THE MICHIGAN ENTOMOLOGICAL SOCIETY

2011-2012 OFFICERS

President
President Elect
Immediate Past President
Treasurer
Secretary
Member-at-Large (2011-2014)
Member-at-Large (2010-2013)
Member-at-Large (2009-2012)
Journal Editor
Associate Journal Editor
Associate Journal Editor
Newsletter Editor
Webmaster

Toby Petrice
David Houghton
Ethan Bright
Tina Ciamatari
Adrienne O’Brien
Sarah Smith
Harry King
Ted Herig
Therese Poland
Ronald Priest
Anthony Cognato
Robert Haack
Mark O’Brien

The Michigan Entomological Society traces its origins to the old Detroit Entomological Society and was organized on 4 November 1954 to “...promote the science of entomology in all its branches and by all feasible means, and to advance cooperation and good fellowship among persons interested in entomology.” The Society attempts to facilitate the exchange of ideas and information in both amateur and professional circles, and encourages the study of insects by youth. Membership in the Society, which serves the North Central States and adjacent Canada, is open to all persons interested in entomology.

There are four paying classes of membership for 2009:

Active—annual dues $25.00
Student (to 12th grade)—annual dues $12.00
Institutional—annual dues $45.00
Sustaining—annual contribution $35.00 or more
Life—$500.00

Dues are paid on a calendar year basis (Jan. 1-Dec. 31).

Memberships accepted before July 1 shall begin on the preceding January 1; memberships accepted at a later date shall begin the following January 1 unless the earlier date is requested and the required dues are paid. All members in good standing receive the Newsletter of the Society and The Great Lakes Entomologist, a semi-annual journal. All active and sustaining members may vote in Society affairs.

All dues and contributions to the Society are deductible for Federal income tax purposes.

SUBSCRIPTION INFORMATION

The journal is published semi-annually as one volume (4 issues) per year. Subscriptions are accepted only on a volume basis. Institutions not desiring the full benefits of membership, may subscribe to the journal for $30.00 per volume. Single copies of The Great Lakes Entomologist are available at $6.00 each, with a 20 percent discount for 25 or more copies sent to a single address.

MICROFILM EDITION: Positive microfilm copies of the current volume of The Great Lakes Entomologist will be available at nominal cost, to members and bona fide subscribers of the paper edition only, at the end of each volume year. Please address all orders and inquiries to University Microfilms, Inc., 300 Zeeb Road, Ann Arbor, Michigan 48106, USA.

Inquiries about back numbers, subscriptions and Society business should be directed to the Secretary, Michigan Entomological Society, Department of Entomology, Michigan State University, East Lansing, Michigan 48824-1115, USA. Manuscripts and related correspondence should be directed to the Editor (see inside back cover).


INSTRUCTIONS FOR AUTHORS

SUBJECTS

Papers dealing with any aspect of entomology will be considered for publication in The Great Lakes Entomologist. Appropriate subjects are those of interest to professional and amateur entomologists in the North Central States and Canada, as well as general papers and revisions directed to a larger audience while retaining an interest to readers in our geographic area.

All manuscripts are refereed by at least two reviewers.

REQUIREMENTS

Manuscripts must be typed with line numbers, double-spaced, with 1” margins on 8 1/2 x 11” or equivalent size paper, and submitted in triplicate with an attached file. Please use italics rather than underline. Use subheadings sparingly and set them in paragraphs in boldface. Footnotes (except for authors’ addresses, which must be on the title page, and treated as a footnote), legends, and captions of illustrations should be on separate pages. Titles should be concise, identifying the order and family discussed. The author of insect species must be given fully at least once in the abstract and text, but not in the title. If a common name is used for a species or group, it should be in accordance with the common names published by the Entomological Society of America. The format for references must follow that described in the style guidelines used by the Entomological Society of America, except that journal titles are not abbreviated.

FIGURES & TABLES

Remember that the printed page area for The Great Lakes Entomologist is 4.5 x 7 inches. Scale your illustrations accordingly. Figures may be printed in black and white or color (see page charges below). Photographs should be high resolution digital files (300 dpi) or glossy finish prints (transparencies are not acceptable). Drawings, charts, graphs, and maps must be scaled to permit proper reduction without loss of detail. Figures should also be sent as electronic files and must meet the following criteria: (1) gray-scale images must be submitted as 300 dpi TIFF or EPS files only; (2) line art or graphs must be sent as 600 dpi TIFF or EPS files only. Scanned images should be saved in the native application. Never embed the images in a word-processing document. Captions for figures should be numbered consecutively and typed in order at the end of the manuscript. Captions should not be attached to illustrations or written on the back of images.

Tables should be kept as uncluttered as possible, and should fit normally across a page when typeset by the printers. Tables cannot be submitted as Excel files or graphics, but only as text.

Contributors should follow the Council of Biology Editors Style Manual, 5th ed., and examine recent issues of The Great Lakes Entomologist for proper format of manuscripts.

MANUSCRIPTS ON DISK

Manuscripts must be submitted as electronic files along with one printed copy, after they have been accepted for publication. The files may be formatted in any popularly used word-processing program. But must be submitted in Rich Text Format (RTF) or Microsoft Word (DOC) to avoid any translation problems. Special formatting notes for submitting manuscripts on disk: the organizational format for a manuscript is as seen in the recent issues of the journal: TITLE, Author(s), Abstract, Introduction, Methods & Materials, Results, Discussion, Acknowledgments, Literature Cited, Tables, and a List of Figures. Do not use extra spaces between paragraphs or references in the Lit. Cited. The columns of text in tables should be aligned with TABS, not spaces. Some symbols may not translate properly from one computer system to another. Do not use exebits. So long as these symbols are clearly seen in the manuscript, adjustments can be made in the copy sent to the printers.

PAGE CHARGES

Papers published in The Great Lakes Entomologist are subject to a page charge of $42.00 per published page. An extra charge will be assessed for pages printed in color; contact the Editor for pricing information. Members of the Society, who are authors without funds from grants, institutions, or industry, and are unable to pay costs from personal funds, may apply to the Society for financial assistance. Application for subsidy must be made at the time a manuscript is initially submitted for publication. Authors will receive a page proof, together with a page charge form. Reprints will be provided as PDF files. Extensive changes to the proof by the author will be billed at a rate of $1.00 per line.

COVER ARTWORK

Cover art or photographs are desired for upcoming issues. They are published free of charge. We only require that they be suitably prepared as described for images above, and that the subject be identified as accurately as possible.

EDITOR’S ADDRESS

All manuscripts for The Great Lakes Entomologist should be sent to the Editor, Therese Poland, USDA Forest Service, 1407 S. Harrison Rd., Rm. 220, E. Lansing, MI 48823. (email: tpoland@fs.fed.us).

OTHER BUSINESS

Other correspondence should be directed to the Secretary, Michigan Entomological Society, c/o Dept. of Entomology, Michigan State University, East Lansing, MI 48824-1115.
# Case-Building Behavior, Persistence, and Emergence Success of *Pycnopsyche guttifer* (Walker) (Trichoptera: Limnephilidae) in Laboratory and *in situ* Environments: Potential Trade-offs of Material Preference

David C. Houghton, Sarah E. Rogers, Kate Hocquard, and Charlotte I. Wolfe .......................................................... 103

# New State Records and Distributional Notes for Some Assassin Bugs of the Continental United States (Heteroptera: Reduviidae)

Daniel R. Swanson .................................................................................................................................................. 117

# A Synopsis of the Coreoidea (Heteroptera) of Michigan

Daniel R. Swanson ........................................................................................................................................... 139

# Bark Beetle (Coleoptera: Curculionidae: Scolytinae) Community Structure in Northeastern and Central Minnesota


# Notes on the Biology of *Saperda imitans* Infesting Wind-Damaged Black Cherry in Allegheny Hardwood Stands

Marc F. DiGirolomo, Douglas C. Allen, and Stephen V. Stehman ........................................................................... 177

# Distribution of *Strongylium crenatum* (Coleoptera: Tenebrionidae) in the United States and First Record from Iowa

Edwin L. Freese ...................................................................................................................................................... 190

# Recent Detections of a Rare Native Lady Beetle, *Coccinella novemnotata* (Coleoptera: Coccinellidae), in Minnesota

Robert L. Koch .................................................................................................................................................... NOTE 196

---

Cover photo

*Banksiola dossuaria*

Photo by David Houghton
Case-Building Behavior, Persistence, and Emergence Success of *Pycnopsyche guttifer* (Walker) (Trichoptera: Limnephilidae) in Laboratory and *in situ* Environments: Potential Trade-offs of Material Preference

David C. Houghton1, Sarah E. Rogers1, Kate Hocquard1, and Charlotte I. Wolfe1

Abstract

When removed from their cases in a non-flow laboratory environment, 5th instar *Pycnopsyche guttifer* (Walker) larvae were always successful in constructing a new case within 24 h when woody debris was present as a material choice. Most were successful within 1 h. Larvae were never successful at case building in the absence of wood in a non-flow environment. These laboratory-constructed ‘emergency cases’ were flimsy, lacking in shape, and larger than field cases. Laboratory case size, shape, and material preference remained constant after repeated daily evacuations over a series of 10 days. Larvae could be induced to construct a case composed of mineral particles only in the absence of wood and when placed in a laboratory stream with simulated flow conditions, or *in situ* in a natural stream. The emergence success of *P. guttifer* specimens induced to build these mineral cases, however, was significantly higher than that of larvae remaining in their field cases or of larvae that built wood cases. This result is likely due to a fungal infection that affected only larvae in wood cases. Our results demonstrate a scenario where a clearly non-preferred case construction material appears to increase survival.

Caddisflies constitute a taxonomically rich and ecologically diverse order of aquatic insects, abundant in nearly all types of freshwater ecosystems (e.g., Wiggins 1996). Caddisflies exhibit little morphological differentiation relative to their ecological diversity, however. Instead, the ability of the order to exploit different habitats and food resources is related to the production of silk from glands in their labium, with subsequent construction of portable cases and fixed retreats (Mackay and Wiggins 1979). Two monophyletic caddisfly lineages are currently recognized: the net spinning Annulipalpia and the tube-case making Integripalpia (Holzenthal et al. 2007a, b). The members of a third—questionably monophyletic—group, the Spicipalpia, construct a variety of case types; a few of these ‘spicipalpians’ do not construct cases until pupation. Our study focused on a species of tube-case maker. Tube cases have been variously proposed as respiratory devices, camouflage, and as physical protection against desiccation, predation, and cannibalism (Williams et al. 1987, Johansson 1991, Otto and Johansson 1995, Zamora-Muñoz and Svensson 1996, Wissinger et al. 2004, Boyero at al. 2006, Nislow and Molles 2006).

While cases are necessary for the survival of caddisfly larvae, they are also a liability. Silk production is energetically expensive, as is transportation of heavy cases (Stevens et al. 1999, Otto 2000). Case construction can lead to difficult trade-offs when larvae do not have easy access to preferred building material (Eggert and Wallace 2003, Statzner et al. 2005). In natural streams,
larvae will sometimes have to travel up to 4 m to find construction particles, even venturing into oxygen-poor habitats that contain the appropriate materials (Elliot 1971, Jackson et al. 1999, Statzner et al. 2005). In laboratory experiments, most larvae will use larger or smaller particles than usual if their preferred sizes are not available (Hanna 1961, Tolkamp 1980). Some can be forced to switch to a different type of mineral (Gaino et al. 2002), and a few will switch from minerals to pieces of vegetation (Hanna 1961, Tolkamp 1980). Some will even construct laboratory cases composed of gold or other precious metals in the absence of other materials (Duprat and Besson 1998). It is not clear how these changes in case particle composition might affect the survival of a larva in nature.

Despite the liabilities of repeated building, many caddisflies construct a new case at each instar. Many will also abandon their cases when stressed by low flow or high temperature, and will readily build another case (Waters 1962, Anderson and Bourne 1974). When forcibly evacuated from their cases in a laboratory environment, many species will immediately construct an ‘emergency case’ (Houghton and Stewart 1998), a structure that tends to be flimsy, lacking in interstitial silk, and giving a mosaic view of the larva. Emergency cases are temporary shelters, and are often improved upon in subsequent hours or days, or else abandoned entirely for a newly-constructed case. Emergency case-building has been documented in both the Spicipalpia and the Integripalpia, suggesting a widespread behavior within Trichoptera (Houghton and Stewart 1998, Gupta and Stewart 2000, Stuart and Currie 2001, Norwood and Stewart 2002).

Our study explored the liabilities of emergency case construction in *Pycnopsyche guttifer* (Walker), a tube-case making integripalpian widespread throughout Michigan and abundant in woodland streams (Houghton et al. 2011a). *Pycnopsyche* cases tend to be constructed of woody debris, although some species will occasionally utilize some small mineral fragments (Wiggins 1996). The specific objectives of our study were to: determine particle preference in *P. guttifer* emergency case construction; assess changes in the size and weight of these emergency cases over repeated forced evacuations; and test if forcible emergency case construction, materials provided for case reconstruction, or environment affected emergence success of adults.

**Materials and Methods**

**Collecting and laboratory design.** Several hundred fifth instar *P. guttifer* larvae were collected from the Saint Joseph (N 41.92º, W 84.82º) and the Little Manistee (N44.03°, W85.73°) Rivers in the lower peninsula of MI. The former population was tested in 2008 and the latter in 2010. The Saint Joseph River is surrounded by a primarily agricultural watershed, although the specific collection site was within the Lost Nations game preserve and had >75% intact riparian habitat (Houghton et al. 2011b). The Little Manistee River features naturally-reproducing populations of native brook trout, *Salvelinus fontinalis* (Mitchill); our specific collecting site was within the Manistee National Forest and, likewise, had intact riparian habitat. Thus, *P. guttifer* specimens were abundant at both sites. The populations were separated by nearly 300km and were assumed to be allopatric. In between experiments, larvae were housed in a Living Stream™ system (Frigid Units, Toledo, OH) with simulated river temperature, photoperiod, and flow regime. All larval field cases appeared to be composed predominately or exclusively of woody material (Fig. 1a).

Three different environments were used during case-building trials. 1) Non-flow: containers of 16×16×6 cm dimension kept at simulated river temperature and with continual water changes, without simulated flow regime. 2) Living Stream: flow-through containers of 32×10×16 cm dimension with simulated river temperature, photoperiod, and flow regime. 3) *In situ*: flow-through containers of the same size placed into a natural stream environment.
Figure 1. *Pycnopsyche guttifer* cases. A: typical field case. B: typical emergency case constructed within 1 h in the non-flow environment. C: typical case constructed over 24 h from woody debris *in situ*. D: typical case constructed over 24 h from mineral particles *in situ*. E: Close-up of *Mucor* (brown) and *Epicoccum* (white) infections on a woody case. Scale bars = 1 cm.
The bottoms of these environments were covered with three different types of case building materials depending on the treatment group. Some were covered with woody garden mulch broken into pieces approximating the size range (1–20 mm) of woody material found in *Pycnopsyche* field cases. Others were covered with non-colored aquarium gravel, likewise broken into a variety of particles sizes (0.5–5 mm). Other groups were given a mixture of both wood and mineral particles in approximately equal volumes and placed randomly within the environment so a larva would have the same access to either material type. The bottoms of all environments included large-diameter (5–10 mm) mineral particles to serve as a natural substrate. None of these larger particles were incorporated into constructed cases.

In all trials, larvae were gently prodded with soft touch forceps through the posterior opening of their case until they evacuated. All statistical tests were conducted using JMP for Windows™ software (JMP 2002). Voucher specimens and cases are deposited in the Hillsdale College insect collection.

**Emergency case-building behavior.** To test how the available case-building materials affected success at building emergency cases over a short period of time, larvae were given either mineral particles only, or a mixture of minerals and woody debris, and their behavior was closely observed for 1 h. Behaviors were placed in three categories: ‘wandering’ throughout the environment without any attempt to manipulate the materials, ‘hiding’ by burying into the substrate, and ‘building’ an emergency case. If a larva was successful in building a case, its behavioral sequence was noted. ‘Case-building success’ was defined as a larva using silk to attach enough particles together to cover itself, regardless of case integrity. While building was considered the most adaptive behavior, hiding was considered more adaptive than wandering since erratic wandering is one of the best predictors of predation risk in nature (Johansson 1991). Furthermore, a caseless larva buried in the substrate was engaging in a behavior in which it also engages with a case (e.g., Wiggins 1996). If a larva exhibited more than one behavior, the more adaptive behavior was recorded. The Saint Joseph River population was tested in the non-flow environment. The Little Manistee River population was tested in both the non-flow and the *in situ* stream environment.

**Particle preference.** To test how the available case-building materials affected case construction over a longer (24 h) period, larvae were given either mineral particles only, woody debris only, or equal volumes of both materials. After 24 h, larvae were removed from the environment and larval success in building an emergency case was noted. The Saint Joseph River population was tested in the non-flow environment. The Little Manistee River population was tested in both the non-flow and the *in situ* stream environment.

**Changes to subsequent emergency cases.** To determine changes in emergency case construction over time, larvae from the Saint Joseph River population were given both woody debris and mineral particles in the non-flow environment. After 24 h the larvae were re-evacuated from their cases and placed back into the non-flow environment. This process was repeated for a total of 10 days and the successive cases compared. Each successive emergency case was air-dried for 12 h, after which they were weighed, and their volumes measured by water displacement. A sample of cases was re-measured 2 months later to assess any changes over time that may have resulted from continued drying. No changes were found; thus, the 12 h drying period likely was sufficient.

**Emergence success.** To determine emergence success after emergency case construction, larvae were removed from their cases and given either mineral particles only, or else mineral particles and woody debris. Larvae from the Saint Joseph River population were tested in the Living Stream environment. A control group composed of individuals remaining in their original field cases was also placed in the Living Stream and given mineral particles to act as a
natural substrate. It was assumed that larvae of the control group would not construct new cases. Treatments were divided into 5 groups of 8 individuals within a flow-through container, for a total sample size of 40 for each treatment. Containers were randomly distributed throughout the Living Stream. Living Stream temperature and photoperiod were adjusted throughout the summer and fall to match the conditions of the Saint Joseph River. Larvae were checked after 3 d to confirm that they had constructed cases and then were not disturbed until adult emergence in September. After emergence, pupal cases were examined for any obvious abnormalities. Any fungi present were identified by preparing specimens with a lacto-fuchsine stain (Dhingra and Sinclair 1995) and mounting them on glass slides.

This experiment was repeated using the Little Manistee River population in 2010. The experimental design was the same as with the Saint Joseph population except that larvae were also tested in the in situ environment simultaneously with those in the Living Stream environment. Also, due to a limited number of larvae, and based on the results of the Saint Joseph experiment and of previous studies showing no difference in the emergence success of control groups (Houghton and Stewart 1998, Stuart and Currie 2001), no control group was used in the Little Manistee River experiment.

Results

Fifty percent of the larvae in the Saint Joseph population given woody debris in the non-flow environment built emergency cases within 1 h, a significantly higher number than those who engaged only in wandering or hiding behaviors (Fig. 2a). Larvae provided with only mineral particles wandered more than they hid and none built a case. For the Little Manistee population, there was no significant difference in the mean number of larvae that engaged in wandering, hiding, or case-building behaviors in the non-flow environment when provided with woody debris (Fig. 2b). Nearly all were able to construct cases within 1 h in the in situ environment using woody debris. As with the Saint Joseph population, all larvae provided mineral particles wandered more than they hid and none were able to construct a case in the non-flow environment. In the in situ environment, however, over 50% of larvae were successful at building mineral cases within 1 h, a significantly higher number than the number of larvae that engaged in wandering or hiding (Fig. 2c).

All larvae of both populations followed a similar emergency case-building sequence: collect pieces of debris, align them parallel to each other, attach them together to form a rudimentary shelter, and hide underneath the shelter with their dorsal side facing downward. Larval emergency cases bore little resemblance to field cases in this or other experiments. Instead they were loosely-constructed piles of debris (Fig. 1b). Larvae left in non-flow environments for several days after emergency case construction remained in these cases until they died without any noticeable changes to case composition.

When given minerals and woody debris, all larvae built emergency cases almost exclusively out of wood at least twice in succession within the 24 h periods; 85% rebuilt at least 5 times, and almost 60% built for all 10 days of the experiment (Fig. 3). Mean weights (0.30 g) and volumes (0.42 mL) of emergency cases were significantly larger than those of field cases (0.20 g and 0.28 mL) (Independent T-test, \( P < 0.02 \) for both). Subsequent emergency cases, however, did not change in either weight or volume over time (\( R^2 < 0.5, \ P > 0.05 \) for all 12 specimens).

In the Saint Joseph population, 100% of larvae were successful at case construction within 24 h when provided with woody debris in the non-flow environment and 0% successful when provided with only mineral particles in the same environment (Table 1). In the Little Manistee population, larvae
provided with woody debris in the non-flow environment were as successful as those provided exclusively with mineral particles in the in situ environment. Larvae provided with both woody debris and mineral particles were able to construct cases 100% of the time in the in situ environment. As with the Saint Joseph population, larvae provided exclusively with mineral particles in the non-flow environment were unable to construct a case within 24 h. All cases constructed during the 24-h periods were similar in appearance to field cases, and constructed more solidly than were emergency cases (Fig. 1c–d).

Nearly 100% of larvae constructed a case suitable for pupation within 3 d in both the Living Stream and in situ environments regardless of material provided. In the Saint Joseph population, emergence success in the Living Stream environment was highest in the mineral case treatment group and lowest in the control and woody debris treatment groups (Fig. 4a). There was no difference in the length of time spent in pupation between the three groups (1-way Analysis of Variance, \( P = 0.37 \)). In the Little Manistee population, larvae in the Living Stream environment given access exclusively to minerals, as well as larvae given access to both minerals and woody debris, had higher adult emergence success than those given access exclusively to woody debris; the woody debris treatment group had 0% emergence (Fig. 4b). In the in situ environment, however, there was no significant difference in emergence success between the treatment groups (Fig. 4c).

**Figure 2.** Mean (+1 SE) percentage of *Pycnopsyche guttifer* larvae (\( n = 20 \) for all treatments) that engaged in each of three types of behaviors during 1 h emergency case construction experiments, based on case material provided within different years and habitats. A: Saint Joseph non-flow laboratory environment. B: Little Manistee non-flow environment. C: Little Manistee in situ environment. Letters denote statistically distinct groups (1-way Analysis of Variance with post-hoc Tukey test). n.s. = not significant.
Figure 3. The percentage of *Pycnopsyche guttifer* larvae (*n* = 12) from the Saint Joseph population in a non-flow environment that constructed a succession of emergency cases throughout the 10 days of our experiment.

