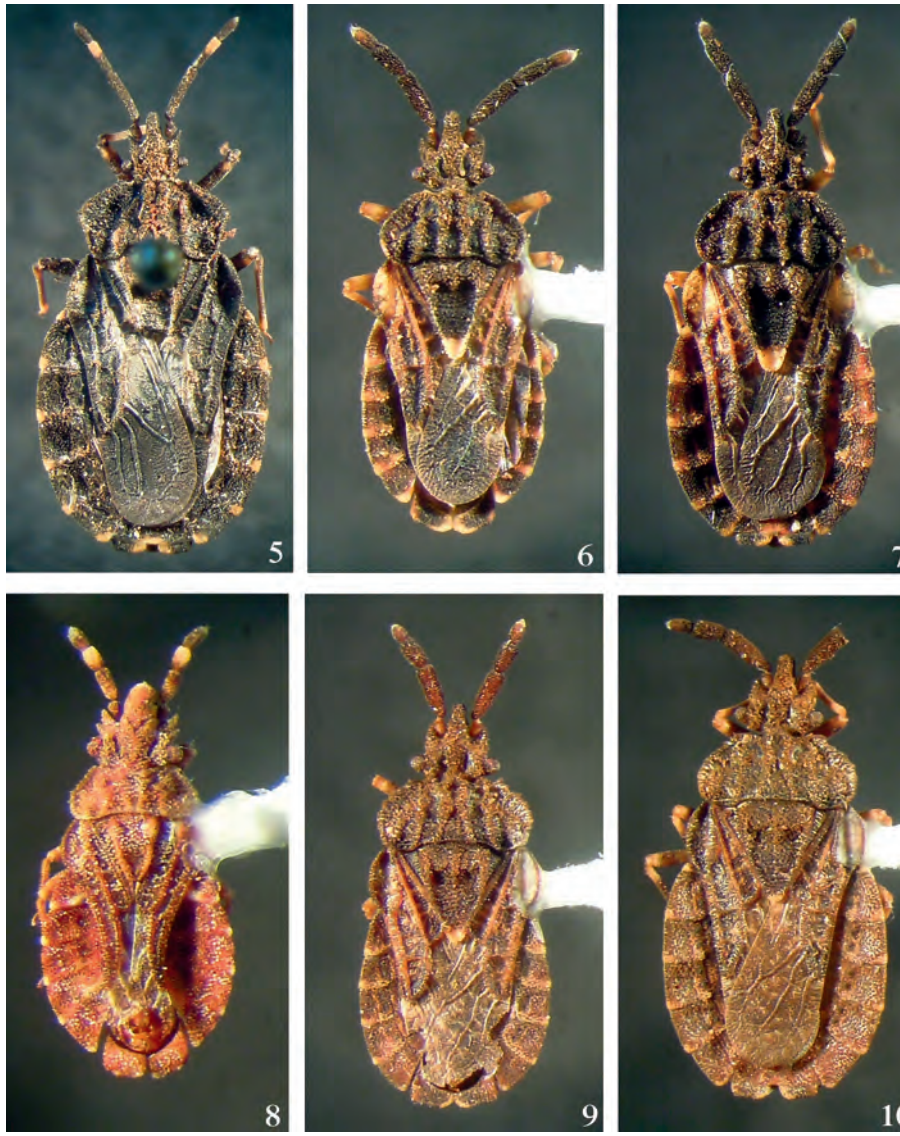

Photo 3: **Figs 5-10**. (**5**) *Aradus ampliatus*, female (10.9mm); (**6**) *Aradus apicalis*, male (5.4mm); (**7**) *Aradus apicalis*, female (6.6mm); (**8**) *Aradus antennalis*, male (3.5mm); (**9**) *Aradus behrensi*, male (5.4mm); (**10**) *Aradus behrensi*, female (6.1mm).