Table 1. Results of 24 h case construction experiments from the Saint Joseph and Little Manistee River populations. Each population constituted a distinct experiment. Groups determined by a Chi-square Goodness of Fit test (*P* < 0.001 for both) followed by Pairwise Chi-square Goodness of Fit tests (with Yates Correction if df < 2), *P* < 0.01 for all significant pairwise comparisons.

<table>
<thead>
<tr>
<th>Population</th>
<th>Material</th>
<th>Environment</th>
<th>n</th>
<th>% successful</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saint Joseph</td>
<td>Wood</td>
<td>Non-flow</td>
<td>6</td>
<td>100%</td>
<td>a</td>
</tr>
<tr>
<td>Saint Joseph</td>
<td>Mixed</td>
<td>Non-flow</td>
<td>5</td>
<td>100%</td>
<td>a</td>
</tr>
<tr>
<td>Saint Joseph</td>
<td>Mineral</td>
<td>Non-flow</td>
<td>8</td>
<td>0%</td>
<td>b</td>
</tr>
<tr>
<td>Little Manistee</td>
<td>Mixed</td>
<td><em>In situ</em></td>
<td>15</td>
<td>100%</td>
<td>a</td>
</tr>
<tr>
<td>Little Manistee</td>
<td>Mixed</td>
<td>Non-flow</td>
<td>15</td>
<td>60%</td>
<td>b</td>
</tr>
<tr>
<td>Little Manistee</td>
<td>Mineral</td>
<td><em>In situ</em></td>
<td>15</td>
<td>53%</td>
<td>b</td>
</tr>
<tr>
<td>Little Manistee</td>
<td>Mineral</td>
<td>Non-flow</td>
<td>15</td>
<td>0%</td>
<td>c</td>
</tr>
</tbody>
</table>
In both populations, both the control cases and those constructed from woody debris became infected while in the Living Stream environment during the summer by two fungal species: the dematiaceous mold *Epicoccum purpascens* (Ehrenb.) (Ascomycota: Dothideomycetes), and the zygomycete *Mucor* sp. (*incertae sedis* in the Zygomycota) (Fig. 1e). No individuals or cases within mineral case treatment groups appeared to be infected despite the random arrangement. Based on subjective observation, cases constructed from a mixture of woody debris and mineral particles appeared to have an intermediate level of fungal infection. No cases in the *in situ* environment appeared to be infected, regardless of case construction material.

**Discussion**

**Emergency case construction within the Trichoptera.** Emergency case construction appears to be a common and possibly homoplastic behavior in the Trichoptera. Within the Integripalpia, for example, Stuart and Currie (2001) found only three families: Brachycentridae, Helicopsychidae, and Odontoceridae, as well as the genus *Ceraclea* (Leptoceridae), that did not construct emergency cases. Taxa that build emergency cases represent both of the major monophyletic divisions of the Integripalpia: Brenventoria and Plenitentoria (Holzenthal et al. 2007a, b). Furthermore, the behavior has been found in the ‘Spicipalpia’ (Houghton and Stewart 1998), which is considered sister to the Integripalpia.

*Figure 4.* Mean (+1 SE) emergence success of *Pycnopsyche guttifer* adults based on the material of their emergency cases (*n* = 40 for all treatments) constructed by each population and under various conditions. A: Saint Joseph Living Stream environment. B: Little Manistee Living Stream environment. C: Little Manistee *in situ* environment. The control group was not forced to construct a laboratory case. Letters denote statistically distinct groups (1-way Analysis of Variance with post-hoc Tukey test). n.s. = not significant.
The purpose of emergency cases appears to be immediate coverage of the larva while it is building its permanent case. Under the highly unnatural conditions of non-flow plastic containers with shallow water, *P. guttifer* larvae constructed such cases rapidly, often within 1 h. Likewise, most larvae were able to construct new emergency cases over consecutive days under these conditions, without notable changes in case size or material composition. Within the Trichoptera, emergency cases sometimes exhibit some superficial resemblance to permanent cases (Houghton and Stewart 1998) or may be barely recognizable as a caddisfly case. The latter was the situation with *P. guttifer*. Indeed, emergency cases were significantly larger than field cases, and were essentially piles of woody debris loosely attached with silk and covering the larva like a blanket.

**Material preference and plasticity.** It appears from our experiments that *P. guttifer* clearly prefers woody debris over mineral material to construct its cases. The presence of wood repeatedly induced the more adaptive behaviors. Larvae denied wood were unsuccessful in building any type of case in the non-flow environment. This preference for building with woody debris was seen over successive evacuations.

The preference of *P. guttifer* for woody debris in case construction is not surprising given that all field cases were also composed almost exclusively of wood. Other observations, however, raise some questions about this preference and its interaction with the case-building environment and length of time given for case building. For example, > 50% of larvae were able to construct cases exclusively out of minerals when placed *in situ* in a natural stream environment for 1 h. Within 24 h, larvae were as successful at constructing mineral cases *in situ* as were larvae in the non-flow containers using the preferred woody debris. Nearly 100% of larvae were able to construct a mineral case for pupation within 3 d in the Living Stream and *in situ* environments.

Perhaps the more natural flow, temperature, and photoperiod of the natural stream and the Living Stream were more conducive to larval adaptation to a non-preferred case-building material than was the non-flow environment. Stuart and Currie (2001) found that “certain species” (unspecified) would not construct cases of any type unless exposed to current flow, suggesting the importance of a more natural environment for adapting to non-programmed case-building activities. The length of time given to a larva for case reconstruction may have also been an important factor in adapting to non-preferred building materials. Stuart and Currie (2001) found that some species took up to 4 days to build a case. Thus, the 24 h that *P. guttifer* larvae were in the non-flow containers in our experiment may not have been sufficient to induce construction of a case with non-preferred materials, whereas 3 days in the Living Stream was sufficient. In the most natural environment of the *in situ* stream, however, 1 h was sufficient time for more than half of the larvae to build a case from non-preferred materials.

Likewise, the more natural conditions of the Living Stream may have been conducive to constructing cases similar to those found in the field instead of the loosely-constructed emergency cases produced in the non-flow environment. Houghton and Stewart (1998) found that *Culoptila cantha* (Ross) (Glossosomatidae) built exclusively emergency cases when placed in a non-flow environment, but built typical cases when placed in a Living Stream environment overnight. The length of time given to larvae may have also been an important factor in determining the type of case that it built. Larvae in our experiment built emergency cases within 1 h in the Living Stream and *in situ* environments, and built typical cases in these environments within 24 h. Time alone cannot explain this difference, however, since larvae in non-flow environments always built emergency cases regardless of the amount of time available. A larva in the unnatural environment of a non-flow container may simply respond by only building an emergency case.
Emergence success. It appears that forcing *P. guttifer* to build emergency cases does not lower its emergence success. In the Saint Joseph population, there was no significant difference between the mean emergence of the control and wood case treatment groups, and the mean of the mineral case treatment group was actually higher than that of the control. Houghton and Stewart (1998) found similar results for *C. cantha*: larvae forced to rebuild their cases in the Living Stream from preferred materials had the same emergence success as those not forced to rebuild. Although forced rebuilding in nature may lead to greater mortality due to predation or other factors, it appears that this activity is not inherently harmful to the larva. Our results corroborate many observations in the field of caddisflies abandoning their cases to drift, or when stressed by adverse environmental conditions.

We found, rather surprisingly, that *P. guttifer* larvae forced to build a case from minerals—a clearly non-preferred material—actually had higher emergence success than those not forced to rebuild their case. These confounding results were likely caused by the infection of the two fungal species, *Mucor* sp. and *E. purpascens*, on the control and wood case treatments groups during both years of the experiment. *Epicoccum* species are not documented as pathogenic on animals, although they have been occasionally isolated from clinical samples, and may be opportunistic (Pritchard and Muir 1987). At the very least, the decomposition of the wood cases likely compromised their integrity and may have caused indirect harm to the *Pycnopsyche* larvae. Species of *Mucor* are known opportunistic pathogens in insects, frequently moving from organic matter to living tissue (Ferron 1978, Milner 1997). Other zygomycete fungi, such as those in the order Entomophthorales, are well known for their harmful effects on insects (Chamilos et al. 2008). Specifically, they are able to metabolize insect cuticles from the outside, making them ideal pathogens to spread from case to larva (Freimoser et al. 2003).

Neither of the fungal taxa isolated from our *Pycnopsyche* cases and larvae have been studied for their specific effects on caddisflies and cases. In light of studies of similar taxa, however, it seems plausible that the organic cases of the control and wood case treatment groups constituted more appropriate substrate for the fungus to colonize and then attack the larva (Rayner and Boddy 1988). Both species likely entered the Living Stream environment on the cases of the control treatment and subsequently spread to larvae of the wood case treatment group. Despite the random arrangement of larvae no mineral case was affected, strongly suggesting that such mineral cases provided protection from the opportunistic fungi.

The *in situ* environment did not have any observed fungal infection, nor were there significant differences in emergence success between treatments. Thus, it is likely that the more natural environment was less conducive to fungal infection and that the mineral cases were not advantageous to the larvae. Constructing a non-preferred mineral case, however, did not confer an obvious disadvantage upon the larvae either.

Implications. The ability to change behavior and morphology relative to different environmental stresses is central to natural selection. Strictly behavioral traits, such as drifting to avoid predators, are considered more plastic than morphological traits (West-Eberhard 1989, Relyea 2001, McIntosh et al. 2002). Caddisfly case construction, however, is a behavioral trait that results in morphological change. Thus, it is considered intermediate in plasticity (Boyero et al. 2006). Case material choice has inherent trade-offs for a larva. For example, mineral cases are heavy, composed of more pieces, require more energy to construct, and are difficult to carry through sediment (Stevens et al. 1999, Otto 2000, Dodson et al. 2000). Conversely, they offer greater resistance to predators (Johannsson 1991, Nislow and Molles 2006, Otto and Johannsson 1995, Boyero et al. 2006) and perhaps also to fungal infection.
Adapting to these trade-offs is crucially important to caddisfly larvae in nature since preferred particles may not always be available and circumstances (e.g., presence of predators or parasites) may differ in different environments. For example, Boyero et al (2006) found that individuals of *Potamophylax latipennis* (Curtis) (Limnephilidae)—a species that constructs both mineral and wood cases in nature—preferred their original wood field case material in laboratory trials, but could be readily induced to switch to minerals in the presence of certain predators. No direct measurement of fitness was made in this experiment, but the authors assumed an increase. They further hypothesized that the mineral case made up for its heavier weight with increased predator protection and that larvae instinctively constructed mineral cases when they could sense such predators.

Conversely, Eggert and Wallace (2003) found that inducing 1st–3rd instar *Pycnopsyche gentilis* (McLachlan) (Limnephilidae) larvae to switch from leaf cases—their preferred material in nature—to mineral cases in the laboratory required total elimination of leaves. The authors also found that *P. gentilis* larvae that did build their cases out of the available minerals had substantially higher mortality due to starvation over a 4-week period. Thus, an induced change in case construction behavior clearly decreased the fitness of the larvae.

Our results suggest a third scenario: an induced change to an obviously non-preferred case construction material actually increased the survival of *P. guttifer*. This increase in emergence success was almost certainly brought about by the protection the mineral cases afforded against fungal infection. Both of the fungi found in our experiment are common in nature. Thus, mineral cases might increase fitness of *P. guttifer* under certain field conditions, such as especially low current flow or high density of the normally gregarious pupae. Our *in situ* experiments, which did not demonstrate such an advantage to mineral cases, were conducted at lower pupal densities than we have observed in the field. Thus, conditions conducive to an increased fitness of larvae with mineral cases may exist in nature.

Further research is needed to investigate these observations. Specifically, treating the Living Stream with a fungicide that does not harm the *Pycnopsyche* larvae would allow for more direct exploration of fungal effects on emergence. Unfortunately, treatment with 10% Tegosept™, an anti-fungal agent commonly used in *Drosophila* cultures (Bahadorani et al. 2008), has thus far led to 100% larval mortality. Conducting case-building experiments in the Living Stream environment in addition to the non-flow and *in situ* environments might help isolate the specific variables (e.g., dissolved oxygen levels, temperature, flow regime) responsible for the increased adaptability in flowing water. Lastly, examining the changes in the survival of larvae with different case types in the presence of various predators or other selection pressures would help to evaluate the relative advantages of the different case types under more real-world conditions.

**Acknowledgments**

We thank R. L. Cooper and, especially, M. N. Thormann for assistance with fungal identification. We thank K. A. Brakel, C. M. Brandin, E. A. Klimas, K. Michels, S. A. Nutile, A. J. Pytel, L. M. Rogers, and M. J. Snider for laboratory and field assistance. Research costs were paid by the Mossberg Conservation Fund and by Hillsdale College biology department funds. The valuable comments of A. J. Pytel, R. J. Shealy, and one anonymous reviewer improved earlier versions of the manuscript. This is paper #3 of the G. H. Gordon BioStation Research Series.
Literature Cited


New State Records and Distributional Notes for Some Assassin Bugs of the Continental United States (Heteroptera: Reduviidae)

D. R. Swanson

Abstract

One hundred sixty-eight new state records are presented for 51 species of assassin bugs found in the United States; distributional and taxonomic notes supplement the records. The current known distribution north of Mexico is provided for each species.

The Reduviidae is a large cosmopolitan group of predatory insects with the greatest diversity found in the tropics. Although the reduviids are not especially speciose in the Nearctic region, 11 subfamilies represented by approximately 150 species in 49 genera occur north of Mexico. Their predatory nature, as a general rule, makes them less common than other herbivorous insects. However, the propensity of many species for positive nocturnal phototaxis means they may be commonly encountered by humans. As it stands, the ranges of many are poorly known.

The author’s preliminary work in the family has uncovered a large number of records unreported in the literature. In an effort to augment the distributional knowledge for the group, 168 new state records for the assassin bugs of the United States are presented herein.

Materials and Methods

The author studied the reduviid holdings of five entomological collections, four in the Midwest and one in the Southeast. Unless otherwise noted, all specimens cited have been at least examined, if not determined, by the author. Also included are several records obtained via personal communication with Dr. Donald Chandler, University of New Hampshire Insect Collection, Durham, New Hampshire, and several records of specimens residing in the author’s personal collection.

The authority on which a state having a published record is based belongs to Froeschner (1988), and, in most cases, the record was affirmed with additional material or the original basis for Froeschner’s record was located. Froeschner’s accounts also are supplemented with references for those state records published after 1988, which includes several recent state surveys (McPherson 1992, Hagerty and McPherson 1999, Chordas III et al. 2005, Hoffman 2006, Chordas III et al. 2008).

All records pertain to specimens vouched in one of the collections listed below. Label data were not copied verbatim although all locality information provided was included. Any additions, changes, or interpretive elements provided by the author are shown in brackets. In most cases, specimen counts are not included as the majority of localities are represented by a single specimen.

13111 Scenic Lake Dr. Apt. 34, Ann Arbor, MI 48108. (email: drswanny@gmail.com).
However, in many cases, multiple localities are included to fortify new records. Distributional or taxonomic notes are offered where deemed necessary. Following each species entry, the current distribution north of Mexico is listed with new state records shown in boldfaced type; abbreviations used for each U.S. state and Canadian province or territory follow the United States Postal Service and the Canadian Post Corporation, respectively.

Collections are designated as follows: Canadian National Collection of Insects, Ottawa, Canada (CNC); Daniel R. Swanson, personal collection (DRS); Florida State Collection of Arthropods, Gainesville, Florida (FSCA); Illinois Natural History Survey Insect Collection, University of Illinois, Champaign, Illinois (INHS); Albert J. Cook Arthropod Research Collection, Michigan State University, East Lansing, Michigan (MSU); North Carolina State University Insect Museum, Raleigh, North Carolina (NCSU); C. A. Triplehorn Insect Collection, Ohio State University, Columbus, Ohio (OSUC); University of Michigan Museum of Zoology Insect Collection, Ann Arbor, Michigan (UMMZ); and University of New Hampshire Insect Collection, Durham, New Hampshire (UNH).

Results

As a result of this investigation, 168 new state records for 51 species in 31 genera have been compiled. Many of these records merely fill in distributional gaps, whereas others offer significant range extensions. The following 35 states (plus District of Columbia) have new records: AL, AR, AZ, CA, CO, DE, FL, GA, IA, ID, IN, KS, KY, LA, MD, MN, MS, MT, NC, NE, NH, NM, NV, OH, OK, OR, PA, SC, TN, TX, UT, WA, WI, WV, WY.

New records are given for nine of the eleven subfamilies (excepting the Bactrodinae and Phymatinae) found within the United States. A brief note is provided for the Bactrodinae. The Phymatinae have been neglected due to the difficulty of identification and the uncertain identity of past records.

Bactrodinae

*Bactrodes spinulosus* Stål, 1862 – Originally described from Mexico, *B. spinulosus* has since been recorded from Puerto Rico, Guatemala, Panama, Colombia, and Venezuela (Stål 1862, Coscarón and Melo 2003). Only recently, Forero (2006) authored the first record of this species from the United States and in doing so, also reported the first U.S. record of the subfamily. Because the record is buried within a publication focused on the Neotropics, it is mentioned here. The specimen bears the following locality information: TEXAS: Big Bend N. P., Pulliam Canyon, 45–6500’, V–12–1959, W. P. M. Manson, 1 male (CNC). The author has not examined this specimen. Forero also cited additional specimens housed in the same institution from the states of Durango and Nuevo León in northern Mexico. It is reasonable to suppose that a population of *B. spinulosus* actually might occur in the southwestern United States, and so the species is included here as part of the U.S. fauna.

Distribution: TX

Ectrichodiinae

*Rhiginia cinctiventris* (Stål), 1872 – Elliott (1938) reported *R. cinctiventris* from Louisiana, and Hussey (1954) reported it from Alabama; these records apparently were overlooked by Froeschner (1988). The specimen on which the latter record is based bears the following locality information: ALABAMA: Clarke Co., Salt Mountain, 6 mi. S. Jackson, May 1935, A. F. Archer, det. R. F. Hussey 1952 [1 male] (UMMZ).

Distribution: AL, LA, NM, TX.

Notes: Leonard (1928) reported R. cruciata from New York, a record apparently overlooked by Froeschner (1988). The above Kansas record represents the current northwestern extent of the range. In reference to the species’ occurrence in Oklahoma, Drew and Schaefer (1963) stated “We have one specimen in our collection; it has no label, but the distribution is such that the species probably occurs in Oklahoma.” Froeschner (1988) included Oklahoma in the distribution of R. cruciata. The author has examined the following specimen, thus confirming the species’ presence in that state: OKLAHOMA: Cleveland Co., 4 October 1947, S. Coppock (FSCA); the date is written illegibly and may represent an April collection, alternatively. This is also the westernmost record in the literature. The species likely will be collected in Arkansas, Delaware, Mississippi and West Virginia as it is known from the surrounding states.

Distribution: AL, FL, GA, IL, IN, KS, KY, LA, MD, MO, NC, NJ, NY, OK, PA, SC, TN, TX, VA.

Emesinae

Barce fraterna (Say), 1832 – ALABAMA: [Jefferson Co.], Birmingham, 14 June 1952, C. A. Triplehorn (FSCA).

Notes: McAtee and Malloch (1925) reported B. fraterna from District of Columbia and Iowa, and Harris and Shull (1944) reported it from Idaho; these records apparently were overlooked by Froeschner (1988). More recently, McPherson (1992) reported it from Michigan, Chordas III et al. (2005) reported it from Arkansas, and Maw et al. (2000) reported it from Alberta, British Columbia, New Brunswick, Nova Scotia, and Saskatchewan. Wygodzinsky (1966) gave characters for differentiating each of the subspecies of B. fraterna although he admitted the characters vary in each instance. He also pointed out that the genitalia remain essentially indistinguishable and concluded these taxa are no more than geographic races. The author has found it impractical to distinguish beyond the species level at this time and includes collectively the range of the three subspecies.

Distribution: USA: AL, AR, CA, CT, DC, FL, IA, ID, IL, IN, KS, LA, MA, MD, ME, MI, MO, NC, NH, NJ, NY, OH, OK, PA, TX, VA, WI; Canada: AB, BC, MB, NB, NS, ON, QC, SK.


Notes: The author has not examined the above specimens. McPherson (1992) reported B. uhleri from Michigan, and Maw et al. (2000) reported it from Ontario.

Distribution: USA: IA, IN, KS, MA, MI, MO, NC, NH, NJ, NY, OK, SD, VA; Canada: AB, ON, SK.

Empicoris culiciformis (DeGeer), 1773 – OHIO: [Franklin Co.], Columbus, 15 October 1951, H. V. Weems, Jr. (FSCA); TEXAS: [Kerr Co.], Kerrville, 25[?] June 1953, J. L. Bottimer (FSCA).
Notes: Smith (1910) reported *E. culiciformis* from New Jersey, McAtee and Malloch (1925) reported it from District of Columbia and Massachusetts, Harris and Shull (1944) reported it from Idaho, Sibley (1951) reported it from Louisiana, and Wygodzinsky (1953) reported it from North Carolina; these records apparently were overlooked by Froeschner (1988). More recently, McPherson (1991a, 1992) reported it from Michigan, and Maw et al. (2000) reported it from British Columbia and Ontario.

**Empicoris errabundus** (Say), 1832 – **OHIO**: Delaware Co., 21 June 1943 [add. dates: 30 May, 5 July, 29 August], D. J. & J. N. Knoll Collrs. (OSUC).

Notes: Torre-Bueno (1923) reported *E. errabundus* from Connecticut, and McAtee and Malloch (1925) reported it from Georgia; these records apparently were overlooked by Froeschner (1988). Maw et al. (2000) reported it from British Columbia, Manitoba, and Nova Scotia. This taxon is treated *sensu* McAtee and Malloch (1925) rather than *sensu* Blatchley (1926); thus, the distribution encompasses those records of *Ploiariodes tuberculata* Banks, 1909.


**Empicoris rubromaculatus** (Blackburn), 1889 – **GEORGIA**: Thomas Co., Thomasville, at light, 23 April 1949, R. F. Hussey (UMMZ; FSCA).

Notes: Wygodzinsky (1953) reported *E. rubromaculatus* from Missouri, and Lattin and Wetherill (2001) reported it from Oregon.


Notes: Snoddy et al. (1976) reported *S. lanipes* from Georgia without providing specific locality information; a specimen examined by the author is provided here: **GEORGIA**: [Gordon Co.], Calhous [sic], 16 August 1949 (MSU). Hoffman (2006) reported this species from Virginia.


Distribution: USA: CT, FL, GA, IN, MS, MO, NC, OR, TX, VA; Canada: BC, CO, NM, UT.

**Acholla multispinosa** (DeGeer), 1773 – **KENTUCKY**: Jackson Co., 0.2 mi. NE Hwy. 421 on Elisha Branch Road, 28 July 2010, 37.4473°N 83.0132°W, 1020 ft., D. R. Swanson #30 [1 female] (DRS).

Notes: Parshley (1917) reported *A. multispinosa* from Connecticut and New Hampshire. The records from Arizona (Blatchley 1926) and Colorado
(Gillette and Baker 1895, Blatchley 1926) are omitted as no specimens have been examined from these states; the records may represent misidentifications of other congeners.

Distribution: USA: CT, IA, IL, IN, KS, KY, MA, ME, MI, MO, NC, NE, NH, NJ, NY, OH, PA, SD, TX, VA, WI, WV; Canada: ON.

_Apiomerus crassipes_ (Fabricius), 1803 – WEST VIRGINIA: Greenbrier Co., Alvon, 18 June 1957, R. A. Scheibner (MSU); Webster Co., Cowen, July 1934 (MSU); Wetzel Co., Rockport, 11 June 1954, D. L. Haynes (MSU).

Notes: Smith (1910) reported _A. crassipes_ from Pennsylvania, Elliott (1938) reported it from Louisiana, and McPherson (1992) reported it from Michigan. Berniker et al. (2011) revised the _crassipes_ group of this large New World genus, and, in doing so, erected six new species. Four of the six new species are found in the United States, and western records formerly attributed to _A. crassipes_ actually refer to _A. californicus_ Berniker and Szerlip, 2011 or _A. montanus_ Berniker and Szerlip, 2011. Thus, records listed by Froeschner (1988) for _A. crassipes_ from Arizona, California, Colorado, New Mexico, Utah, and British Columbia are excluded. Berniker et al. (2011) added Alabama, Arkansas, District of Columbia, Delaware, Georgia, Iowa, Kentucky, Maryland, Mississippi, and Tennessee to the range.

Distribution: AL, AR, CT, DC, DE, FL, GA, IA, IL, IN, KS, KY, LA, MD, MI, MN, MO, MS, NC, NE, NJ, NY, OH, OK, PA, TN, TX, VA, WV.


Notes: Osborn and Drake (1915) reported _A. cristatus_ from Ohio, and Elliott (1938) reported it from Louisiana; these records apparently were overlooked by Froeschner (1988). More recently, Chordas III et al. (2005) reported it from Arkansas, and Hoffman (2006) reported it from Virginia. Maw et al. (2000) reported it from Ontario. Being a well-documented species in the eastern states, it is worthwhile to consider how far west the range extends. As a new western limit is established here, the author thought it useful to include supplementary localities: NEW MEXICO: Grant Co., nr. cliff on Gila Riv., 28 May 1976, B. A. Triplehorn Collector (OSUC); Union Co., Capulin Mtn. Natl. Mon., 20 August 1972, alt. [illegible] met. (INHS).

Distribution: USA: AR, AZ, DC, DE, FL, GA, IA, IL, IN, KS, KY, LA, MD, MS, MO, NC, NJ, NM, NY, OH, OK, PA, SC, TN, TX, VA, WV; Canada: ON.

Notes: This species previously was known only from Arizona and western Texas; the new records mark a significant northward range extension.

Distribution: AZ, ID, NM, TX, UT.


Notes: The two species in this genus were treated recently (McPherson et al. 1992) and the distribution is preserved from that work. Parshley (1917) reported *F. aptera* from Vermont, and Wheeler, Jr. (2000) reported it from Maryland, Pennsylvania, Virginia, and West Virginia. However, the following state records are based on Froeschner (1988) and pre-1992 literature; thus, they may actually represent *F. spinosula* Stål, 1872: Colorado, Oklahoma, North Carolina, South Carolina, South Dakota, Utah, Vermont, and Alberta. The occurrence of *F. aptera* in Colorado is affirmed with the following specimen: COLORADO: [Weld Co.], Milliken, 23 June 1968, J. Matanzo Collector, det. J. Maldonado C. 1985, OSUC 372987 (OSUC). Despite the uncertainty, it seems both species are probably distributed widely in the continental United States.

Distribution: USA: AL, CO, CT, DC, FL, IL, IN, KS, MA, MD, ME, MI, MO, NC, ND, NH, NJ, NY, OH, OK, PA, SC, SD, TX, UT, VT, VA, WV; Canada: AB, NB, ON, QC.


Notes: The Florida record (Froeschner 1988) is questionable, and the source of this record could not be located. Members of *Heza Amyot & Serville, 1843* are known to occur throughout the Caribbean (Maldonado 1990), but a misidentification of *Rocconota annulicornis* (Stål), 1872 remains a distinct possibility.

Distribution: AZ, CA, FL, TX.


Notes: Torre-Bueno (1923) reported *P. barberi* from New York, and Blatchley (1926) reported it from Indiana. The locality data for some vouchered specimens are included to affirm the latter record: INDIANA: [Kosciusko Co.], Winona Lake, summer 1910 (FSCA); [Parke Co.], Turkey Run, 6 June 1926, K. F. Auden (INHS); Tippecanoe Co., Intersection of S.R. 26 & 600W, 10 April 1977, M. Minno (FSCA). More recently, Chordas III et al. (2005) reported it from Arkansas.

Distribution: AR, IL, IN, KS, LA, MD, MO, NC, NY, OH, OK, SC, TN, TX, VA.

*Pselliopus cinctus* (Fabricius, 1776) – ALABAMA: Cleburne Co., Summit of Cheaha Mt., 5 July 1939, J. J. Friauf (UMMZ); ARKANSAS: Cleburne
Co., Greere Ferry, 29 August 1969, T. H. Wilson (INHS); [Garland Co.], Hot Springs, (OSUC); Montgomery Co., Mt. Ida, 15 June 1978, R. L. Fischer (MSU); Scott Co., Mill Creek, 5 mi. E. “Y” City, 10 July 1965, J. & L. Donahue (MSU);

**DELAWARE**: [New Castle Co.], Newark, 1 November 1954, Coll. C. A. Triplehorn (OSUC);

**IOWA**: [Story Co.], Ames, [old label, date illegible, appears as 11 September ‘91] (FSCA);

**KENTUCKY**: [Floyd Co.], Prestonburg, 20 June 1957, R. L. Fischer (MSU); Laurel Co., Bald Rock, 11 June 1978, R. L. Fischer (MSU); idem. A. Porter (MSU);

**MISSISSIPPI**: [Lafayette Co.], Oxford, 2 May 1949, H. V. Weems, Jr. (FSCA);


Notes: Sibley (1951) reported *P. cinctus* from Louisiana. The author has not examined the specimens from New Hampshire.

**Pselliopus latifasciatus** Barber, 1924 – **ARKANSAS**: 1941 [no further information] (INHS); **GEORGIA**: Lowndes Co., Twin Lakes, 4 October 1991, Lloyd R. Davis Jr. (FSCA).

Notes: The label on the Arkansas specimen reported above is printed with “Co. Texas, 1940”. “Ark.” is written clearly over the locality in blue ink; the last digit of the year is emended in the same manner. Because Arkansas lies within the known distribution of *P. latifasciatus*, the author has chosen to treat this specimen as a valid voucher for the state.


Notes: On the above specimen, the author does not know if the quotation denotes the collector, the determination, or the collector’s determination.

**Pselliopus zebra** (Stål), 1862 – **NEW MEXICO**: [Hidalgo Co.], 18 mi. N. Cloverdale, 12 August 1955, R. R. Dreisbach (MSU); Lincoln Co., Ruidoso, 3 July 1961, G. C. Eickwort (MSU); Otero Co., 7.5 mi. S. Ruidoso, 3 June 198_, S. L. Heydon (INHS).

Notes: Froeschner (1988) listed “Carolina” in the distribution of *Repipta taurus*, and Hoffman (2006) provided a North Carolina record. The species doublessly occurs in South Carolina and will eventually be collected there. The new records are expected based on the known occurrence in Louisiana and Florida. The Colorado record (Gillette and Baker 1895) is questionable, but *R. taurus* can be confused with few other species. The records for southern Illinois and Pennsylvania are interesting, and it remains to be seen how far north this species occurs.


Notes: Froeschner (1988) listed “Carolina” in the distribution of *Repipta taurus*, and Hoffman (2006) provided a North Carolina record. The species doubtlessly occurs in South Carolina and will eventually be collected there. The new records are expected based on the known occurrence in Louisiana and Florida. The Colorado record (Gillette and Baker 1895) is questionable, but *R. taurus* can be confused with few other species. The records for southern Illinois and Pennsylvania are interesting, and it remains to be seen how far north this species occurs.

Notes: Harris and Shull (1944) reported R. ventralis from Idaho, a record apparently overlooked by Froeschner (1988). McPherson (1992) reported it from Michigan, and Maw et al. (2000) reported it from Manitoba. The author has not examined the specimen from New Hampshire. Four subspecies are listed by Froeschner (1988), but Maldonado (1990) listed them all as junior synonyms of R. ventralis without justification. As an in-depth study is needed to determine the validity of these subspecies, the distribution given below refers to the collective complex.

Distribution: USA: AZ, CA, CO, ID, IL, IN, MA, ME, MI, MN, MO, MT, ND, NE, NH, NM, OK, OR, TX, UT, WA, WY; Canada: AB, BC, MB, SK.


Notes: Blatchley (1926) reported R. annulicornis from Maryland, and Sibley (1951) reported it from Louisiana; these records were apparently overlooked by Froeschner (1988). More recently, Hagerty and McPherson (1999) reported it from Illinois, Chordas III et al. (2005) reported it from Arkansas, and Hoffman (2006) reported it from Virginia. The new records are more or less within the expected range for the species. Hoffman (2006) stated the species must occur statewide in Kentucky and Tennessee, and a specimen confirming its presence in the latter state is presented above. Froeschner (1988) listed Kentucky among the distribution, and while the author has not seen specimens from that state, it undoubtedly occurs there, as Hoffman suggests. Additionally, R. annulicornis should occur in Delaware, Mississippi, South Carolina, and West Virginia.

Distribution: AL, AR, FL, GA, IL, IN, KY, LA, MD, NC, NJ, NY, OH, PA, TN, TX, VA.


Distribution: AZ, CO, UT.

Notes: Harris and Shull (1944) reported S. confusa from Idaho, a record apparently overlooked by Froeschner (1988). See notes under the following species.

Distribution: AZ, CA, CO, ID, MT, TX, UT.


Notes: Osborn (1900) reported S. diadema from Ohio, and Elliott (1938) reported it from Louisiana; these records apparently were overlooked by Froeschner (1988). Schaefer and Wolf (2003) reported it from Iowa and Texas, and Maw et al. (2000) reported it from Manitoba, New Brunswick, Northwest Territories, and Saskatchewan. This species is one of the most commonly encountered and widespread species in North America. It is known from 47 of the 48 contiguous United States; it is unreported from Wyoming. Sinea diadema is difficult to separate from the previous species without comparing the male genitalia (Schaefer and Wolf 2003). As such, S. confusa may have a more extensive range than previously thought, as some of the records for S. diadema may represent S. confusa. Despite this uncertainty, S. diadema probably still occurs transcontinentally in North America.

Distribution: USA: AL, AR, AZ, CA, CO, CT, DC, DE, FL, GA, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV; Canada: AB, BC, MB, NB, NS, NT, ON, QC, SK.


Notes: Elliott (1938) and Sibley (1951) reported S. rileyi from Louisiana. Misidentifications of species within the spinipes group are rather common, and this genus is in need of revision. The author has seen authentic S. rileyi specimens from Arizona, New Mexico, and Texas. The other records are based
on literature published before 1951, excepting the Washington record (Schaefer and Wolf 2003), and may represent misidentifications.


Notes: Schaefer and Wolf (2003) reported *S. spinipes* from Connecticut and Iowa. As mentioned above, members of this species group often are misidentified. However, *S. spinipes* certainly is the most common species in the spinipes group, and the general range depicted by the distribution given below seems more or less accurate.

**Zelus cervicalis** Stål, 1872 – GEORGIA: Bibb Co., Macon, 5 April 1923 [add. date: 6 April 1924], T. H. Hubbell (UMMZ); Decatur Co., Woodruff Dam, 23 May 1954 [add. date: 13 September 1954], R. F. Hussey (FSCA); Decatur Co., 4 mi. SW Bainbg, [sic], Ga97, 11 September 1954, R. F. Hussey (FSCA); Decatur Co., Dist. 21, Lot 423, 1 mi. N. state line, 8 June 1953, R. F. Hussey (FSCA); Decatur Co., Nr. Blue Spring, Dist. 21, Lot 337, 17 August 1953, F. N. Young (UMMZ); [Gordon Co.], Calhous [sic], 19 August 1949 (MSU); Mitchell Co., DeWitt, 19 June 1915, C. S. Spooner (INHS); [Thomas Co.], Thomasville, 30 May 1915 [add. date: 23 June 1915], C. S. Spooner (INHS); [Troup Co.], La Grange, 19 June 1954, R. L. Fischer (MSU); MISSISSIPPI: Harrison Co., Handsboro, 17 August 1944, Pierce Brodkorb, [add. dates: 25 August 1944, 29 August 1944, 4 September 1944] (UMMZ); [Lafayette Co.], Oxford, 2 May 1949, H. V. Weems, Jr. (FSCA); TENNESSEE: Shelby Co., Millington, 7 September 1970 [add. date: 29 September], R. V. Dowell (OSUC).

Notes: Chordas III et al. (2005) reported *Z. cervicalis* from Arkansas. The California record (Van Duze 1917) probably is erroneous and thus, not included here for the time being. The author is of the opinion that Hart (1986) may have inappropriately synonymized *Zelus pictipes* Champion, 1899 under *Z. cervicalis*. In addition to the femoral markings, Hart remarked that there are significant differences in leg length/body length ratios and several differences in the male genitalia; both are characters Hart used to diagnose *Zelus* species in his key. Hart also admitted he did not know whether the western population is isolated from the eastern one in Mexico. The author has not investigated the situation in enough detail to offer a more concrete conclusion and intends only to convey some doubt. In any event, it seems improbable that *Z. cervicalis sensu* Hart will be found in western Texas or New Mexico; the Arizona record refers to a disjunct population previously known as *Z. pictipes*.

**Zelus luridus** Stål, 1862 – ARIZONA: [Pima or Santa Cruz Cos.], Santa Rita M., 24 June 1939, D. J. & J. N. Knoll Collrs. [1 female] (OSUC); [Graham

Notes: Osborn (1900) reported *Z. luridus* from Ohio, and Parshley (1917) reported it from Massachusetts; these records apparently were overlooked by Froeschner (1988). Although Froeschner (1988) reported this species from California, the occidental extension of several typically eastern elements presented in this work necessitates the inclusion of the following corroborative records: CALIFORNIA: [Mariposa Co.], Clark’s Station, 4100 ft., 9 May [18]79, Andreas Bolter Collection (INHS); [Mariposa Co.], Yosemite Valley, 4000 ft., 10 May [18]79, Andreas Bolter Collection (INHS).

Distribution: USA: AL, AR, AZ, CA, CO, CT, DE, FL, GA, IA, ID, IL, IN, KS, KY, LA, MA, ME, MD, MI, MN, MO, MS, NC, NE, NH, NJ, NM, NY, OH, OK, PA, RI, SC, SD, TN, TX, VA, VT, WI, WV, WY; Canada: MB, ON, QC.

*Zelus renardii* Kolenati, 1856 – ARKANSAS: Ouachita Co., Camden, 0.3 mi S. Hwy. 24, night lights, 31 August 2010, 33.5810°N 92.8343°W, #54, 130 ft., D. R. Swanson (DRS); NEW MEXICO: Lincoln Co., Ruidoso, 2 July 1961, G. C. Eickwort (MSU); [San Miguel Co.], Las Vegas, Andreas Bolter Collection (INHS).

Notes: The Arkansas record represents the easternmost record of this species. Knowlton and Harmston (1940) reported *Z. renardii* from Utah, and Werner and Butler, Jr. (1957) reported it from Arizona; these records apparently were overlooked by Froeschner (1988).

Distribution: AR, AZ, CA, KS, LA, NM, TX, UT.


Notes: Sibley (1951) reported *Z. tetracanthus* from Louisiana; the record apparently was overlooked by Froeschner (1988). More recently, Maw et al. (2000) reported it from Manitoba, New Brunswick, Nova Scotia, and Saskatchewan. The author has not examined the specimens from New Hampshire. Much variation exists in the color pattern of this species and many of these forms were accorded specific status at one time. Hart (1986) synonymized most of these forms, presumably although not explicitly stated, based on the near identical male genitalia. It seems probable that this species is found continent-wide in the United States.

Distribution: USA: AL, AZ, CA, CO, CT, FL, ID, IL, IN, KS, LA, MA, ME, MI, MN, MO, MS, NC, NE, NH, NJ, NM, NV, NY, OK, SD, TN, TX, UT, VA, WI, WY; Canada: AB, BC, ON, QC.
Microtominae

*Microtomus purcis* (Drury), 1782 – TENNESSEE: Obion Co., Reelfoot Lake, 4 September 1919, F. M. Gaige (UMMZ); WEST VIRGINIA: [Huntington Co.], Huntington, 26 October 1907, Coll. by: G. A. Akerlind (UMMZ).

Notes: Froeschner (1944) reported *M. purcis* from Missouri, Hagerty and McPherson (1999) reported it from Illinois, Chordas III et al. (2005) reported it from Arkansas, and Hoffman (2006) reported it from Virginia. The author could not locate the source of the Colorado record cited by Froeschner (1988); it seems doubtful. The species undoubtedly occurs in Kentucky and Mississippi and eventually should be collected there.

Distribution: AL, AR, CO, FL, GA, IL, IN, LA, MD, MO, NC, OK, SC, TN, TX, VA, WV.

Peiratinae


Notes: Osborn and Drake (1915) reported *M. picipes* from Ohio; this record apparently was overlooked by Froeschner (1988). More recently, McPherson et al. (1991) reported it from Arizona, McPherson (1992) reported it from Michigan, Chordas III et al. (2005) reported it from Arkansas, and Hoffman (2006) reported it from Virginia. Another widely distributed species, *M. picipes* probably occurs transcontinentally in North America. Froeschner (1988) listed *Melanolestes abdominalis* (Herrich-Schaeffer), 1846 as a valid species but McPherson et al. (1991) showed that *M. abdominalis* was a synonym of *M. picipes*. The author agrees with Hoffman (2006) in rejecting the purported occurrence of *M. pici-cornis* Stål in the Nearctic Region as stated by Coscaron and Carpintero (1994) in their revision of the genus. The specimens examined by the author support Hoffman’s conclusion.

Distribution: USA: AL, AR, AZ, CA, CO, CT, DC, DE, FL, GA, IA, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, NH, NJ, NM, NY, OH, OK, PA, RI, SC, SD, TN, TX, UT, VA, WV; Canada: QC.

Notes: Elliott (1938) reported R. hamatus from Louisiana; this record apparently was overlooked by Froeschner (1988). More recently, Hagerty and McPherson (1999) reported it from Illinois, Chordas III et al. (2005) reported it from Arkansas, and Hoffman (2006) reported it from Virginia.

Distribution: AR, FL, IL, KS, LA, MO, MS, NC, OK, SC, TN, TX, VA.


Distribution: AZ, CA, NM, NV, TX.


Notes: Drew and Schaefer (1963) reported this peiratine from Oklahoma, Willemse (1985) reported it from Kentucky and Maryland, and Chordas III and Kremers (2009) reported it from Arkansas. Willemse (1985) is followed regarding its taxonomic status.

Distribution: AR, FL, GA, IL, IN, KS, KY, LA, MD, MI, MO, NC, NJ, OH, OK, SC, TX, VA.

Reduviinae


Notes: Previously, P. arizonicus has been recorded only from Arizona, and the above data represent significant extensions to the North and to the East. This species has been collected most commonly from the mountains of southeastern Arizona, particularly the Huachucas, and the localities above all affirm an affinity for montane habitats.

Distribution: AZ, ID, TX, UT.


Notes: Harris and Shull (1944) reported *R. personatus* from Idaho, Sibley (1951) reported it from Louisiana, Wygodzinsky and Usinger (1964) reported it from Arizona, California, Nevada, Oregon, and Washington, and Eads and Campos (1983) reported it from Colorado; these records apparently were overlooked by Froeschner (1988). More recently, Hoffman (2006) reported it from Virginia, and Maw et al. (2000) reported it from New Brunswick. As a predator of bed bugs, *R. personatus* is commonly synanthropic. Originally an Old World species, this now cosmopolitan bug should be found transcontinentally in the United States. Known from 41 of the 48 contiguous United States, it is unreported from Arkansas, Delaware, Minnesota, Mississippi, Montana, North Dakota, and Rhode Island.

Distribution: USA: AL, AZ, CA, CO, CT, FL, GA, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MO, NC, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV, WY; Canada: BC, NB, ON, QC.

**Saicinae**


Notes: Sibley (1951) reported *O. acuminatus* from Louisiana, McPherson (1992) reported it from Michigan, Hoffman (2006) reported it from Virginia, and Chordas III et al. (2008) reported it from Ohio.

Distribution: AL, DC, DE, FL, GA, IL, IN, KS, KY, LA, MA, MD, MI, MN, MO, NC, NJ, NY, OH, OK, PA, SC, TX, VA.


Notes: The new record represents a significant inland extension for this species. When Blinn (1990) erected the new genus, he added the Mississippi data in addition to Barber's holotype. The Virginia record cited by Froeschner (1988) for *Saica florida* Barber, 1914 actually represents another saicine species (Blinn 1994).