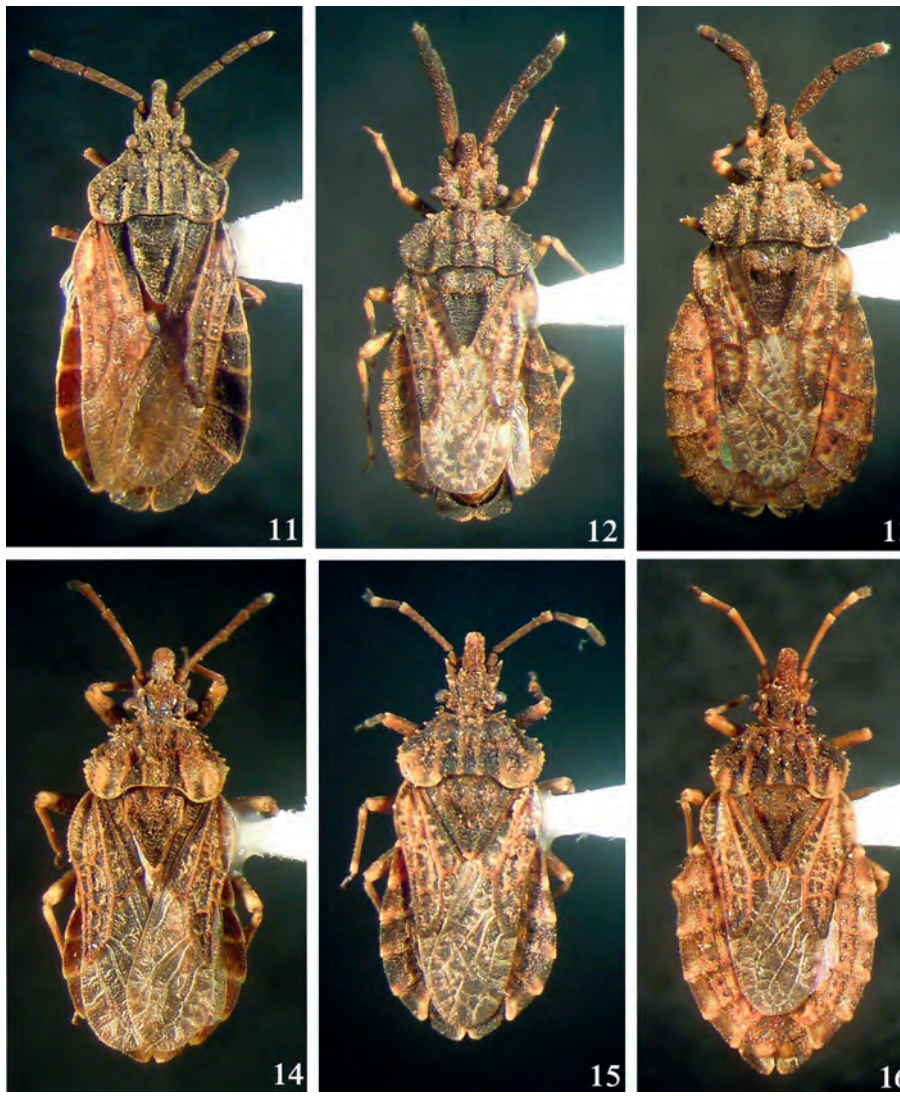

Photo 4: **Figs 11-16**. (**11**) *Aradus compressus*, female (7.7mm); (**12**) *Aradus pannosus*, male (5.8mm); (**13**) *Aradus pannosus*, female (6.6mm); (**14**) *Aradus persimilis*, male (6.2mm); (**15**) *Aradus proboscideus*, male (6.8mm); (16) *Aradus proboscideus*, female (8.3mm).