Distribution: FL, KY, MS.
Stenopodainae

**Diaditus semicolon** Stål, 1859 – Blinn (2009) reported specimens of *D. semicolon* from Cecil County, Maryland (NCSU) and Palm Beach County, Florida (FSCA) as “new distribution records for this species.” Each of these records is represented by a single individual and the author has seen the specimen deposited in FSCA. The Maryland record probably is based on an adventitious individual; it is unlikely that a Neotropical species would be established in the northeastern United States. The situation is not as clear-cut with the Florida record as the state is notorious for the entry of Neotropical species. Blinn (2009) also reported a single specimen from Isabela, Puerto Rico, which may lend support to the idea of a Caribbean extension. However, as *D. semicolon* is otherwise known only from South America (Argentina, Bolivia, Brazil, Uruguay, Venezuela) and now Panama (an additional, entirely plausible record provided by Blinn), it seems premature to suggest that this reduviid has become established in the United States. Further doubt is cast on the suggestion because some species of *Diaditus* are known to come readily to lights and thus, are encountered more frequently (see below). Until additional specimens are collected, *D. semicolon* should be considered a strictly Central and South American species.


Notes: The range of *D. tejanus* has been the subject of several short papers since its description. McPherson et al. (1995) extended the range from Alvin, Texas, to Highlands and Gadsden Counties, Florida, supplemented with specimens from Hancock County, Mississippi. Blinn (2009) added Alabama and Georgia to the list, while providing additional specimens from Florida and Mississippi. McPherson et al. (1995) suggested that *D. tejanus* may be restricted by coastal factors; Blinn (2009), based on his findings, agreed with the hypothesis. In addition to those from Arkansas, the author has collected specimens at various localities in Texas that show *D. tejanus* is not limited to the coastal plain:

**TEXAS**: Bosque Co., Meridian, 0.2 NE. on Hwy. 22, Family Dollar, 1 Sept. 2010, 31.9172°N 97.6633°W, #60, 760 ft., D. R. Swanson [4 males, 1 female] (DRS); Bosque Co., Laguna Park, 0.1 mi. NE. on Hwy. 22, 1 September 2010, 31.8591°N 97.3774°W, #61, 590 ft., D. R. Swanson [1 male] (DRS); Clay Co., Henrietta, Church of Christ on Hwy. 82, 2 September 2009, 33.8159°N 98.2067°W, #121, 930 ft., D. R. Swanson [2 females] (DRS); Clay Co., Henrietta, 1.3 mi. E. hospital on Hwy. 82, 2 September 2009, 33.8163°N 98.1749°W, #126, 875 ft., D. R. Swanson [5 males, 2 females] (DRS); Jack Co., Jacksboro, 0.3 mi. E. Hwy 148 jct. on 281, 2 September 2009, 33.2247°N 98.1583°W, #128, 1060 ft., D. R. Swanson [2 males, 2 females] (DRS); Real Co., Leakey, Texaco gas station on Hwy. 83, 7 September 2009, 29.7141°N 99.7629°W, #162, 1590 ft., D. R. Swanson [1 male] (DRS). *D. tejanus* seems to be a fairly widespread, common assassin bug. It readily comes to lights and may occur in numbers when encountered. It will be interesting to see how far north, both inland and along the eastern coast, the range of this species extends.

**Distribution**: AL, AR, FL, GA, LA, MS, SC, TX.

**Narvesus carolinensis** Stål, 1859 – CALIFORNIA: Imperial Co., Fort Yuma, 9 September 1926, C. L. Hubbs, [22 males, 5 females] (UMMZ); [Imperial Co.], 2 mi. N. U.S. 80 on road to Ogilby (13 mi. W. Yuma AZ) on desert flat, 20

Notes: Blatchley (1926) reported *N. carolinensis* from Indiana, Readio (1927) reported it from Kansas, Sibley (1951) reported it from Louisiana, and Giacchi (1974) reported it from New Mexico; these records apparently were overlooked by Froeschner (1988). More recently, McPherson (1992) reported it from Michigan.


Notes: Blatchley (1926) reported *O. geniculatus* from Alabama, Sibley (1951) reported it from Louisiana, and Barber (1930) reported it from Maryland, New Jersey, and Tennessee; these records apparently were overlooked by Froeschner (1988). More recently, Hagerty and McPherson (1999) reported this stenopodaine from Illinois, Chordas III et al. (2005) reported it from Arkansas, and Hoffman (2006) reported it from Virginia. This species may be difficult to separate from *O. apiculatus* Reuter, 1882, known from Illinois (Malloch 1920), Kansas (Blatchley 1926), Missouri, and Texas. However, the distribution given below should still be accurate.

Distribution: AL, AR, AZ, CO, FL, GA, IL, KS, KY, LA, MD, MO, MS, NC, NJ, NM, OH, OK, SC, TN, TX, VA.

**Pnirontis infirma** Stål, 1859 – DISTRICT OF COLUMBIA: 18 May, Herbert Osborn Collection (OSUC); MISSISSIPPI: Harrison Co., Handsboro, 16 June 1944 [add. dates: 24 June 1944, 18 August 1944], Pierce Brodkorb (UMMZ); [Harrison Co.], Biloxi, 9 October 1945, J. T. Polhemus (FSCA); OHIO: [Franklin Co.], Columbus, (OSUC); [Hardin Co.], McGuffy, July 1944, C. R. Neiswander Collr. (OSUC); SOUTH CAROLINA: Beaufort Co., Hardeeville, 25 September 1930, T. H. Hubbell (UMMZ); Beaufort Co., 1.1 mi. N. Limehouse (US17), 20 August 1947, T. H. Hubbell (UMMZ).

Notes: Froeschner (1988) gave “Carolina” as part of the distribution and the author has provided locality data for South Carolina. Blatchley (1926) reported *P. infirma* from Alabama, and Sibley (1951) reported it from Louisiana; these records apparently were overlooked by Froeschner (1988).

Distribution: AL, DC, FL, GA, IL, LA, MS, NJ, OH, SC, TX.

Notes: Elliott (1938) reported *P. languida* from Louisiana, Hagerty and McPherson (1999) reported it from Illinois, and Hoffman (2006) reported it from Virginia.

**Distribution:** AR, FL, GA, IL, LA, NC, OK, SC, TX, VA.


**Distribution:** AR, DC, FL, GA, IL, IN, KY, MD, MI, MO, NC, OH, SC, TN, TX, VA.


Distribution: USA: AR, AZ, CA, CO, CT, DE, FL, IA, IL, IN, KS, KY, LA, MA, MD, ME, MI, MO, MS, NC, NE, NH, NJ, NY, OH, OK, SC, TN, TX, VA; Canada: AB, MB, NB, ON, QC.


Notes: The author has examined only those specimens represented by the above data. Maw et al. (2000) reported P. sericea from British Columbia, Ontario, and Quebec; the British Columbia record is of particular interest as, at present, an eastern distribution within North America north of Mexico seems attributable to the species. Parshley (1917) reported P. sericea from New Hampshire, and McPherson (1992) reported it from Michigan. Hoffman (2006) stated his previous Virginia record (Hoffman, 1953) was based on a misidentification and that no authentic Virginia records were known; thus, it is not included. Elliott (1938) reported this species from Louisiana, although Sibley (1951) never found P. sericea, despite collecting large numbers of P. pectoralis. Sibley also noted that the specimen on which Elliott’s record was based had been destroyed. Similarly, Readio (1927) reported S. sericea from Texas, but Elkins (1951) never saw specimens from Texas. However, the Louisiana and Texas records are retained as there is no evidence to suggest the original records were spurious.

Distribution: USA: FL, IL, IN, LA, MA, MD, MI, NC, NE, NH, NY, PA, SC, TX; Canada: BC, ON, QC.


Notes: This species was reported from Kentucky and Virginia by Giacchi (1989) and from Michigan by McPherson (1992). Previously, this species was included under S. culiciformis (Fabricius), 1775 and S. cinerea Laporte, 1833; Giacchi (1969) revised the genus and described S. spinulosa for the species commonly found in the United States.

Distribution: USA: AL, AR, FL, GA, IL, IN, KS, KY, LA, MI, MO, MS, NC, NJ, NY, OH, OK, PA, SC, TN, TX, VA, WV; Canada: NB.

Triatominae

Triatoma longipennis Usinger, 1939 – No member of the phyllosoma complex, the group to which T. longipennis belongs, is known to occur in the United States. Uhler (1876) reported “Meccus phyllosoma” from “near San Diego” in California although the color character mentioned (“deep black… the only red present is upon the outer edge of the abdomen”) precludes the phyllosoma complex. Two specimens of T. longipennis, a male and a female, were found among
material borrowed from the Illinois Natural History Survey (INHS). The male has a printed label which reads only “Tex.” and no determination label is present. The female has no locality label and two separate determination labels, one erroneously indicating the genus “Pirates” and the other indicating a misidentification of the triatomine species, [Conorhinus] “dimidiatus”. A printed label with “Andreas Bolter Collection” is found on both specimens. Based on examinations by the author, the Andreas Bolter Collection contains material presumably collected from the late nineteenth and early twentieth century with locality labels typical of the kind found on the aforementioned specimens. *Triatoma longipennis* is known to occur in the Mexican states of Aguascalientes, Chihuahua, Colima, Jalisco, Nayarit, Sinaloa, and Zacatecas (Lent and Wygodzinsky 1979), and thus, the species’ occurrence in Texas is not inconceivable. However, the author is hesitant to report a new United States record because, to the author’s knowledge, no other individuals of this large, conspicuous species have been taken in the United States. This is particularly troubling when one considers that *T. longipennis* is a member of a well-studied subfamily infamous for hematophagy and as potential disease vectors; this notoriety has made the triatomines the focus of intensive collecting efforts and biogeographical studies (i.e. Ryckman 1962, Lent and Wygodzinsky 1979). An additional concern is the sparse and potentially spurious nature of the label. The possibility of adventitious specimens also remains. Given these doubts, the author excludes *T. longipennis* from the reduviid fauna of the United States until corroborative material is examined or collected.

*Triatoma sanguisuga* (LeConte), 1855 – WEST VIRGINIA: [Barbour Co.], Philippi, At Arcs, 10 June 1909 (INHS).

Notes: Blatchley (1926) reported *T. sanguisuga* from New Jersey; this record apparently was overlooked by Froeschner (1988). The Arizona record (Froeschner 1988) is excluded as it represents *Triatoma indictiva* Neiva, 1912, a species previously afforded subspecific rank under *T. sanguisuga*. The area of overlap between these species is shown by Lent and Wygodzinsky (1979).

Distribution: AL, AR, FL, GA, IL, IN, KS, KY, LA, MD, MO, MS, NC, NJ, OH, OK, PA, SC, TN, TX, VA, WV.

Acknowledgments

I thank Mark O’Brien, Insect Division, UMMZ, for his support of my entomological projects, his sponsorship regarding loaned material, and his always helpful advice regarding preparation of the manuscript. My thanks also to the collections managers and curators under whose charge I was able to peruse several collections: Gary Parsons, Albert J. Cook Arthropod Research Collection, MSU; Luciana Musetti, C. A. Triplehorn Insect Collection, OSUC; Dmitry Dmitriev, Illinois Natural History Survey, INHS; and Susan Halbert, Florida State Collection of Arthropods, FSCA. I also am grateful to Donald Chandler, University of New Hampshire Insect Collection, UNH, and Thomson Paris, Florida State Collection of Arthropods, FSCA, for communications regarding additional specimen data. I thank Steve Chordas III, Ohio State University, for his kind correspondence regarding several reduviid state records. I am particularly grateful to J. C. Jones and M. Brummermann, each for a donation of several reduviid specimens.

Literature Cited


Leonard, M. D. 1928. A list of the insects of New York with a list of the spiders and certain other allied groups. Ithaca: The University. 1121 pages.


Osborn, H. 1900. A list of Hemiptera collected in the vicinity of Bellaire, Ohio. The Ohio Naturalist 1: 11-12.


A Synopsis of the Coreoidea (Heteroptera) of Michigan

D. R. Swanson¹

Abstract

An overview of the species of Coreoidea (Alydidae, Coreidae, and Rhopalidae) found in Michigan is presented, along with identification keys, distribution maps, and relevant literature. New state records for Alydus pilosulus Herrich-Schaeffer (Alydidae: Alydinae), Merocoris distinctus Dallas (Coreidae: Meropachyinae), Leptoglossus corculus (Say) (Coreidae: Coreinae), Leptoglossus oppositus (Say) (Coreidae: Coreinae), and Liorhyssus hyalinus (Fabricius) (Rhopalidae: Rhopalinae) are included.

Although many of the species are regarded as economically important and several conspicuous species are oft-encountered near human habitations, no treatment exists for the families of the Coreoidea in the state of Michigan. Furthermore, the literature containing pertinent information for this group begets a rather short list. O’Brien (1983, 1988) enumerated the publications dealing with the terrestrial arthropods of Michigan, and from these works, only two contribute to the knowledge of the Coreoidea. These short regional faunal lists provided by Townsend (1890) and Hussey (1922) recorded Heteroptera collected from the vicinity of Constantine in Saint Joseph County and Berrien County, respectively.

To augment the knowledge of the Michigan Heteroptera, the author herein presents the findings from his study of the Coreoidea housed in the two major university collections in southern Michigan. County records were compiled, identification keys were modified, and the existing natural history information was summarized. Given the scarcity of literature regarding this group in the Great Lakes region, the author has provided references based on extralimital specimens where applicable.

Materials and Methods

The identification of all 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. Location of counties from which specimens were collected in Michigan are depicted in Figure 1. In the few instances where it is provided, label data are not transcribed verbatim, but locality information is included in its entirety.

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

¹3111 Scenic Lake Dr. Apt. 34, Ann Arbor, MI 48108. (email: drswanny@gmail.com).
Results and Discussion

Superfamily COREOIDEA

The superfamily Coreoidea comprises three families in the Nearctic region: Alydidae, Coreidae, and Rhopalidae. The Alydidae and Rhopalidae have been treated as subfamilies of the Coreidae, but their familial rank has been secured (Schaefer 1964, 1965). The characters diagnosing the Coreoidea include some of the abdominal trichobothria present in triplets, a small scutellum not reaching apex of clavus, 4-segmented antennae, hemelytral membrane with 11 or more veins, and presence of ocelli (Henry 1997). All are phytophagous as a general rule with some species attacking commercially cultivated plants; data on food plants of the superfamily were summarized by Schaefer and Mitchell (1983). Extra-phytophagous sources have been summarized by Adler and Wheeler, Jr. (1984). The economic importance of the Alydidae, Coreidae, and Rhopalidae was discussed by Panizzi et al. (2000), Mitchell (2000), and Schaefer and Kotulski (2000), respectively; several species found in Michigan are discussed in more detail by these authors, and each specific account is noted under the appropriate heading below. Each of the three coreoid families is represented in Michigan, and 25 species in 18 genera are found in the state (Table 1).

Figure 1. The counties of the State of Michigan.
Most of these species are treated by Blatchley (1926) and Torre-Bueno (1941) although these works are outdated and do not focus specifically on the superfamily. Hoffman (1975) also treated the Coreoidea of Virginia and all Michigan species excepting *Coriomeris humilis*, *Alydus conspersus*, *Brachycarenus tigrinus*, and *Stictopleurus knighti* are found there. The following key is modified from Schaefer’s (1965) treatment.

Key to the North American families of Coreoidea

1 Opening of scent glands absent or inconspicuous; usually less than 10 mm in length (except *B. trivittata*)

2

1’ Opening of scent glands present, auricles located between meso- and metacoxa; usually greater than 10 mm in length

---

**Table 1.** Species of Alydidae, Coreidae, and Rhopalidae found in Michigan.

<table>
<thead>
<tr>
<th>Alydidae</th>
<th>Coreidae</th>
<th>Rhopalidae</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Alydus conspersus</em> Montandon, 1893</td>
<td><em>Acanthocephala terminalis</em> (Dallas), 1852</td>
<td><em>Arhyssus lateralis</em> (Say), 1825</td>
</tr>
<tr>
<td><em>Alydus eurinus</em> (Say), 1825</td>
<td><em>Anasa armigera</em> (Say), 1825</td>
<td><em>Arhyssus nigristernum</em> (Signoret), 1859</td>
</tr>
<tr>
<td><em>Alydus pilosulus</em> Herrich-Schaeffer, 1847</td>
<td><em>Anasa tristis</em> (DeGeer), 1775</td>
<td><em>Boisea trivittata</em> (Say), 1825</td>
</tr>
<tr>
<td><em>Megalotomus quinquespinosus</em> (Say), 1825</td>
<td><em>Catorhintha mendica</em> Stål, 1870</td>
<td><em>Brachycarenus tigrinus</em> (Schilling), 1829</td>
</tr>
<tr>
<td><em>Protenor belfragei</em> Haglund, 1868</td>
<td><em>Chariesterus antennator</em> (Fabricius), 1803</td>
<td><em>Harmostes reflexulus</em> (Say), 1832</td>
</tr>
<tr>
<td></td>
<td><em>Coriomeris humilis</em> (Uhler), 1872</td>
<td><em>Liorhyssus hyalinus</em> (Fabricius), 1794</td>
</tr>
<tr>
<td></td>
<td><em>Euthochtha galeator</em> (Fabricius), 1803</td>
<td><em>Stictopleurus knighti</em> Harris, 1942</td>
</tr>
<tr>
<td></td>
<td><em>Leptoglossus corculus</em> (Say), 1832</td>
<td><em>Stictopleurus punctiventris</em> (Dallas), 1852</td>
</tr>
<tr>
<td></td>
<td><em>Leptoglossus occidentalis</em> Heidemann, 1910</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Leptoglossus oppositus</em> (Say), 1832</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Merocoris distinctus</em> Dallas, 1852</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Piezogaster alternatus</em> (Say), 1825</td>
<td></td>
</tr>
</tbody>
</table>
Head narrower and shorter than pronotum; bucculae extending posteriorly beyond base of antennae in lateral view .........................Coreidae

Head nearly as wide and as long as pronotum; bucculae shorter, not extending posteriorly beyond base of antennae in lateral view Alydidae

Family ALYDIDAE Amyot and Serville, 1843

The Alydidae are represented in Michigan by 5 species in 3 genera, and its members are commonly known as the broad-headed bugs. Fracker (1918) revised the family (as subfamily Alydinae of the Coreidae) although Schaefer (2004) more recently keyed the New World genera; the following key is modified principally from these works. The Micrelytrinae are thought to feed on grasses and sedges, while those in the Alydinae are well-documented feeders on various legumes, although they occasionally feed opportunistically on carrion and fecal matter (Payne et al. 1968, Schaefer 1980, Schaefer and Mitchell 1983). Adults peak from late summer to early fall, and the eggs probably overwinter (Fracker 1918). Nymphs of the alydine genera found in Michigan are ant-mimetic.

Key to the Alydidae of Michigan

1 Metafemur unarmed ventrally (Micrelytrinae); second rostral segment much longer than third and fourth combined (Micrelytrini); juga split at apex, much longer than tylus ........................................ Protenor belfragei

1’ Metafemur armed ventrally with one or two rows of spines (Alydinae); second rostral segment subequal or shorter than third and fourth combined; juga not split at apex, not conspicuously longer than tylus ..........2

2 (1’) First antennomere longer than second (Megalotomus); fourth antennomere with basal portion contrastingly pale; metafemur usually distinctly bicolorous, basal half pale, apical half red-brown .................. Megalotomus quinquespinosus

2’ First antennomere shorter than second (Alydus); fourth antennomere essentially unicolorous, fuscous; metafemur usually unicolorous, fuscous 3

3 (2’) Membrane of hemelytra with scattered fuscous spots; [humeral angles rounded] ...................................................... Alydus conspersus

3’ Membrane without spots, uniformly infuscate ...........................................4

4 (3’) Humeral angles sharply angulate; lateral margins of pronotum usually pale .................................................. Alydus pilosulus

4’ Humeral angles rounded; lateral pronotal margins not conspicuously pale .................................................. Alydus eurinus

Subfamily ALYDINAE Amyot and Serville, 1843

Genus ALYDUS Fabricius, 1803

Alydus conspersus Montandon, 1893. (Fig. 2). – This species was reported from Constantine, Michigan in the original description (Montandon 1893). Hussey (1922) also reported this species (as Coriscus conspersus) from Berrien County where he noted it as “abundant in the fields and meadows about Warren Woods during June and July.” Label information indicates this species has been collected nocturnally at lights in Otsego County, and this species also has been collected from Isle Royale, Keweenaw County. The biology of A. conspersus was studied in Wisconsin by Yonke and Medler (1968). 169 specimens examined. Collection dates from 5 June to 9 October.

Alydus eurinus (Say), 1825. (Fig. 3). – This species was reported from Michigan by Townsend (1890) and Hussey (1922), but the records seem to have been overlooked by Froeschner (1988a). Townsend (1890) reported adults on the wing from July to September while Hussey (1922) noted “from the same
localities as *Alydus conspersus*, but much less numerous...[also] from a clump of beach grass on the fore-dune near Sawyer.” In Livingston County, it has been taken on flowering spurge (*Euphorbia corollata* L.) and wild bergamot (*Monarda fistulosa* L.), and in Kent County, it was taken on wild indigo (*Baptisia* sp.) and swamp milkweed (*A. incarnata* L.) in a suburban garden. This species also has been collected from Isle Royale, Keweenaw County. The biology of *A. eurinus* was studied in Wisconsin by Yonke and Medler (1968). 291 specimens examined. Collection dates from 26 May to 24 October.

*Alydus pilosulus* Herrich-Schaeffer, 1847. (Fig. 4). – (NEW STATE RECORD). It appears that this species has not previously been reported from Michigan (Froeschner 1988a). It is not surprising that this alydine occurs in the state; the few specimens examined might explain its having been unreported. It remains to be seen whether *A. pilosulus* is restricted to the southern part of Michigan. In Kent County, it was taken on wild indigo (*Baptisia* sp.) and swamp milkweed (*A. incarnata* L.) in a suburban garden. The biology of this species was studied in Wisconsin by Yonke and Medler (1968). This species is treated briefly under the less economically-important species by Panizzi et al. (2000). 22 specimens examined. Collection dates from 23 June to 16 October.

Genus MEGALOTOMUS Fieber, 1860

*Megalotomus quinquespinosus* (Say), 1825. (Fig. 5). – Sometimes referred to as the lupine bug, this species was reported from Michigan by Townsend (1890) as *Alydus quinque-spinosus*. Hussey (1922) also reported this alydine from Berrien County where it was taken “from roadside grasses in the Warren Woods.” Specimen labels indicate *M. quinquespinosus* has been taken on Queen Anne’s lace (*Daucus carota* L.) in Jackson County, on pods of wild indigo (*Baptisia* sp.) in Washtenaw County, and from a garter snake (*Thamnophis* sp.) carcass in Livingston County. The biology of this species was studied in Wisconsin by Yonke and Medler (1965); they additionally noted it has been taken on smooth sumac (*Rhus glabra* L.) at Douglas Lake, Cheboygan County, Michigan. This species also is briefly mentioned under the less economically important species by Panizzi et al. (2000). 197 specimens examined. Collection dates from 17 June to 6 October.
Subfamily MICRELYTRINAE Stål, 1867

Genus PROTENOR Stål, 1867

*Protenor belfragei* Haglund, 1868. (Fig. 6). – This species was reported from Michigan by Townsend (1890) and Hussey (1922); the latter indicated it was “taken from grasses in a marshy locality behind the Sawyer Dunes; others were taken at Stevensville and at Klute’s Lake.” Fracker (1918) indicated this species feeds on members of the Cyperaceae. 318 specimens examined. Collection dates from 30 May to 18 October.

Family COREIDAE Leach, 1815

Commonly known as the leaf-footed bugs, the family Coreidae is the largest and most diverse in the Coreoidea. In Michigan, the Coreidae are represented by 12 species in 9 genera although a note is provided for a potentially adventive southern species, *Leptoglossus phyllopus* (Linnaeus), 1767. Baranowski and Slater (1986) treat the Coreidae of Florida and the vast majority of the Nearctic species are found in that state; *Leptoglossus occidentalis* and *Catorhintha mendica* are the only Michigan species not discussed in that work. Packauskas (1994) keyed the New World taxa to tribe and provided references for further identification; he also provided the most recent catalog for the New World species of this family (Packauskas 2010). The following key was synthesized from several of these works (Blatchley 1926, Baranowski and Slater 1986, Packauskas 1994).

Key to the Coreidae of Michigan

1 Apex of metatibia ending in short projecting spine (Meropachyinae); metafemur strongly arcuate and clavate (Merocorini) ............ *Merocoris distinctus*

1’ Apex of metatibia without projecting spine; metafemur not strongly arcuate and clavate, although may be incrassate........................................2

2 (1’) Anteocular region lacking median sulcus; tibiae not sulcate on outer surface (Pseudophloeinae); antennae, head and pronotum beset with small seta-bearing granules........................................*Coriomeris humilis*
2'  Anteocular region with median sulcus; tibiae usually sulcate on outer surface (Coreinae); not beset with small seta-bearing granules
3 (2')  Metatibiae of both sexes dilated on one or both sides to form a thin foliaceous flange
3'  Metatibiae of both sexes simple, terete
4 (3)  Head deflexed, only slightly prolonged beyond antennal bases; tylus compressed and projected upward between antenniferous tubercles as a triangular spine; first antennomere at least 1.5 times longer than head (Acanthocephalini)
4'  Head porrect, much prolonged beyond antennal bases; tylus compressed but deflexed between antenniferous tubercles; first antennomere subequal to length of head (Anisoscelini: Leptoglossus)
5 (4')  Outer dilation of metatibia distinctly scalloped; [corial fascia reduced to one or two small spots on vein]
5'  Outer dilation of metatibia entire, smoothly convex
6 (5')  Outer dilation of metatibia distinctly longer than inner dilation; abdominal tergites entirely dark or nearly so; corial fascia present, confined to veins; posterior margin of male genital capsule usually with median V-shaped notch
6'  Outer dilation of metatibia subequal to inner dilation; fourth and fifth abdominal tergites with striking orange-yellow markings, each interrupted medially by a black spindle or diamond-shaped mark; corial fascia present though sometimes faint or absent; posterior margin of male genital capsule usually with median subrectangular notch
7 (3')  Metafemur armed beneath with many teeth, strongly swollen in males
7'  Metafemur unarmed beneath or armed with only 2-3 small teeth, not swollen in either sex
8 (7)  Ocellar tubercles large; metathoracic scent gland auricle with single disc; antenniferous tubercles armed laterally (Acanthocerini); male with metatibia more or less straight

Figure 6. Distribution of Protenor belfragei in Michigan.
8' Ocellar tubercles small; metathoracic scent gland auricle with pair of divergent discs; antennaliferous tubercles unarmed (Nematopini); male with metatibia strongly bent .............................. Piezogaster alternatus

9 (7) Third antennomere dilated and compressed on both sides, others terete; antennaliferous tubercles very prominent; tylus strongly and abruptly deflexed, the space between the tubercles unfilled (Chariesterini) ......

................................................................. Chariesterus antennator

9' All antennomeres terete; antennaliferous tubercles not prominent; tylus not strongly deflexed, the space between the tubercles filled (Coreini) ......10

10 (9') Eyes distinctly projecting beyond apical angle of pronotum; ocelli separated by nearly twice the distance between them and eyes; abdominal spiracles closer to lateral margins than to anterior or posterior margins....................

.............................................................................. Catorhintha mendica

10' Eyes not or slightly projecting to apical angle of pronotum; ocelli separated by distance equal to distance between them and eyes; spiracles equidistant from lateral, anterior, and posterior margins of ventrite (Anasa) .................................................................11

11 (10') Head with long spines near the antennal bases ....... Anasa armigera

11' Head unarmed .................................................................. Anasa tristis

Subfamily COREINAE Leach, 1815
Tribe ACANTHOCEPHALINI Stål, 1870
Genus ACANTHOCEPHALA Laporte, 1833
Acanthoccephala terminalis (Dallas), 1852. (Fig. 7). – This species was reported from Michigan by Hussey (1922), although this record seems to have been overlooked by Froeschner (1988b) but included by McPherson et al. (2011). Hussey noted “adults were taken occasionally from dense tangles of herbage in damp localities...and some were also found on the white ash (Fraxinus americana). Nymphs were beaten from a number of different trees, but were found in numbers only on the ash.” Hussey continued with descriptions of all instars (except the fourth) in some detail. Yonke and Medler (1969a, 1969c) provided information about the immature stages and biology of this species in Wisconsin. McPherson et al. (2011) reviewed Acanthoccephala and keyed the species north of Mexico. 132 specimens examined. Collection dates from 3 May to 10 November.

Tribe ACANTHOCERINI Bergroth, 1913
Genus EUTHOCHTHA Mayr, 1865
Euthochtha galeator (Fabricius), 1803. (Fig. 8). – Occasionally referred to as the helmeted squash bug, this species was reported from Michigan by Townsend (1890) and Hussey (1922). The former noted “on various weeds in May and June,” and the latter stated “taken from ragweed in a pear orchard near the Warren Woods...and one was taken in flight at Harbert.” Yonke and Medler (1969a, 1969b) provided information about the immature stages and biology of this species in Wisconsin where it occurs on a wide range of host plants. This coreid occasionally injures citrus, rose, and other cultivated fruits and ornamentals (Mead 1981). 65 specimens examined. Collection dates from 3 May to 10 November.

Tribe ANISOSCELINI Amyot and Serville, 1843
Genus LEPTOGLOSSUS Guérin-Méneville, 1831
Leptoglossus corculus (Say), 1832. (Fig. 9). – (NEW STATE RECORD).
Label data as follows: MICHIGAN: Allegan Co., 18 May 1959, R. & K. Dreischbach, det. J. C. Lutz [1 male] (MSU). As this species is known from Illinois and
Wisconsin (Katovich and Kulman 1987), it is not surprising to find *L. corculus* in Michigan. Katovich and Kulman (1987) noted this species attacking red pine (*Pinus resinosa* Solander) in Wisconsin; adults were first collected in late June. This species is commonly known as the leaf-footed pine seed bug. Mitchell (2000) discussed the economic significance of this species, and Elbel et al. (1981) described the nymphs. The genus was revised by Allen (1969). The key by McPherson et al. (1990) was modified slightly by Gall (1992) for the species of *Leptoglossus* found in the United States. 1 specimen examined. Collection date is 18 May.

*Leptoglossus occidentalis* Heidemann, 1910. (Fig. 10). – The western conifer seed bug was first reported from Michigan by McPherson et al. (1990); the distribution and biology of *L. occidentalis* in Michigan are covered in that work and only a few details are reproduced here. This species feeds on several species of pine (Pinaceae) (Katovich and Kulman 1987, McPherson et al. 1990, Gall 1992). *L. occidentalis* is univoltine and overwinters as an adult (McPherson et al. 1990). Collection dates reflect the bug’s tendency to enter human habitations, where the overwintering adults often are considered a nuisance. Overwintering individuals have been shown to cause some structural damage to plumbing materials (Bates 2005). The author believes the number of specimens in university collections may be negatively influenced by this synanthropic overwintering; species perceived as extremely common or easily obtainable are rarely collected or completely ignored (see also *Boisea trivittata* (Rhopalidae) below). While the eastward expansion of this species into the Great Lakes region has been fairly recent, it seems likely that *L. occidentalis* occurs widely in the state, at least throughout the Lower Peninsula. The economic significance of this species was discussed by Mitchell (2000). The genus was revised by Allen (1969). McPherson et al. (1990) provided a key to the U.S. species of the genus; Gall (1992) modified the couplet pertaining to two of the species found in Michigan. 68 specimens examined. Collection dates from 27 January to 16 December.

*Leptoglossus oppositus* (Say), 1832. (Fig. 11). – (NEW STATE RECORD). Label data as follows: MICHIGAN: [Wayne Co.], Ecorse, 8 November 1933, Rec’d Ralph Beebe, det. H. G. Barber, det. R. Packauskas 1995 [1 male] (UMMZ). The locality label indicates the specimen was “on a brick wall nubbed with
There is no apparent reason to doubt the validity of this record; in fact, the author was surprised to find only a single specimen among material examined, given that *L. oppositus* is recorded from Illinois, Indiana, Minnesota, New York, Ohio, and Wisconsin. Yonke and Medler (1968a) noted, however, that this species is rare in Wisconsin. Chittenden (1925) provided brief notes about the biology of this species in Virginia. *L. oppositus* feeds on a variety of host plants including many cultivated crops although, compared to other members of the genus found in Michigan, this species is considerably less injurious to conifers (Blatchley 1926, Baranowski and Slater 1986). The economic significance of this species was discussed by Mitchell (2000). Allen (1969) revised the genus and McPherson et al. (1990) keyed the species occurring in the United States. 1 specimen examined. Collection date is 8 November.

*Leptoglossus phyllopus* (Linnaeus), 1767 – One individual of this species from Michigan was found in the material examined. Label data as follows: MICHIGAN: Ingham Co., T4N R210, Sec. 7, home, 20 February 1976, M. C. Nielsen (MSU). The following information written on the underside of the label was nearly missed by the author: “from ‘romaine’ lettuce package.” This specimen clearly represents an unnatural introduction, and unless a breeding population is confirmed, *L. phyllopus* should be regarded as an adventive species in Michigan. This coreid is known from New York and Iowa but no records exist for any other Midwestern states. *L. phyllopus* is readily separated from all species of *Leptoglossus* native to Michigan by the conspicuous straight transverse fascia of the hemelytra and from *L. corculus* and *L. occidentalis* by the scalloped outer margin of the metatibial dilation.

**Tribe CHARIESTERINI Stål, 1867**

**Genus CHARIESTERUS Laporte, 1832**

*Chariesterus antennator* (Fabricius), 1803. (Fig. 12). – Often known as the euphorbia bug, this species was reported from Michigan by Hussey (1922). He commented “this is the most characteristic bug of the fore-dunes, where it appears to be restricted to a single food-plant, the flowering spurge (*Euphorbia corollata*). Nymphs and adults are abundant here through the summer.” Wheeler, Jr. (1981) noted association of *C. antennator* with several *Euphorbia* spp., and Blatchley (1926)
listed other presumed host plants in various eastern states. Ruckes (1955) revised the genus. 70 specimens examined. Collection dates from 5 June to 19 September.

Tribe COREINI Leach, 1815
Genus ANASA Amyot and Serville, 1843

Anasa armigera (Say), 1825. (Fig. 13). – Commonly known as the horned squash bug, this species was reported from Michigan by Hussey (1922) from “grasses in an alder-buttonbush swamp at new Buffalo.” The species of this genus are well-known pests of cucurbits, and Parshley (1918) reported this species feeding on both cultivated and star-cucumber in New England. This economic impact of this species was treated briefly by Mitchell (2000). Beard (1937) described and illustrated the nymphs. Brailovsky (1985) revised and keyed the genus. 33 specimens examined. Collection dates from 30 April to 8 September.

Anasa tristis (DeGeer), 1775. (Fig. 14). – The infamous squash bug was reported from Michigan by Townsend (1890) and Hussey (1922). The former noted “the matured insects become active in sunny weather about the last of August.” Hussey (1922) provided the following details:

“Mr. Hubbell took one individual of this common species at Klute’s Lake, near Three Oaks…and a number of specimens were collected at light in our camp on the lake shore early in July. A winter-killed individual of the preceding year was found under the bark of a dead pine on the fore-dune.”

Several individuals examined by the author were taken from a wood cellar in Washtenaw County. This insect may seek overwintering sites in human habitations, and this predilection probably accounts for the earliest and latest collection dates. Yonke and Medler (1969a) provided notes on the immature stages and biology of this species in Wisconsin as a supplement to the extensive study of these species by Beard (1940). As with other species of this genus, A. tristis is a pest of cultivated cucurbits and star-cucumber (Parshley 1918, Beard 1940; Mitchell 2000) discussed the economic importance of this species. Brailovsky (1985) revised and keyed the genus. 145 specimens examined. Collection dates from 25 February to 12 December.

Figure 11. Distribution of Leptoglossus oppositus in Michigan.
Figure 12. Distribution of Chariesterus antennator in Michigan.
Genus CATORHINTHA Stål, 1859

Catorhintha mendica Stål, 1870. (Fig. 15). – This species was reported from Michigan by Hoebeke and Wheeler, Jr. (1982b), who also provided information on biology and dispersal. Yonke and Medler (1969a) provided biological notes on this species in Wisconsin, and Slater (1943) described the instars. This coreid is associated with Mirabilis spp. (Balduf 1942, 1957, Hoebeke and Wheeler, Jr. 1982b). Brailovsky and Garcia (1987) revised and keyed the genus. 16 specimens examined. Collection dates from 21 June to 7 October.

Tribe NEMATOPINI Amyot and Serville, 1843

Genus PIEZOGASTER Amyot and Serville, 1843

Piezogaster alternatus (Say), 1825. (Fig. 16). – This species was reported from Michigan by Van Duzee (1917) under the binomial Archimerus alternatus. The author has not been able to locate an earlier literature record; neither Townsend (1890) nor Hussey (1922) mentioned this species. The Michigan specimen found in material examined bears the following label data: MICHIGAN: Cass Co., Dr. Lawless Co. Park, T6S, R13W, Sec. 32, UV, 16 September 1995, M. C. Nielsen [1 male] (MSU). O’Shea (1980) incorrectly synonymized P. alternatus with P. calcarator (Fabricius), 1803 (Packauskas, pers. comm.). The latter species is restricted to the southeastern states, and Blatchley (1926) correctly keyed the two species. Yonke and Medler (1969a, 1969d) provided much information about the immature stages and biology of this species in Wisconsin; it commonly occurs on Desmodium spp. (Leguminosae). 1 specimen examined. Collection date is 16 September.

Subfamily MEROPACHYINAE Stål, 1867

Genus MEROCORIS Perty, 1833

Merocoris distinctus Dallas, 1852. (Fig. 17). – (NEW STATE RECORD). To the author’s knowledge, no species of Merocoris have been reported from Michigan even though this species is known from surrounding regions and a considerable number of specimens have been examined. Label data indicate this species has been taken “on Solidago” in Dickinson County and “sweeping fallow roadsides.
Solidago dominant. Some shrubs.” in Isabella County. This species has been collected from Isle Royale, Keweenaw County. There has been much confusion about how to treat the three taxa occurring in the United States; Baranowski and Slater’s (1986) interpretation of Merocoris typhaeus (Fabricius), 1798 as an essentially Floridian species is followed here. Species of the genus probably feed on Polygala spp., but they have been observed on Baccharis spp. and Solidago spp. (Schaefer and Mitchell 1983). It has also been recorded feeding on a tortoise carcass in New York (Engelhardt 1912). Yonke and Medler (1969a) provided notes on the biology of this species in Wisconsin, including another incidence of its association with carrion. A key to the tribe containing the Nearctic species was given by Brailovsky and Barrera (2009). 88 specimens examined. Collection dates from 4 May to 27 September.

Subfamily PSEUDOPHLOEINAE Stål, 1867

Genus CORIOMERIS Westwood, 1842

Coriomeris humilis (Uhler), 1872. (Fig. 18). – This species was reported from Michigan by Hussey (1922) “beaten from willow in a gravel pit at Hartbert.” The records for Eaton, Kent, and Wayne counties were approximated from Dolling and Yonke (1976); no specimens were examined by the author from these localities. Label data on specimens from Isabella County indicate “Sweeping fallow roadside. Solidago dominant. Some shrubs.” The genus was revised and the Nearctic species keyed by Dolling and Yonke (1976); they also suggested C. humilis is univoltine, peaks from June to July, and overwinters as an adult. Feeding is not known to occur outside the Leguminosae (Dolling and Yonke 1976, Schaefer and Mitchell 1983). The presence of this species in the eastern United States, along with some of the Michigan records housed in the UMMZ, is briefly discussed by Slater and Schaefer (1963). 21 specimens examined. Collection dates from 3 March to 17 September.

Family RHOPALIDAE Amyot and Serville, 1843

Members of this family are commonly known as the scentless plant bugs. Most are small and inconspicuous although one (the boxelder bug, Boisea trivittata)
is well known and frequently encountered in large aggregations around homes. In Michigan, the Rhopalidae are represented by 8 species in 6 genera. Schaefer and Chopra (1982) provided a list of food plants. Hambleton (1908) revised the genus Corizus which then included four of the Michigan taxa treated below (punctiventris, hyalinus, lateralis, and nigristernum). More recently, Hoebeke and Wheeler, Jr. (1982a) treated the species of this family found east of the Mississippi; all of the species presently known from Michigan are included and the following key is modified from that reference.

Key to the Rhopalidae of Michigan

1. Lateral pronotal margins distinctly notched behind anterior margin (Serenithinae); conspicuously colored, black and red; length 11 mm or more
   - Boisea trivittata

1'. Lateral pronotal margins straight or slightly sinuate, without distinct notch behind anterior margin (Rhopalinae); generally inconspicuously colored; length usually a little more than 9 mm

2 (1'). Metafemur incrassate, bearing a series of prominent spines (Harmostini)
   - Harmostes reflexulus

2'. Metafemur not incrassate, lacking prominent spines

3 (2'). Metapleuron not or only indistinctly divided into episternum and epimeron; metathoracic scent gland openings indistinct or absent; pronotal cicatrices generally ending in a closed loop (Stictopleurus)

3'. Metapleuron distinctly divided into episternum and epimeron; metathoracic scent gland openings more conspicuous; pronotal cicatrices not ending in a closed loop

4 (3). Projection of apical margin of male genital capsule with apex rounded; paramere without subbasal enlargement, flat and tapering; female conspicuously reddish
   - Stictopleurus knighti

Figure 17. Distribution of *Merocoris distinctus* in Michigan.
Figure 18. Distribution of *Coriomeris humilis* in Michigan.
4' Projection of apical margin of male genital capsule with apex emarginated; paramere with pronounced globose enlargement basally, strongly tapering distally, recurved so that posterior face is concave; female fuscotestaceous, not conspicuously reddish.......................... *Stictopleurus punctiventris*

5 (3') Pronotum with distinct, but narrow collar anteriorly; pronotum between collar and cicatrices forming a distinct ridge which is polished and impunctate, or at most with a few punctures; abdomen truncate, broadly rounded apically ........................................................................... *Liorhyssus hyalinus*

5' Pronotum without collar anteriorly; pronotum anterior to cicatrices not smooth or polished, always with numerous coarse punctures; abdomen triangulate apically ...............................................................................6

6 (5') Head quite short, more than 1.5 times as broad as long; rostrum short, not or barely extending to metasternum; posterolateral margin of metapleuron strongly angulate, with prominent and pointed projection laterally................................................................. *Brachycarenus tigrinus*

6' Head longer, less than 1.5 times as broad as long; rostrum extending beyond metasternum; posterolateral margin of metapleuron usually straight or slightly sinuate (Niesthrini: *Arhyssus*)...............................7

7 (6') Apical margin of male genital capsule somewhat emarginated; female with ultimate tergite broadly triangular; coloration lighter, pale dull yellow to reddish.......................................................... *Arhyssus lateralis*

7' Apical margin of male genital capsule more or less straight; female with ultimate tergite acutely triangular; coloration darker, dark gray-white to red-brown or fuscous-black ..................................... *Arhyssus nigristernum*

Subfamily RHOPALINAE Amyot and Serville, 1843

Tribe HARMOSTINI Stål, 1873

Genus HARMOSTES Burmeister, 1835

*Harmostes reflexulus* (Say), 1832. (Fig. 19). – This species was reported by Hussey (1922), who noted: “taken in the fields about the Warren Woods... and one swept from roadside grasses at Lakeside.” It has been collected from cultivated strawberry in Berrien County. Members of the tribe Harmostini feed on Asteraceae (Compositae) (Schaefer and Mitchell 1983). Yonke and Medler (1967) and Yonke and Walker (1970a, 1970b) provided biological notes. Göllner-Scheiding (1978a) revised the genus. 164 specimens examined. Collection dates from 11 February to 17 October.

Tribe NIESTHRINI Chopra, 1967

Genus ARHYSSUS Stål, 1870

*Arhyssus lateralis* (Say), 1825. (Fig. 20). – Townsend (1890) probably was the first to report this species from Michigan (as *Corizus lateralis*), but he mistakenly included it within the Berytidae. Hussey (1922) also listed this species from Michigan (as *Corizus lateralis*), noting it “very abundant in the grassy fields around the Warren Woods from late June to September, and in similar localities in the dune region during July.” Hambleton (1909) and Readio (1928) provided biological information for the species in Ohio and Kansas, respectively. Paskewitz and McPherson (1983) provided information on life history of the species in southern Illinois as well as laboratory rearing techniques. Chopra (1968) revised and keyed the genus. 211 specimens examined. Collection dates from 9 March to 13 November.

*Arhyssus nigristernum* (Signoret), 1859. (Fig. 21). – This species was reported by Hussey (1922) as *Corizus bohemanni* [sic]. In Isabella County, it was taken by “sweeping brackensweet fern fallow field”, and in Jackson County, it was
taken on Queen Anne’s lace (*Daucus carota* L.). This species also has been collected from Isle Royale, Keweenaw County. Chopra (1968) revised and keyed the genus. 78 specimens examined. Collection dates from 27 April to 19 September.