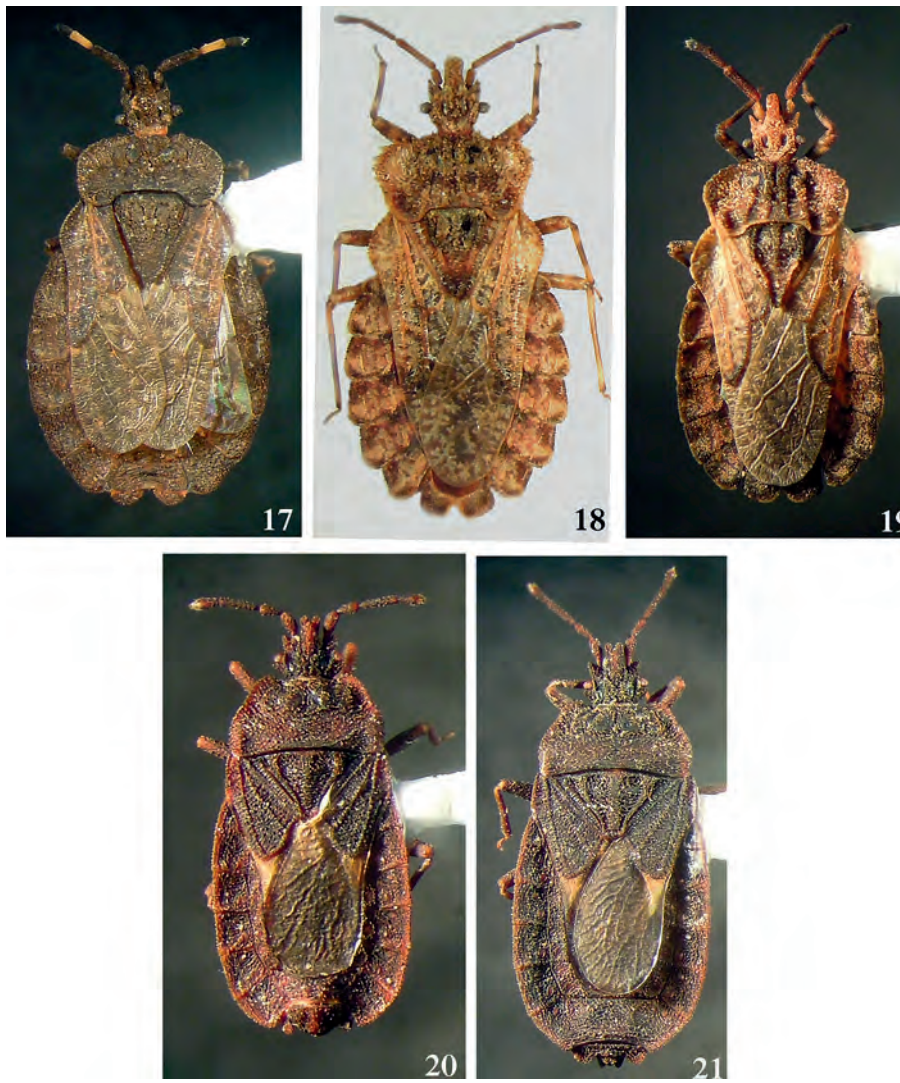

Photo 5: **Figs 17-21**. (**17**) *Aradus patibulus*, female (7.4mm); (**18**) *Aradus crenatus*, male (9.9mm) (Ontario, Prince Edward Co., CEHI); (**19**) *Aradus linsleyi*, male (8.6mm); (**20**) *Mezira pacifica*, male (6.1mm); (**21**) *Mezira pacifica*, female (7.6mm).