Tribe RHOPALINI Amyot and Serville, 1843

Genus BRACHYCARENUS Fieber, 1860

*Brachycarenus tigrinus* (Schilling), 1829. (Fig. 22). – This adventive Old World species was reported from Michigan by Wheeler, Jr. (1992), who collected a single specimen in a cemetery in Dansville, Ingham County, on hoary alyssum (*Berteroa incana* (L.)). The author visited the locality and collected another individual,
demonstrating the presence of an established population in Michigan. The specimen bears the following label data: MICHIGAN: Ingham Co., Dansville, Fairview Cemetery, SW. corner, 2 September 2011, 42.5539°N 84.2964°W, #46, 950 ft., D. R. Swanson [1 male] (DRS). The specimen was taken simultaneously with *Stictopleurus punctiventris*, and *Harmostes reflexulus* was taken in the surrounding area. The generic placement of this species has varied, with many earlier references relegating *Brachycarenus* to a subgenus of *Rhopalus* Schilling, 1827; however, Dolling’s (2006) treatment is followed here. In the United States, *B. tigrinus* is associated with crucifers (Brassicaceae) (Wheeler, Jr. and Hoebeke 1988). The presence and subsequent spread of *B. tigrinus* in the United States has been well-documented (Hoebeke 1977, Hoebeke and Wheeler, Jr. 1982, Wheeler, Jr. and Hoebeke 1988, 1999, Wheeler, Jr. 2004), and Scudder (2007) reported the first record from Canada. Wheeler, Jr. and Hoebeke (1988) provided biological information. Göllner-Scheiding (1978b) reviewed and keyed *Rhopalus*, including the two species in *Brachycarenus*. 1 specimen examined. Collection dates from 15 July to 2 September.

**Genus LIORHYSSUS Stål, 1870**

*Liorhyssus hyalinus* (Fabricius), 1794. (Fig. 23). – **(NEW STATE RECORD).** Label data as follows: MICHIGAN: Jackson Co., Jackson, 27 August 1963, R. & J. Matthews [1 female] (MSU). It is assumed that this is not an adventitious individual because several other coreoids examined by the author (*Catorhintha mendica*, *Chariesterus antennator*, *Harmostes reflexulus*, and *Stictopleurus punctiventris*) bear identical locality data; it would not be unexpected to find these species syntopically. Furthermore, *L. hyalinus* is known from Indiana, Ohio, and Ontario (Henry 1988) which supports the presence of this species in Michigan. This rhopalid sometimes is referred to as the hyaline grass bug. Readio (1928) provided information on the life history of this species in Kansas. Carlson (1959) studied economic effects of this insect in California; it is also discussed by Schaefer and Kotulski (2000). Göllner-Scheiding (1976) revised and keyed the genus. 1 specimen examined. Collection date is 27 August.

**Genus STICTOPLEURUS Stål, 1872**

*Stictopleurus knighti* Harris, 1942. (Fig. 24). – This species was reported from Thompson, Michigan by Harris (1944); however, the Agricultural College record is excluded because labels of this type typically denote ownership rather than a collecting locality (O’Brien 1998). This species can be difficult to separate from the following species, and *S. knighti* may occur more widely in the state than is evidenced by the distribution map. Göllner-Scheiding (1975) revised the genus and included a key to species. 6 specimens examined. Collection dates from 3 June to 22 August.

*Stictopleurus punctiventris* (Dallas), 1852. (Fig. 25). – This species was reported from Michigan by Harris (1944), although he included no specific localities. In Livingston County, *S. punctiventris* has been taken on flowers of prairie fleabane (*Erigeron strigosus* Muhl. ex Willd.). It also has been collected from Isle Royale, Keweenaw County. Yonke and Medler (1967) provided life history information for this species (as *S. crassicornis*). Göllner-Scheiding (1975) revised the genus and included a key to species. 198 specimens examined. Collection dates from 25 March to 27 September.

**Subfamily SERINETHINAE Stål, 1873**

**Genus BOISEA Kirkaldy, 1910**

*Boisea trivittata* (Say), 1825. (Fig. 26). – The presence of the boxelder bug in Michigan was first referenced by McDaniel (1933), although no specific locality was given and the record was understandably overlooked (Schaefer 1975, Henry 1988). The collection dates reflect the tendency of this species to enter human habitations...
in search of overwintering sites. This behavior, coupled with the massive vernal and autumnal aggregations witnessed on man-made structures, make *B. trivittata* the most encountered and, perhaps, the best known coreoid in Michigan. As previously noted (see *Leptoglossus occidentalis* (Coreidae) above), the high frequency of encounter between humans and insects doubtlessly accounts for the low county representation among material in collections, and *B. trivittata* probably occurs state-wide in Michigan. This species is closely tied to boxelder (*Acer negundo* L.), although feeding is not restricted to this plant (Schaefer and Kotulski 2000,
Slater and Schaefer 1963). This species has been studied in Michigan (Bouldrey and Grimnes 1995, Grimnes et al. 2003), and its life history has been documented (Smith and Shepard 1937, Tinker 1952). Yoder and Robinson (1990) presented information on behavior in an urban setting. Wheeler, Jr. (1982) provided information on its economic importance and life history. Slater and Schaefer (1963) reported aspects of distribution and eastward dispersal. Schaefer (1975) treated the two species of Boisea found in the Nearctic region; Göllner-Scheiding (1980) revised the genus. 192 specimens examined. Collection dates from 27 February to 3 December.

Acknowledgments

I thank Mark O’Brien (UMMZ) for his suggestion of undertaking this project, his sponsorship regarding loaned material, and his constant support of my entomological pursuits. I am grateful to Gary Parsons (MSU) for accommodating several visits to the collection in East Lansing to study the material under his care. To Dr. Richard Packauskas, Fort Hays State University, Hays, Kansas (FHSU), I am indebted for his invaluable comments on the manuscript as well as communication regarding specimens residing in his institution. I owe many thanks to Dr. A. G. Wheeler, Jr., Clemson University, Clemson, South Carolina and an anonymous reviewer for their helpful suggestions for improving the manuscript. I also thank Abigail Alvarez for her patience and advice which allowed me to create the distribution maps.

Literature Cited


Mead, F. W. 1981. The coreid bug, Euthochtha galeator (Fabricius) in Florida (Hemiptera: Coreidae). Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Entomology Circular No. 222, 4 pages.


Packauskas, R. J. 2010. Catalog of the Coreidae, or Leaf-footed Bugs, of the New World. Fort Hays Studies, Fourth Series, Number 5. 270 pages.


Bark Beetle (Coleoptera: Curculionidae: Scolytinae) Community Structure in Northeastern and Central Minnesota

Jesse A. Pfammatter¹, David R. Coyle², Ann M. Journey³, ⁴, Tiffany L. Pahs³, John C. Luhman³, Valerie J. Cervenka³, ⁵, and Robert L. Koch²

Abstract

Large-scale surveys of forest insects provide two distinct benefits: the detection of invasive and exotic species that cause millions of dollars of damage annually to forest and ornamental industries, and the addition of a wealth of species distribution and diversity information to the scientific community. We intensively surveyed the Northeast and East-central regions of Minnesota from 2006-2008 for invasive/exotic and native Scolytinae using Lindgren funnel traps baited with one of four lures (α/β-pinene, ultra-high-release ethanol [EtOH], EtOH+α-pinene, and Ips 3-part). We captured 16,841 scolytines (representing 25 genera) of which over 40% were Ips pini (Say) and Ips grandicollis (Eichhoff). We found two exotic Scolytinae, Scolytus multistriatus (Marsham) and Scolytus schevyrewii Semenov, both of which had previously been recorded in Minnesota. Two native species, Conophthorus coniperda (Schwarz) and Crypturgus pusillus (Gyllenhal), were reported for the first time in Minnesota. Non-metric multi-dimensional scaling and analysis of similarities indicate that lure types capture different Scolytinae communities, while year, weather pattern and region factors were not significant. We also report the seasonal phenology of the seven most abundantly captured species; Dendroctonus valens LeConte, Hylastes porculus Erichson, Hylurgops rugipennis pinifex (Fitch), I. grandicollis, I. pini, Orthotomicus caelatus (Eichhoff) and Pityophthorus spp. Eichhoff.

1Department of Entomology, University of Wisconsin, 345 Russell Labs, Madison, WI, 53706. (e-mail: pfammatter@wisc.edu).
2D.B. Warnell School of Forestry and Natural Resources, University of Georgia, 180 Green Street, Athens, GA, 30602.
3Plant Protection Division, Minnesota Department of Agriculture, 625 Robert Street North, Saint Paul, MN, 55155.
4Current affiliation: Department of Entomology, University of Minnesota, 1980 Folwell Avenue, Saint Paul, MN, 55108.
5Current affiliation: Division of Forestry, Minnesota Department of Natural Resources, 500 Lafayette Road, Saint Paul, MN, 55155.

Bark and ambrosia beetles (Coleoptera: Curculionidae: Scolytinae) are phloehophagous, xylophagous and xylomycetophagous insects, with over 475 species in North America (Wood 1982). Most species oviposit in weakened and dying host trees where larvae feed/develop, contributing greatly to primary decomposition in forests (Wood 1982). Scolytines are primarily attracted to host trees via volatile oleoresins, terpene hydrocarbons, alcohols, or other substances emitted by injured or dying host tissue (Rudinksy 1966), and often secondarily attracted by the release of beetle-produced sex pheromones (Wood 1970). At high populations, several species within the Scolytinae (e.g., Dendroctonus spp.) are capable of mass attacking and killing well-defended host trees, causing significant disturbances within healthy forest stands (Raffa et al. 1993). Anderson (1961) estimated that more than 60% of all insect-related tree mortality is caused...
by bark and ambrosia beetles, making the scolytines one of the most important groups of insect pests impacting North American forests (Rabaglia et al. 2006).

Scolytinae introductions represent a growing threat to native forests. Due to their vast range and diverse environment, forests are particularly susceptible to damage by exotic insect species (Liebhold et al. 1995). Exotic insects can alter biogeochemical processes (Peltzer et al. 2010), threaten rare native species (Wagner and Van Driesche 2010), and contribute to range alteration of native species, especially when the effects of future climate change are considered (Walther et al. 2009). An increasing number of exotic species make their way into North America each year, costing the U.S. economy an estimated $137 billion annually (Pimentel et al. 2000). The $8.6 billion forest products industry in Minnesota (http://www.minnesotaforests.com/resources/pdfs/economy.pdf), combined with the high potential for Curculionidae invasion near U.S. ports-of-entry (Liebhold et al. 1995), make insect community surveys and management studies a priority in this region. Invasive species are generally managed via chemical, biological, or silvicultural methods, yet success of these methods varies (Gandhi and Herms 2010).

A proactive approach, including effective monitoring programs (i.e., early detection) and open communication among scientists and managers, is universally regarded as the most valuable tool in invasive species management (Lovett et al. 2006). Rapid response efforts such as eradication and/or quarantine efforts are often more effective when coupled with early detection strategies. Continued monitoring programs, such as CAPS (Cooperative Agricultural Pest Survey) and USFS (US Forest Service) programs, help assist in the early detection of invasive/exotic species, allowing more appropriate/cost effective management or eradication techniques to be implemented (Haack 2006), as well as provide a framework for a survey and description of known and native species communities (Gandhi et al. 2010).

In addition to information gathered on the presence or absence of invasive species, surveys of insect communities provide an invaluable wealth of ecological information. Survey data can be used to study the effects of climate change (Hillstrom and Lindroth 2008) and land management strategies (Wilby et al. 2006), as well as provide an abundance of information on interspecific interactions. Broad surveys aid in the understanding of complex ecological interactions by providing data on primary and secondary species within a community, the latter of which can be very important to and are often missing from studies on primary species interactions (Abbot et al. 2009). Elucidating interspecies relationships with the aid of survey data may provide insight into the population ecology of individual keystone species (Elton and Miller 1954).

Using four different lures over a three-year period, we intensively sampled regions of Minnesota that are at high-risk for exotic bark and ambrosia beetle introductions. Overstocked pine stands near high-risk introduction sites such as port areas, green waste areas, and major stone and tile importers, were targeted as trapping locations. Trapping focused primarily on stands of host trees or parklands close to potential introduction sites in or near metropolitan areas. The objectives of this study were to detect any new, exotic Scolytinae infestations, describe the known Scolytinae community in terms of spatial and temporal variation, and evaluate the trapping efficacy of the attractant lures used in the survey.

Methods and Materials

Study locations. All sampling occurred in Northeast and East-central Minnesota (Table 1). Average temperatures and rainfall were slightly higher in the East-central than the Northeast region (Table 2). Overall, the counties surveyed had nearly 101,000 ha of pine and mixed hardwoods. All study sites were at least 0.02 ha in size and contained plantings at least three trees wide.
Table 1. County level allocation of sampling effort from 2006 to 2008 in seven counties in Minnesota. Total number of traps deployed includes all lure types (α/β-pinene (NA 2006), EtOH+α-pinene (NA 2006 and 2007), EtOH (NA 2008), and Ips 3-part).

<table>
<thead>
<tr>
<th>Region</th>
<th>County</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>Traps deployed</th>
</tr>
</thead>
<tbody>
<tr>
<td>East-central</td>
<td>Anoka</td>
<td>3</td>
<td>2</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Northeast</td>
<td>Carlton</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>East-central</td>
<td>Chisago</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>East-central</td>
<td>Hennepin</td>
<td>10</td>
<td>7</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>East-central</td>
<td>Sherburne</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Northeast</td>
<td>St. Louis</td>
<td>11</td>
<td>9</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>East-central</td>
<td>Stearns</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>East-central</td>
<td>Wright</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>28</td>
<td>27</td>
<td>54</td>
<td>135</td>
</tr>
</tbody>
</table>

**Trapping methodology.** Trapping was based on United States Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS) guidelines (PPQ/EDP/EP 2006). A detection network consisting of semiochemical-baited Lindgren funnel traps (Lindgren 1983) was established and maintained in stands of host trees (Pinus resinosa Ait, Pinus strobus L, Pinus banksiana Lamb, and Pinus sylvestris L). Traps were hung at least 25 m apart, in partial shade, and at least 30 cm above the ground. Funnel traps were hung with dry collection cups (containing Vapona) in 2006 – 2007 and wet collection cups (containing propylene glycol) in 2008. Traps were baited with one of four lure types; 1) Sirex lure with α/β-pinene (170 g of 70:30 blend S(-) α/β-pinene at ~50% enantiomeric excess) in 2007 – 2008, 2) ultra high-release ethanol (EtOH) (100 ml of 95% EtOH) in 2006 – 2007, 3) EtOH+α-pinene (100 ml of 95% EtOH and 85 g of R(-) α-pinene at ~50% enantiomeric excess) in 2008, and 4) Ips 3-part exotic bark beetle lure (3.5 g of 2,3,2-methylbutenol, 40 mg of racemic ipsdienol, and 150 mg of S(-) cis-verbenol; 2006-2008). Given all lures were not used in each year, ‘NA’ is used to indicate non-sampled years. Traps were checked approximately every two weeks, and lures were changed every four to six weeks per manufacturer directions. Lures were obtained from Phero Tech, Inc. (now Contech Enterprises, Delta, BC, Canada) for the initial batch in 2006, and Synergy Semiochemical Corp. (Burnaby, BC, Canada) for the remainder of 2006 as well as 2007 – 2008. Traps in the East-central region were monitored from 14 June to 26 October 2006, 16 April to 18 October 2007, and 7 April to 27 October 2008. Traps in northeastern Minnesota were monitored from 24 May to 11 October 2006, 16 April to 18 October 2007, and 9 April to 23 October 2008. Samples collected from traps were delivered to the St. Paul office of the Minnesota Department of Agriculture and stored in a freezer for processing. All bark beetles were sorted to species by the lead trapper (AMJ in 2006, TLP in 2007 and 2008) and verified by Dr. John Luhman (Minnesota Department of Agriculture). Voucher specimens are housed in the University of Minnesota Insect Museum, St. Paul, Minnesota.

**Statistical analyses.** The original purpose of this study was to identify new exotic Scolytinae, and we accept that our sample design lacks symmetry in terms of trapping lures and effort (Table 1). This uneven sample design provided significant challenges regarding data analyses, and therefore we have taken a conservative and exploratory approach. All data were analyzed using R statistical software version 2.14.0 for Mac OS X (R Development Core Team 2011), and all analyses were performed (except rarefaction curves) on species community data standardized by trap days.
Table 2. Average temperature during the study period (April-October, 2006-2008) and total precipitation and snowfall (year round, 2006-2008) in Duluth, MN (212248 Duluth WSO AP) and New Hope, MN (215838 NEW HOPE). Duluth and New Hope are chosen to be representative of Northeast and East-central Minnesota. Temperature, precipitation and snowfall were recorded by the National Weather Service and obtained from the University of Minnesota climate center (http://climate.umn.edu/hidradius/radius.asp).

<table>
<thead>
<tr>
<th>Year</th>
<th>Duluth</th>
<th>New Hope</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ave. Max. Temp. (°C)</td>
<td>Ave. Min. Temp. (°C)</td>
</tr>
<tr>
<td>2006</td>
<td>18.9</td>
<td>8.0</td>
</tr>
<tr>
<td>2007</td>
<td>19.1</td>
<td>7.8</td>
</tr>
<tr>
<td>2008</td>
<td>17.3</td>
<td>6.8</td>
</tr>
</tbody>
</table>
Rarefaction curves were used to determine if sampling intensity was adequate to capture the majority of bark beetle diversity in our study areas, defined as the bark beetle community attracted to at least one of the trap lures; $\alpha/\beta$-pinene, EtOH, EtOH+$\alpha$-pinene and $Ips$ 3-part (Heck et al. 1975). Rarefaction curves were calculated using study site as the unit of replication for each year independently and collectively (function: specaccum, package: vegan, method: rarefaction, permutations = 100). Trap catch data were aggregated additively (function: aggregate, constraints: trap year and trap site).

Due to the high number of traps with zero captures, data for individual species and total Scolytinae captures failed to meet the normality requirement for analysis of variance. All transformation attempts were unsuccessful at achieving normality; therefore, combined with the community-based nature of our data we used ordinal analytical methods (Kruskal 1964, Minchin 1987). Community-level trends were visualized using non-linear multi-dimensional scaling (NMS) (function: nmds, package: ecodist, 300 runs, random start configuration). Statistical trends in community assemblage data were calculated by analysis of similarities (ANOSIM) (function: anosim, package: vegan) (Clark 1993). Ordination and ANOSIM analyses were performed on community data resembled to a Bray-Curtis distance matrix data (function: distance, package: ecodist). Data used to create the distance matrix was standardized by total trap days and aggregated additively (function: aggregate, constraints: region, trap type, week and year). Aggregated samples with fewer than five total species captured were removed from the data matrix for NMS analyses. Likewise, individual species appearing in less than five samples were removed from NMS analysis. Species correlations vectors (Jongman et al. 1995) (function: vf, package: ecodist) for the seven most abundant beetle species were fit on the NMS ordinations. Significant species correlations ($P < 0.05$) are denoted with an asterisk (fig. 2).

Phenology curves (function: xyplot, package: lattice) created for the seven most abundant scolytine species were compiled from additively aggregated (function: aggregate, constraints: trap date and type) data.

**Results**

We captured 16,841 Scolytinae, representing 13 tribes, 25 genera, and 52 species, of which more than 40% were $Ips$ grandicollis (Eichhoff) and $Ips$ pini (Say) (Table 3). Native species captures of Conophthusor coniperda (Schwarz) and Crypturgus pusillus (Gyllenhal) are new Minnesota state records. The only exotic Scolytinae captured were Scolytus multistriatus (Marsham) and Scolytus chevreyrei Semenov, neither of which were new to Minnesota. Exotic species accounted for only 0.16% of total Scolytinae captured in our study.

Rarefaction analyses indicated that we surveyed a majority of the Scolytinae diversity in Minnesota (as possibly sampled by our 4 lure types) over the entire study period, but not within an individual year; due in large part to the variations in lure composition and deployment between years (Fig. 1).

The Scolytinae community in the East-central region did not differ in species composition from that of the Northeast region (ANOSIM $R = 0.075$, $P = 0.191$). Species community composition did not differ based on average yearly temperature (Table 2) (ANOSIM $R = -0.013$, $P = 0.510$) or total yearly precipitation/snowfall (Table 2) (ANOSIM $R = -0.013$, $P = 0.500$). The community did not significantly vary among years (ANOSIM $R = 0.065$, $P = 0.200$) (Fig. 1), although large swings in individual species abundances were observed from the unstandardized data (e.g., $Hylurgops$ rugipennis pinifex I(Fitch)).

Lure types caught different communities of Scolytinae (ANOSIM $R = 0.802$, $P < 0.001$) (Fig. 2). $\alpha/\beta$-Pinene was the most effective lure for catching a broad range of abundant Scolytinae (Table 3, Fig. 2), although $I.pini$ and Lymantor decipiens...
Table 3. Total bark and ambrosia beetles (Coleoptera: Curculionidae: Scolytinae) captured in East-central and Northeast Minnesota from 2006-2008 using four lure types (α/β-pinene (NA 2006), EtOH+α-pinene (NA 2006 and 2007), EtOH (NA 2008), and Ips 3-part). Total beetle captures have been broken down by year, lure type and study region.

<table>
<thead>
<tr>
<th>Tribe</th>
<th>Species</th>
<th>Year</th>
<th>Lure</th>
<th>Region</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2006</td>
<td>α/β-pinene</td>
<td>EtOH+α-pinene</td>
<td>EtOH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2007</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2008</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xyleborini</td>
<td><em>Anisandrus obesus</em> (LeConte)</td>
<td>42</td>
<td>1</td>
<td>358</td>
<td>12</td>
</tr>
<tr>
<td>Corthylini</td>
<td><em>Conophthus coniperda</em> (Schwarz)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Corthylini</td>
<td><em>Conophthus resinosae</em> Hopkins</td>
<td>1</td>
<td>14</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Corthylini</td>
<td><em>Conophthus spp.</em> Hopkins</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cryptalini</td>
<td><em>Cryphalus ruficollis</em> Hopkins</td>
<td>0</td>
<td>4</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Crypturgini</td>
<td><em>Crypturgus borealis</em> Swaine</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>Crypturgini</td>
<td><em>Crypturgus pusillus</em> (Gyllenhal)</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Corthylini</td>
<td><em>Corhylus punctatissimus</em> (Zimmerman)</td>
<td>0</td>
<td>3</td>
<td>21</td>
<td>3</td>
</tr>
<tr>
<td>Tomicini</td>
<td><em>Dendroctonus rufipennis</em> Kirby</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Tomicini</td>
<td><em>Dendroctonus simplex</em> LeConte</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Tomicini</td>
<td><em>Dendroctonus valens</em> LeConte</td>
<td>19</td>
<td>684</td>
<td>292</td>
<td>890</td>
</tr>
<tr>
<td>Dryocoetini</td>
<td><em>Dryocoetes affaber</em> (Mannerheim)</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Dryocoetini</td>
<td><em>Dryocoetes autographus</em> (Ratzburg)</td>
<td>2</td>
<td>23</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Dryocoetini</td>
<td><em>Dryocoetes caryae</em> Swaine</td>
<td>0</td>
<td>88</td>
<td>49</td>
<td>101</td>
</tr>
<tr>
<td>Dryocoetini</td>
<td><em>Dryocoetes spp.</em> Eichhoff</td>
<td>0</td>
<td>72</td>
<td>130</td>
<td>106</td>
</tr>
<tr>
<td>Corthylini</td>
<td><em>Gnathotrichus materiarious</em> (Fitch)</td>
<td>6</td>
<td>108</td>
<td>68</td>
<td>112</td>
</tr>
<tr>
<td>Hylastini</td>
<td><em>Hylastes porculus</em> Ericson</td>
<td>6</td>
<td>962</td>
<td>700</td>
<td>1178</td>
</tr>
<tr>
<td>Hylesinini</td>
<td><em>Hylesinus aculeatus</em> Say</td>
<td>7</td>
<td>18</td>
<td>37</td>
<td>21</td>
</tr>
<tr>
<td>Tomicini</td>
<td><em>Hylurgopinus rufipes</em> Eichhoff</td>
<td>4</td>
<td>15</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Hylastini</td>
<td><em>Hylurgops rugipennis pinifex</em> (Fitch)</td>
<td>0</td>
<td>899</td>
<td>82</td>
<td>933</td>
</tr>
<tr>
<td>Ipini</td>
<td><em>Ips grandicollis</em> Eichhoff</td>
<td>88</td>
<td>1427</td>
<td>2574</td>
<td>1909</td>
</tr>
<tr>
<td>Ipini</td>
<td><em>Ips perroti</em> Swaine</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ipini</td>
<td><em>Ips pini</em> Say</td>
<td>1164</td>
<td>427</td>
<td>975</td>
<td>107</td>
</tr>
<tr>
<td>Dryocoetini</td>
<td><em>Lymantor decipiens</em> (LeConte)</td>
<td>310</td>
<td>33</td>
<td>45</td>
<td>4</td>
</tr>
<tr>
<td>Micracini</td>
<td><em>Micracis swainei</em> Blackman</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Micracini</td>
<td><em>Micracis spp.</em> LeConte</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tribe</td>
<td>Species</td>
<td>Year</td>
<td>Lure</td>
<td>Region</td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------------------------</td>
<td>------</td>
<td>------</td>
<td>-----------------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2006</td>
<td>2007</td>
<td>2008</td>
<td>α/β-pinene</td>
</tr>
<tr>
<td>Corthylini</td>
<td>Monarthrum mali (Fitch)</td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Ipini</td>
<td>Orthotomicus caelatus (Eichhoff)</td>
<td>41</td>
<td>734</td>
<td>455</td>
<td>771</td>
</tr>
<tr>
<td>Ipini</td>
<td>Orthotomicus latidens (LeConte)</td>
<td>0</td>
<td>11</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Ipini</td>
<td>Orthotomicus spp. Ferrari</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Phloeotribini</td>
<td>Phloeotribus piceae Swaine</td>
<td>0</td>
<td>9</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Ipini</td>
<td>Pityogenes hopkinsi Swaine</td>
<td>2</td>
<td>23</td>
<td>31</td>
<td>20</td>
</tr>
<tr>
<td>Ipini</td>
<td>Pityogenes plagiatius (LeConte)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Ipini</td>
<td>Pityokeine sparsus (LeConte)</td>
<td>0</td>
<td>5</td>
<td>97</td>
<td>17</td>
</tr>
<tr>
<td>Ipini</td>
<td>Pityokeine spp. Fuchs</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Corthylini</td>
<td>Pityophthorus consimilis LeConte</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Corthylini</td>
<td>Pityophthorus lautos Eichhoff</td>
<td>2</td>
<td>0</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>Corthylini</td>
<td>Pityophthorus puberulus (LeConte)</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Corthylini</td>
<td>Pityophthorus spp. Eichhoff</td>
<td>129</td>
<td>731</td>
<td>596</td>
<td>978</td>
</tr>
<tr>
<td>Polygraphini</td>
<td>Polygraphus rufipennis (Kirby)</td>
<td>2</td>
<td>52</td>
<td>48</td>
<td>64</td>
</tr>
<tr>
<td>Scolytini</td>
<td>Scolytus multistriatus (Marsham)</td>
<td>3</td>
<td>2</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>Scolytini</td>
<td>Scolytus muticus Say</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Scolytini</td>
<td>Scolytus piceae (Swaine)</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Scolytini</td>
<td>Scolytus schevryevi Semenov</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Scolytini</td>
<td>Scolytus spp. Geofroy</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Xyloterini</td>
<td>Trypodendron betulae Swaine</td>
<td>0</td>
<td>11</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Xyloterini</td>
<td>Trypodendron lineatum (Olivier)</td>
<td>0</td>
<td>101</td>
<td>211</td>
<td>79</td>
</tr>
<tr>
<td>Xyloterini</td>
<td>Trypodendron retusum (LeConte)</td>
<td>0</td>
<td>20</td>
<td>29</td>
<td>2</td>
</tr>
<tr>
<td>Xyloterini</td>
<td>Trypodendron spp. Stephens</td>
<td>1</td>
<td>74</td>
<td>585</td>
<td>41</td>
</tr>
<tr>
<td>Xyleborini</td>
<td>Xyleborus spp. Eichhoff</td>
<td>120</td>
<td>643</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Xyleborini</td>
<td>Xyleborinus politus (Say)</td>
<td>0</td>
<td>38</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1975</td>
<td>7258</td>
<td>7500</td>
<td>7470</td>
</tr>
</tbody>
</table>
Figure 1. Rarefaction curves of all Scolytinae captured using all trap lure types (α/β-pinene (NA 2006), EtOH+α-pinene (NA 2006 and 2007), EtOH (NA 2008), and Ips 3-part) as accumulated by total sites sampled for 2006, 2007, 2008, and all sample years combined.

Figure 2. NMS plot of Scolytinae community composition using trap captures in the, Northeast and East-central regions of Minnesota from 2006-2008. Bray-Curtis resembled data are labeled by lure type (α/β-pinene (NA 2006), EtOH+α-pinene (NA 2006 and 2007), EtOH (NA 2008), and Ips 3-part). Species correlations are overlaid for the seven most abundant beetle species, significant correlations ($P < 0.05$) are denoted with an asterisk.
(LeConte) were captured in higher numbers with Ips 3-part lures, Trypodendron spp. Stephens with EtOH+α-pinene, and Xyleborus spp. Eichhoff with EtOH. Species vector correlations overlaid on the ordination in Figure 2 were significant for Hylastes porculus Erichson, I. pini, I. grandicollis, and Pityophthorus spp. Eichhoff ($P < 0.050$) with H. porculus, I. pini, and Pityophthorus spp. trending towards α/β-pinene and EtOH+α-pinene lures, while I. grandicollis trended towards Ips lures (Fig. 2). Differences in species abundance between lure types were therefore primarily attributed to H. porculus, I. grandicollis, I. pini, and Pityophthorus spp. (Fig. 2).

Phenology curves for the seven most abundantly captured species indicated a high amount of intra- and inter-annual variation (Fig. 3). While we have standardized all the phenology curves by trap days, it is important to remember that not all lures were used in each year and caution must be taken to ensure direct comparison of phenologies between years are done within the framework of lure type. For example, it would not be appropriate to compare Dendroctonus valens LeConte captures with α/β-pinene lure across all sample years, as α/β-pinene was not sampled in 2006. D. valens populations were generally low except those captured with α/β-pinene lure (Fig. 3A). Populations of D. valens peaked in late spring of 2007 versus fall in 2008 (Fig. 3A). H. porculus populations peaked in June each year and were two and a half times larger in 2007 than in 2008 as sampled by α/β-pinene lure (Fig. 3B). H. rugipennis pinifex was rarely captured in 2006 or 2008, but populations were relatively high in 2007 on the α/β-pinene lure (Fig. 3C). I. pini populations tended to peak in the fall, and were nearly four times as high in 2006 compared with 2007 and 2008 (Fig. 3D). I. grandicollis were most effectively captured on EtOH+α-pinene lure, but also showed strong attractiveness to α/β-pinene lure (Fig. 3E). Orthotomicus caelatus (Eichhoff) populations were variable, with peak flight occurring at a different time each year (Fig. 3F). Pityophthorus spp. generally peaked during June each year and were captured with a variety of lure types (Fig. 3G).

**Discussion**

We captured 52 species of Scolytinae during three years of sampling. While rarefaction curves indicate we sampled a majority of the Scolytinae community (as possibly sampled by the study lure types) (Fig. 1), a catalog of Scolytinae in Michigan and species richness estimates from other temperate states (Idaho, Indiana, Maryland, Montana, Oregon and Washington) indicate that our captures probably approach half of the total Scolytinae richness in Minnesota (Cognato et al. 2009). A similar study in the Superior National Forest captured 34 species of Scolytinae from 2000-2003 (Gandhi et al. 2009).

Recent surveys sampling native bark and ambrosia beetle communities have captured at least 58% invasive and exotic species (Coyle et al. 2005, Miller and Rabaglia 2009, Gandhi et al. 2010). We trapped only two exotic species comprising only 0.16% of total captures in this study. While we feel confident in the robust nature of our protocol (Fig. 1), this lack of exotics is surprising considering the proximity of our sample regions to Lake Superior shipping ports and the increasing record of exotic bark beetle interceptions near U.S. ports-of-entry (Liebhold et al. 1995). The lack of establishment by exotic Scolytinae in Minnesota could be due, in part, to the relatively cold winter climate or less stand disturbances due to the presence of National Forest and the Boundary Waters National Park.

Individual Scolytinae species showed high inter-year and regional variation (i.e., D. valens) (Fig. 3). Our results concur with previous studies showing high geographic (Hulcr et al. 2008) and annual (Brockerhoff et al. 2006) variation in Scolytinae capture rates. Annual variation in Scolytinae captures is not uncommon, often due to long-term weather changes (Bentz et al. 2010),
Figure 3. Phenology of the seven most abundant Scolytinae captured in Minnesota from 2006-2008: A) *Dendroctonus valens*, B) *Hylastes porculus*, C) *Hylurgops rugipennis pinifex*, D) *Ips grandicollis*, E) *Ips pini*, F) *Orthotomicus caelatus* and G) *Pityophthorus* spp. While we have standardized all the phenology curves, not all lures (α/β-pinene (NA 2006), EtOH+α-pinene (NA 2006 and 2007), EtOH (NA 2008), and *Ips* 3-part) were used in each year and caution must be taken to ensure direct comparison of phenologies between years are done within the framework of lure type.
severe weather events (Gandhi et al. 2007), and even regular weather variation (Aukema et al. 2005). We were unable to detect any differences in Scolytinae community based on weather events most likely due to our course scale analyses of these factors. While we observed large variations in individual species abundances, the overall Scolytinae community we captured remained relatively static throughout the three-year study period.

We observed large variations in the Scolytinae community captured by each lure type (Fig. 2). This type of response to semiochemical lures has been well documented for α-pinene, EtOH, and Ips lures (Gandhi et al. 2009); however, few studies have looked at this type of community response with the addition of other terpenoid lure components (Poland et al. 2004). We found strong variation in the Scolytinae community captured by α/β-pinene lure. α/β-pinene seems to be attractive to a much larger suite of Scolytinae than other lure types used in this study (Table 3). Gandhi et al. 2009 found similar attraction to α/β-pinene in the Superior National Forest, Minnesota. However, we did not sample α- or β-pinene independently and thus were unable to discern the full nature of β-pinene’s effects.

Phenologies observed in this study were similar to previously published work. For instance, the phenology of I. grandicollis was nearly identical to that observed in Ohio (Gandhi et al. 2010). Flight of D. valens and I. pini was similar to that in Arizona (Gaylord et al. 2006). Flight of H. porculus, I. grandicollis, and I. pini was similar to that observed in Wisconsin red pine stands (Ayers et al. 2001; Erbilgin and Raffa 2002). Observations on D. valens, H. pinifex and O. caelatus presence on red pine in Michigan indicate similar emergence times, although our study indicates a longer flight period for both D. valens and O. caelatus (Kennedy and McCullough 2002).

In summary, exotic Scolytinae were uncommon in our study, and α- and β-pinene were effective bait components. Phenologies for several Scolytinae indicated mostly univoltine life histories, with the possible exception of D. valens (Fig. 3A) and I. grandicollis (Fig. 3E). Insect surveys are an invaluable contribution to our knowledge of natural systems, yet they are unfortunately rarely published. This study contributes to the taxonomic and biodiversity knowledge of the Scolytinae of Minnesota, and studies such as these (e.g., Gandhi et al. 2010) could serve as a baseline for future work.

Acknowledgments

We thank Nathan Goodell, Heidi Hagman, and Stephanie Visker (Minnesota Department of Agriculture) for field and laboratory assistance. Dennis Haugen (US Forest Service) provided valuable discussions and assistance in the early stages of this work. Claudio Gratton, Nicholas Keuler, Kenneth Raffa and Phil Townsend (UW-Madison) provided invaluable support and statistical assistance. Kamal Gandhi wrote a thorough and insightful review of this manuscript. This project was based on the non-target insects captured in surveys partially funded by the USDA Forest Service and the USDA Animal and Plant Health Inspection Service.

Literature Cited


Notes on the Biology of *Saperda imitans* Infesting Wind-damaged Black Cherry in Allegheny Hardwood Stands

Marc F. DiGirolomo¹, Douglas C. Allen² and Stephen V. Stehman²

Abstract

This paper reports observations made on the life history and biology of *Saperda imitans* Felt & Joutel in black cherry, *Prunus serotina* Ehrh. *S. imitans* was the principle longhorned beetle (Coleoptera:Cerambycidae) reared from bolts collected from 68 wind-thrown black cherry at the Kane Experimental Forest in northwestern Pennsylvania. It was also the only species that overwintered in the sapwood/outer heartwood, and thus impacted the commercial value of these trees. *Gaurotes cyanipennis* (Say) was the only other cerambycid reared from caged bolts taken from wind-thrown black cherry. The cerambycids *Stenocorus vittiger* (Randall), *Arthophylax attenuatus* (Haldman), *G. cyanipennis*, *Neoclytus acuminatus acuminatus* (F.), *Clytus ruricola* (Olivier), *Cyrtophorus verrucosus* (Olivier), and *Astylopsis macula* (Say) were captured in ethanol-baited Lindgren® funnel traps placed in wind-thrown stands, but were not reared from cherry logs. *S. imitans* was not caught in these traps and apparently it is not attracted to ethanol baits. Neither *S. imitans* nor *G. cyanipennis* were reared from completely uprooted trees (dead) or trees with a major portion of the root system still embedded in soil (live). Preferred hosts were black cherry with moist phloem and epicormic branches with <25% live foliage (dying). The density of *S. imitans* galleries was similar for dying trees in each of three diameter classes; 20-30 cm, >30-40 cm, >40 cm. Samples taken from the upper half of the first 5 m of black cherry boles had a higher density of galleries than did those from the lower half. The beetle was recovered in low numbers from branches <10 cm in basal diameter. *S. imitans* is univoltine and in 2007 peak emergence of adults occurred from late May to early June. Results identified the condition of wind-damaged black cherry most susceptible to an infestation of *S. imitans*. This information can be used to establish salvage priorities following a weather event such as this.

Trees that are blown down in violent weather and not salvaged on a timely basis often set the stage for additional forest disturbances, such as fire and increased risks for outbreaks of inner-bark and wood-boring insects (Stathers et al. 1994). Delaying salvage also may allow these insects to reduce the quality of logs recovered from damaged stands (e.g., Wickman 1965, Gardiner 1975, Nevill and Whitehead 1996) or to threaten the survival or quality of live trees in portions of a stand that escaped storm damage (Barry et al. 1993, Eriksson et al. 2005).

On 20-21 July 2003, the Allegheny National Forest (ANF) in northwestern Pennsylvania experienced a series of thunderstorms, downbursts and an F1 tornado, causing extensive windthrow (USDA For. Serv. 2004). Trees were

¹USDA-APHIS, Plant Protection and Quarantine, Worcester, MA (e-mail: mfdigiro@yahoo.com).
²State University College of Environmental Science and Forestry, 1 Forestry Drive, Syracuse, NY 13210 (e-mail: dcallen@esf.edu, svstehma@esf.edu).
moderately to severely damaged on 5,000 ha of the 525,000 ha affected by the storm (Evans et al. 2007). Because of concerns expressed by certain environmental groups who objected to the removal of downed woody material following the storm, salvage of windthrown black cherry, *Prunus serotina* Ehrh., was delayed for three growing seasons. Black cherry is the most desired timber species throughout much of the northeastern United States. Cherry logs from the Allegheny Plateau are less prone to gum defects and the heartwood is a lighter pink compared to cherry grown elsewhere (Cassens 2004); therefore, this resource is highly valued for lumber and veneer (Pennsylvania State University 2007).

*Saperda imitans* Felt & Joutel (Coleoptera:Cerambycidae:Lamiinae) was the most abundant cerambycid reared from the boles of windthrown black cherry in 2005 and 2006. It was the only member of this beetle family that excavated an overwintering gallery in the wood of this tree, making it of special interest because of its potential to degrade cherry logs used for lumber or veneer.

The genus *Saperda* is of economic significance, because several members of the group have an affinity for commercially important tree species in which the larvae feed in the phloem and then excavate overwintering galleries in the sapwood and, in the case of black cherry, the outer heartwood (Solomon 1995). This damage may result in defects that negatively impact the value of timber for veneer. The distribution of *S. imitans* is restricted to northeastern North America (Linsley and Chemsak 1995), and it is considered rare compared to other species of Cerambycidae known from this region (Lingafelter 2007). This windthrow event provided an unusually abundant source of suitable habitat for the beetle that presented an opportunity to learn more about its biology. Current knowledge about *S. imitans* is limited to reports that it feeds on various young hardwoods (Lingafelter 2007) including hickory (Yanega 1996) and that its size and markings may closely resemble some specimens of *S. lateralis* F. and *S. tridentata* Olivier.

In this paper we report observations of the beetle’s life history, host relations, and describe its damage to black cherry logs.

**Methods**

**Study area.** The 1,443 ha Kane Experimental Forest (KEF) (N41°36′26″,W78°46′30″) lies within the ANF in northwestern Pennsylvania. The region is located within the Northern Unglaciated Allegheny Plateau Section of the Laurentian Mixed Forest Province. These forests are dominated by even-aged, second growth cherry-maple stands, a subtype of the more northern beech-birch-maple forest (Eyre 1980). The most common species are black cherry, sugar maple (*Acer saccharum* Marsh.), red maple (*A. rubrum* L.) and American beech (*Fagus grandifolia* Ehrh.). Elevations range from 548 to 640 m. Most forest stands at KEF are 50 to 100 yr old (USDA For. Serv. 1999).

**Attraction of cerambycid adults to ethanol-baited traps.** To determine the relative abundance and temporal activity of wood-boring beetles attacking windthrown black cherry, a transect of five Lindgren® 12-unit funnel traps were deployed beginning approximately 21 m from a road edge and spaced 21 m apart in a line perpendicular to the road in each of three wind-damaged stands from 5 May through 31 August 2006. Traps were suspended from a wooden arm attached to a wooden stake ≈ 2 m above ground and baited with ultra high release (UHR) ethanol lures with a release rate of 0.35g/d at 20°C (Pherotech, Inc., now ConTech Enterprises, Delta, BC, Canada). Approximately 100 ml of ethylene glycol was placed in the bottom of each collection cup to preserve trapped insects. Traps were serviced (samples collected, preservative replaced, lures checked and replaced as needed) once a week.
Within-tree distribution of *S. imitans*. Four bands of bark 30 cm wide and 1.25 m apart were removed from each of 68 windthrown black cherry trees. Band 1 was positioned with the lower edge 25 cm above ground. The base of band 2 was positioned at 1.80 m, band 3 at 3.35 m, and band 4 at 4.9 m. The four bands encompassed the first 5.2 m of the tree bole, the most valuable part of a tree in forest stands managed for sawtimber (Trimble 1965). When accessible, the surface area of each band was determined by measuring its circumference (cm) and multiplying by 30 cm (band width). Occasionally, one or more of the lower bands were partially buried in soil or litter. When this occurred, gallery counts were limited to the exposed portion of the bole. Under these conditions, surface area was determined by multiplying band length (30 cm) by the length of the exposed portion of the circumference. Gallery density was expressed as number/1000 cm² of bole area.

Susceptible host conditions. The mean trunk diameter of these 68 black cherry trees at breast height (1.4 m, dbh) was 35.7 ± 0.9 cm. To determine if bark thickness, as reflected by host size (dbh), influenced susceptibility to the beetle, the trees were assigned to one of three size classes; small (20-30 cm diam., n = 16), medium (>30-40 cm, n = 33) or large (>40 cm, n = 19). Bark thickness has been shown to be positively correlated with diameter at breast height in sugar maple (Smith 1969).

To determine host condition preferred by *S. imitans*, sample trees with three bands or more in contact with the ground (n = 32) were classified as resting on the ground. Gallery density on these trees was compared to that of the remaining 36 trees, which were classified as suspended off the ground (Table 1).

A major portion of the root system for 24 trees remained embedded in soil and these individuals possessed many foliated epicormic branches; moist, light colored phloem; and tight bark (live trees). Twenty two trees had mostly dead epicormic branches (or if alive the epicormic branches had < 25% green foliage); brown, moist phloem; and bark that was easily peeled (dying trees). The remaining 22 trees had no evidence of epicormic branching; dry, dark phloem; and loose bark (dead trees).