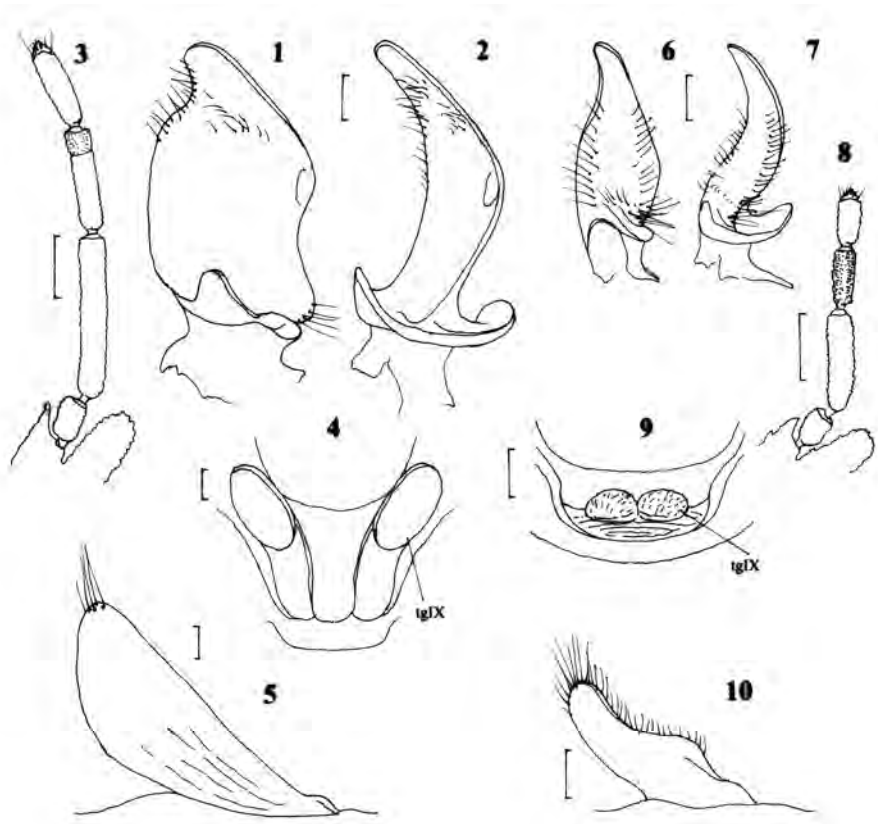

Table I: Male genitalic structures and antennae. **Figs 1-10**. (1-5) *Aradus ampliatus*; (6-10) *Aradus patibulus*; (1,2,6,7) left paramere; (4,9) tergite IX; (5,10) right parandrium; (3,8) left antenna. Dotted part of antennae is yellowish. Tg IX = tergite IX of the pygophore. Scale bar = 0.5mm for Figs 3, 8 and 0.1mm for all other figures.

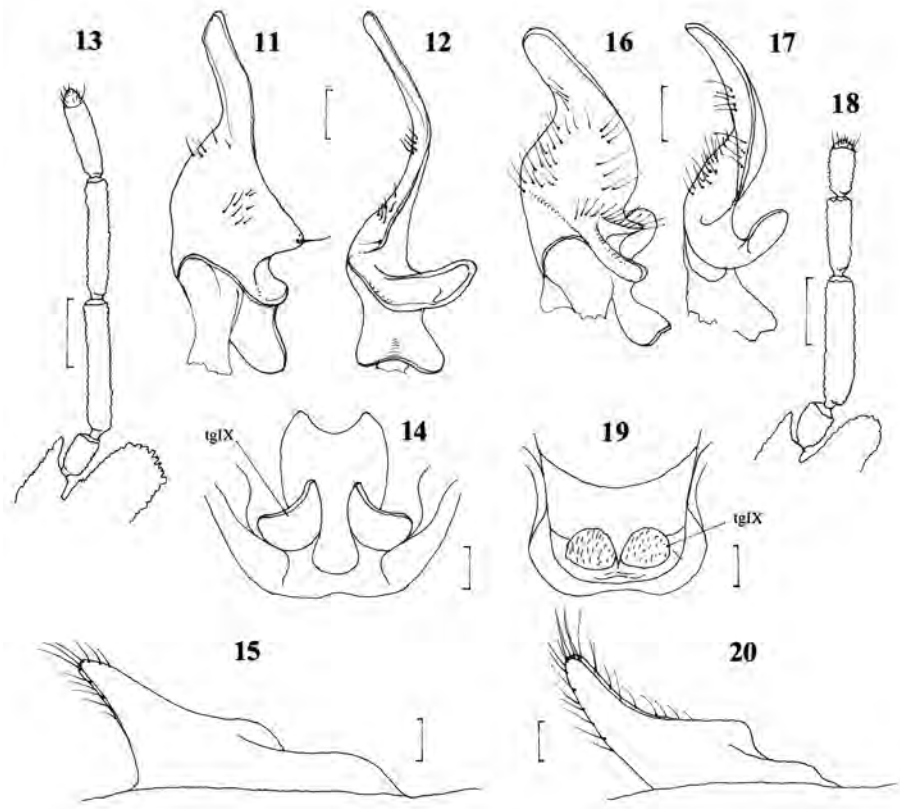

Table II: Male genitalic structures and antennae. **Figs 11-20**. (11-15) *Aradus crenatus*; (16-20) *Aradus linsleyi*; (11,12,16,17) left paramere; (14,19) tergite IX; (15,20) right parandrium; (13,18) left antenna. Tg IX = tergite IX of the pygophore. Scale bar = 0.5mm for Figs 13, 18 and 0.1mm for all other figures.