Branch bark thickness and the moisture content of the inner bark where cerambycid larvae feed may influence oviposition and larval survival. Large diameter branches of black cherry with thick bark appeared to retain moisture longer than thin-barked ones; however, thicker bark may inhibit oviposition, especially in the cerambycid subfamily Lamiinae in which females of many species (Linsley 1961), including those in the genus *Saperda* (e.g., Drouin and Wong 1975, Nord *et al.* 1972), use their mandibles to chew a depression in the bark where they oviposit (Linsley 1961). We addressed this issue by comparing *S. imitans* gallery density/1000 cm² among branches of different sizes (basal diameter); ten small diam. (< 5 cm basal), 39 medium diam. (5 – 10 cm) and 15 large diam. (> 10 cm) branches taken from the 24 wind-thrown black cherry

<table>
<thead>
<tr>
<th>Tree Size (dbh cm)</th>
<th>Tree Position</th>
<th>Condition of Epicormic Branches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On the Ground</td>
<td>Off the Ground</td>
</tr>
<tr>
<td>&gt; 40</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>&gt; 30 – 40</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>20 – 30</td>
<td>14</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 1. Sample sizes for different host conditions utilized by *S. imitans* infesting wind-thrown black cherry trees at the Kane Experimental Forest, Pennsylvania (2005).
with live epicormic branches. A band of bark 30 cm wide was removed from the base of each branch and another where branch diam. approached 1 cm. Area of each band was calculated as the branch circumference at the point where the band was removed × 30 cm (the width of the band). The density of *S. imitans* galleries on the two bands were averaged to quantify infestation density for each branch.

**Number of larval instars.** Twice a week in 2005, beginning in late May, larvae were removed from beneath the bark of a number of windthrown black cherry trees infested by *S. imitans* and identified to species. Larvae were killed in a mixture of 95% ethanol (70 ml), kerosene (10 ml), acetic acid (20 ml), and dioxane (10 ml) (K.A.A.D) (Triplehorn and Johnson 2005), and then stored in 80% ethanol.

To document larval instars, maximum head capsule widths (in dorsal view) were measured to the nearest 0.001 mm. The length and width of larvae and adults were measured to the nearest 0.5 mm using a Nikon® stereomicroscope (model SMZ 1500) and a calibrated ocular micrometer.

*Saperda imitans* larvae were distinguished from *Gaurotes cyanipennis* (Say) larvae, the only other cerambycid encountered, by the appearance of their galleries. Galleries of *G. cyanipennis*, confirmed by the presence of adults in their natal galleries, were found to be relatively narrow compared to those of *S. imitans*.

Adults of *S. imitans* were reared from bolts removed from windthrown cherry logs selected systematically while inspecting damaged stands. These log sections were 20-30 cm in dia. and 30-40 cm long. They were placed in several outdoor emergence cages constructed of galvanized trash cans covered with screening and with drainage holes drilled in the bottom. Beetles were removed daily and placed in 3.8 L, wide-mouthed glass jars with screened tops. Initially, several beetles occupied each jar, but as soon as a mating pair was noted the pair was removed and placed in a separate jar to observe mating and to determine whether this species constructed an oviposition niche. To encourage continued mating and oviposition, pairs were provided either fresh cherry foliage and a piece of cherry wood with the bark intact, or only wood with intact bark, or only foliage. The latter was included because adults of other species of *Saperda* are known to feed on host foliage (e.g., Drouin and Wong 1975, Nord et al. 1972.)

**Statistical analyses.** Wilcoxon Signed Rank Tests were used to compare densities at different band heights and to identify heights (bands) with significantly higher mean densities of galleries. For each tree, the difference in gallery density for each pair of heights was the variable analyzed using the Wilcoxon test. The four heights yield six Wilcoxon tests comparing pairs of heights. The experimentwise Type I error rate for these six tests was controlled at 0.05 using the Bonferroni adjustment of the P values. The effect of tree size (large, medium and small diameter classes, Table 1) on the density of *S. imitans* was evaluated using a one-way ANOVA. For this analysis, density/1000 cm² was defined using all four sample heights. A two-way factorial ANOVA was used to test for differences in gallery density for the treatment factor position of windthrown trees relative to the ground (on or off the ground). Tukey’s multiple comparison test was used to control the experimentwise Type I error rate at 0.05 for the set of all 15 possible pairwise comparisons among the 6 simple effect means of the factorial treatment design. Gallery density (denoted X) was transformed to Log₁₀(X+1) to better satisfy the equal variance (of treatment groups) and normality assumptions of ANOVA. Statistical testing was based on the transformed data, but descriptive results show the means of the untransformed data for ease of interpretation of treatment differences. All means are presented with their associated standard error shown after the ± symbol. Analyses were completed in Minitab (2007).
Attraction of cerambycid adults to ethanol-baited traps. Seven species of cerambycids were captured in the Lindgren® funnel traps in storm-damaged stands during 15 weeks of trapping: *Cyrtophorus verrucosus* (Olivier), *Microgoes oculatus* (LeConte), *Anthophylax attenuatus* (Haldman), *Stenocorus vittiger* (Randall), *Neoclytus acuminatus acuminatus* (F.), *G. cyanipennis*, *Clytus ruricola* (Olivier) and *Astylopsis macula* (Say) (Table 2). *S. imitans* was not recovered from the ethanol-baited traps even though it was the dominant species reared (*n* = 80) from bolts of black cherry. It was the only cerambycid that excavated an overwintering gallery in sampled cherry bolts. Larvae of *G. cyanipennis* also were recovered from wind-thrown cherry. When these larvae complete development they exit the log and overwinter in litter (Knell 1946).

**Biology of Saperda imitans.** The first of 80 adults of *S. imitans* emerged in outdoor rearing cages on 29 May 2007 and emergence continued through 26 June (Fig. 1). Peak emergence occurred between the last week of May and the first week of June. The sex ratio was ~1:1, 39 males and 41 females.

In captivity adults fed on the midribs and petioles of cherry leaves. Mating occurred in glass rearing jars and beetles remained *in copula* for one to several hours. Oviposition was never observed in either rearing jars containing fresh cherry bolts or in the field.

Tree excavations revealed that larvae fed beneath the outer bark and engraved an erratic, shallow gallery in the inner bark (phloem), leaving little evidence of activity on the surface of the sapwood (Fig. 2). Early instars packed their galleries tightly with dark brown frass. Once the larva entered the wood to excavate the over-wintering gallery, the frass contained light brown to reddish wood chips. When they reached the final instar, larvae tunneled perpendicularly or slightly obliquely an average of 2.5 ± 0.05 cm (*n* = 80) into the sapwood or outer heartwood before turning and boring parallel to the wood grain (Fig. 3). Average total gallery length was 4.1 ± 0.01 cm. Over-wintering galleries were plugged with frass and excelsior-like wood shavings immediately posterior to

<table>
<thead>
<tr>
<th>Species</th>
<th>Dates Captured (mo/da/yr): Number Captured</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Cyrtophorus verrucosus</em></td>
<td>5-30-06: 9, 5-17-05: 1, 5-30-06:1, 6-26-06: 2</td>
</tr>
<tr>
<td><em>Microgoes oculatus</em></td>
<td>6-19-06: 2, 6-26-06: 1, 7-4-06: 2,7-31-06: 1</td>
</tr>
<tr>
<td><em>Anthophylax attenuatus</em></td>
<td>5-30-06: 1, 6-19-06: 1, 6-26-06: 1</td>
</tr>
<tr>
<td><em>Stenocorus vittiger</em></td>
<td>6-19-06: 1, 6-26-06: 1</td>
</tr>
<tr>
<td><em>Neoclytus a. acuminatus</em></td>
<td>9-19-06: 1, 6-26-06: 1</td>
</tr>
<tr>
<td><em>Gaurotes cyanipennis</em></td>
<td>5-30-06: 1, 6-12-06: 1, 6-19-06: 6, 6-26-06: 1</td>
</tr>
<tr>
<td><em>Clytus ruricola</em></td>
<td>6-13-05: 14, 6-20-05: 8, 6-28-05: 14, 7-5-05: 6, 7-12-05: 3, 7-19-05: 3, 7-25-05: 1</td>
</tr>
<tr>
<td><em>Astylopsis macula</em></td>
<td>6-28-05: 1, 7-19-05: 1</td>
</tr>
</tbody>
</table>
Figure 1. Temporal pattern of emergence for adults of *Saperda imitans* reared from black cherry bolts in outdoor cages. Kane, PA, 2007.

Figure 2. Larval gallery of *Saperda imitans* on the surface of black cherry sapwood. Gallery width (arrow) is 5 mm.
the pupal cell (Fig. 3). Excavation of galleries in October-November and again in March indicated pupation occurred in spring. Emerging adults chewed oval exit holes through the bark. Dimensions of these exit holes averaged 5.4 ± 0.15 mm long by 3.4 ± 0.11 mm wide (n = 50).

Susceptible host conditions. Large branches contained significantly ($P = 0.010$) more insects/1000 cm$^2$ (1.23 ± 0.54, n = 15) than branches 5-10 cm in diameter (0.23 ± 0.11, n = 39). *Saperda imitans* galleries were not observed in branches <5 cm in diameter.

There was no significant difference in the mean density of *S. imitans* galleries/1000 cm$^2$ of bole surface area ($F = 1.00; df = 2.65; MS = 4.248E-07 (\log_{10} x + 1); P = 0.37211$) among small, medium, and large diameter trees where X is the density aggregated over all four samples for each tree in each class.

Wilcoxon’s Test based on Bonferroni adjusted $P$-values (Table 3) demonstrated that gallery density at heights 1 (mean $= 1.8 \pm 0.7/1000$ cm$^2$) and 2 (mean $= 2.1 \pm 0.7$) were not significantly ($P = 1.00$) different; the same held true for densities at heights 3 (mean $= 4.1 \pm 1.1$) and 4 (mean $= 5.7 \pm 1.4$) ($P = 0.48$). Densities at heights 3 and 4 were significantly greater ($P = 0.02$ and 0.00, respectively) than the density at height 1. Density at height 4 was significantly ($P = 0.006$) greater than density at height 2. Densities at bole heights 2 and 3 were not significantly different ($P = 0.036$).

Epicormic branch condition on windthrown cherry and tree position relative to the ground significantly affected *S. imitans* gallery density. There was also a significant interaction between tree position and condition of epicormic branches; trees on the ground had more live epicormic branches compared to trees off the ground (Table 4). Tukey’s pairwise comparisons (Table 5) indicated that gallery density on trees that were off the ground with dying epicormic branches (i.e., some foliage retained but it had discolored or wilted) was significantly higher than

---

**Figure 3.** Over-wintering gallery of *Saperda imitans* in black cherry. The pupal chamber (arrow) is 8 mm wide.
Table 3. Matrix of Bonferroni adjusted $P$ values from Wilcoxon’s Test for differences in the density of *S. imitans* galleries at different band heights.

<table>
<thead>
<tr>
<th>Band Height</th>
<th>Mean (±S.E.) Number of Galleries / 1000cm²</th>
<th>Band 2</th>
<th>Band 3</th>
<th>Band 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1</td>
<td>1.8(0.7)</td>
<td>1.00</td>
<td>0.02</td>
<td>0.001</td>
</tr>
<tr>
<td>Band 2</td>
<td>2.1(0.7)</td>
<td>__</td>
<td>0.36</td>
<td>0.001</td>
</tr>
<tr>
<td>Band 3</td>
<td>4.1(1.1)</td>
<td>__</td>
<td>__</td>
<td>0.48</td>
</tr>
<tr>
<td>Band 4</td>
<td>5.7(1.4)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Results of ANOVA testing for effects of the condition of epicormic branches (absent, dead, alive) and the position (on the ground, off the ground) of black cherry blow-down on the log-transformed density ($\log_{10}(X+1)$) where $X$ is density of *S. imitans* galleries/1000cm² of bole area. Kane, PA 2005.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>MSa</th>
<th>F-ratio</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition of epicormic branches</td>
<td>2</td>
<td>4.6183</td>
<td>5.12</td>
<td>0.009</td>
</tr>
<tr>
<td>Tree position</td>
<td>1</td>
<td>3.8325</td>
<td>4.25</td>
<td>0.044</td>
</tr>
<tr>
<td>Epicormics*Position</td>
<td>2</td>
<td>4.0045</td>
<td>4.44</td>
<td>0.016</td>
</tr>
<tr>
<td>Error</td>
<td>62</td>
<td>0.9028</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Results of Tukey’s all pair-wise comparisons for mean (±SE) densities of *S. imitans* galleries/1000cm² of bole area by tree position and status of epicormic branches (absent, dead, alive) using means of four sample bands for each of 68 wind-thrown black cherry trees dissected near Kane, PA 2005.

<table>
<thead>
<tr>
<th>Epicormic branches*</th>
<th>Dying</th>
<th>Absent</th>
<th>Alive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree Position*</td>
<td>Dying</td>
<td>Absent</td>
<td>Alive</td>
</tr>
<tr>
<td>Off the ground (n=36)</td>
<td>7.83 ± 1.7 A</td>
<td>4.30 ± 2.0 AB</td>
<td>0.12 ± 1.7 B</td>
</tr>
<tr>
<td>On the ground (n=32)</td>
<td>1.48 ± 2.1 B</td>
<td>5.00 ± 1.8 AB</td>
<td>1.34 ± 1.9 B</td>
</tr>
</tbody>
</table>

*Values that share the same letter are not significantly different based on analysis of log-transformed density, but treatment means of untransformed data are presented to facilitate interpretation of magnitude of treatment differences.
gallery density for trees in contact with the ground with epicormic branches in the same condition. Gallery density on wind-thrown cherry that never produced these branches (i.e., tree roots were completely or nearly completely pulled out of the soil) did not differ significantly regardless of tree position. Gallery density on trees with live epicormic branches was similar for trees both on and off the ground.

**Number of instars.** A frequency diagram of head capsule widths failed to clearly separate larval instars (Fig. 4). The extensive overlap most likely resulted from sexual dimorphism. A histogram of larval head capsule widths with irregular and overlapping peaks is not uncommon for cerambycids in general (e.g., Pershing and Linit 1989, Forschler and Nordin 1991) and other species of *Saperda* in particular (e.g., Nord et al. 1972, Drouin and Wong 1975). Head capsule widths for *S. imitans* ranged from 0.77 to 3.08 mm.

Adult females (n = 36) averaged 13.7 ± 0.1 mm in length compared to 11.6 ± 0.1 mm for males (n = 44), and females had a longer and wider terminal abdominal segment. The average length of preserved final instar larvae (n = 282) was 24.3 ± 0.2 mm.

**Discussion**

Host specificity and preferred substrate conditions vary among species in the genus *Saperda*. In North America host preference for *S. tridentata* approaches monophagy on *Ulmus* spp., especially *U. americana* L. The two most important European species (the large poplar longhorn, *S. carcharias* (L.) and the small poplar longhorn, *S. populnea* (L.)) (Kenis and Hilszczanski 2004) are oligophagous on both *Populus* and *Salix* (Evans et al. 2004). In eastern North America, *S. lateralis* is polyphagous and infests species of broadleaved trees in several genera (e.g., *Ulmus, Tilia, Fraxinus, Acer, Quercus*) (Lingafelter 2007). Similarly, preferred substrate conditions, such as host moisture

![Figure 4. Distribution of maximum cranial widths for larval stages of *Saperda imitans* (n = 534).](image-url)
content, nutrients and temperature, differ from one species to another. For example, *S. cretata* Newman (Solomon 1995) and the gall former *S. inornata* Say (Nord et al. 1972) attack apparently healthy hosts while *S. carcharias* is capable of infesting both healthy and weakened hosts (Evans et al. 2004). *Saperda vestita* Say prefers stressed and weakened *Tilia* spp. (Johnson and Williamson 2006), and *S. lateralis* is associated with dead hosts (Stein and Tagestad 1976).

Yanega (1996) stated that *S. imitans* utilizes “various dead hardwoods,” implying that the species has several different hosts. Specimens have been recovered from *Carya* spp. (Felt and Joutal 1904), *Salix* spp. (Linsley and Chemsak 1995) and *Acer* spp. (Vlasak and Vlasavakova 2002). To the best of our knowledge, however, it has never been recovered in large numbers from these hosts. The relatively high numbers found in the windthrown black cherry at the KEF suggests that *P. serotina* may be a common host for this cerambycid. Our work at the KEF associated this species with dying or recently dead hosts; that is, host material with relatively tight bark and moist inner bark. Downed but live trees with root systems partially buried in the soil with many live epicormic branches did not have high densities of *S. imitans* larvae and neither did dead trees with loose bark and dry inner bark.

Hanks (1999) recommended four categories for classifying host condition at the time of attack by species of Cerambycidae. Because none of his categories strictly match our observations for *S. imitans*, using his classification was problematic. The closest comparison is his description for a “stressed host (SH).” The key criterion in this category is that “infested hosts usually die, often as a direct result of larval colonization.” Infested windthrown black cherry we observed at KEF died even in the absence of *S. imitans* The insect may have hastened mortality, but it did not appear to be the cause.

In their description of the genus, Linsley and Chemsak (1995) stated that all species breed in living trees. While true for several species of *Saperda*, many utilize trees that have been subjected to a severe stress from which the host is not likely to recover. Examples include *S. imitans* in black cherry damaged by severe wind documented in this study as well as *S. tridentata* in elms dying from Dutch elm disease (Solomon 1995). Our observations indicated that *S. imitans* adults feed on host leaves and petioles or the bark of twigs prior to mating and oviposition, similar to most species in the genus (Linsley and Chemsak 1995).

Many species of *Saperda* require two to several years to complete a single generation, variation that can be attributed mainly to differences in latitude for a widely distributed species such as *S. candida* (F.) (USDA ARS 1965). Similarly, variables such as the moisture content (e.g., Nakamura 1994) and nutritional quality of the phloem (e.g., Akbulut and Linit 1999) and meteorological conditions (e.g., Watari et al. 2002) may affect rate of development of cerambycid larvae. The pattern of adult emergence from caged bolts (Fig. 1) and observations of larval development under field conditions suggest that adults of *S. imitans* emerge and oviposit once a year. Individuals emerging after the first week of June most likely represent eggs deposited relatively late during the previous growing season. Even though variation in the substrate conditions mentioned above affect cerambycid development rates (e.g., Pershing and Linit 1989), all of our caged bolts came from trees that were in similar condition (dying) and were cut at the same time to minimize variation in host condition. In terms of susceptibility of wind-thrown black cherry to infestation by *S. imitans*, results of this study may help forest owners to establish salvage priorities in order to minimize grade loss.
Acknowledgments

The following agencies and personnel are gratefully acknowledged for their financial support and logistical assistance during the course of this project: S. Stout and colleagues, US Forest Service, Northern Research Station, Irving, PA; J. Wiedenbeck, US Forest Service, Northern Research Station, Princeton, WV; Division of Lands and Forests, NY State Dept. of Environmental Conservation; We thank E. R. Hoebeke, Department of Entomology, Cornell University, Ithaca, NY for verifying beetle identifications and J. Wernet and N. Dickerson for field assistance. We thank M. Fierke and K. Adams, State University College of Environmental Science and Forestry (SUNY, ESF), Syracuse, NY for their thoughtful pre-submission reviews, and five referees for their careful reviews and many helpful recommendations.

Literature Cited


Distribution of *Strongylium crenatum* (Coleoptera: Tenebrionidae) in the United States and first record from Iowa

Edwin L. Freese

Abstract

*Strongylium crenatum* Mäklin (Coleoptera: Tenebrionidae) is reported from Iowa for the first time. After discovering that Iowa represented a large range extension for this species, label data were collected to update its range. Numerous insect collections and references were checked and specimens representing 17 states were located.

The first Iowa specimen of *Strongylium crenatum* Mäklin, 1864, was collected at Sharon Bluffs State Park, Appanoose County, on 21 July 2007 by Doug Veal using a combination UV-florescent light. The location in southern Iowa is about nine miles from the Missouri-Iowa border. The specimen was later identified by Charles Triplehorn, who indicated the specimen represented an interesting range extension of a rarely encountered species. Research of the internet and published sources confirmed that the distribution of this species was poorly known; this paper updates the known range of this beetle.

According to Triplehorn and Spilman (1973) “This species is found in the southeastern United States, reaching as far north as the Ohio River and as far west as Dallas” and “Mäklin based his new species on a single specimen merely labeled North America.” George Horn (1870) in his revision of the Tenebrionidae of America listed *S. crenatum* under “Unknown Species.” Charles Leng (1920) listed the species from Florida and North America while Triplehorn and Spilman (1973) had only 36 specimens at hand for their study. Triplehorn (pers. comm.) considered this species quite rare and indicated the Iowa specimen was a big surprise. Thomas and Okins (2011) presented a key to the seven species of *Strongylium* occurring in Florida. Generally what Triplehorn and Spilman (1973) wrote still holds true: “We know very little about this species.”

This beetle species was described by Fredrik Wilhelm Mäklin who lived in Finland from 1821-1883 (Anonymous 1883). The generic name *Strongylium*, which in Greek means “round”, was proposed by Englishman William Kirby in 1818 (Triplehorn and Spilman 1973). The specific epithet *crenatum* probably refers to the small rounded knobs or teeth on each side of the pronotum but may also refer to the sub-crenate punctate-striate elytra (Mäklin 1864). Triplehorn and Spilman (1973) indicated specimens have “brownish elytra which have greenish reflections”; Thomas and Okins (2011) indicated “elytra brown with iridescent green sheen” in their key; Mäklin (1864) indicated his one specimen was “greenish-brassy, color transparent reddish-brown”. Specimens examined often vary from shiny reddish-brown to dark brown in color with greenish metallic color present to almost absent. “The length is 7.4 to 10.8 mm and the width is 2.2 to 3.4 mm” (Triplehorn and Spilman 1973).
Steiner, Jr. (2008) wrote “In Maryland, adults occur from late May to early September and do not overwinter,” while Triplehorn and Spilman (1973) indicated “Adults were collected May 6th to July 22nd.” According to Steiner, Jr. (1995) “Strongyliines tend to live in relatively hard wood...” and (Steiner, Jr. 2008) “Larvae tunnel in dead standing wood and probably in rotten wood in live trees.” Triplehorn and Spilman (1973) provided the following information on larvae: “reared from decayed ash log; in moist decayed persimmon log.” Baker (1972) and Drooz (1985) covered the entire family of Tenebrionidae in one paragraph mentioning that “A few species in the genus Strongylium bore into the wood of living trees at stubs or wounds.”

Methods

Searches were made for information and specimens on the internet, in the literature, and by contacting collection managers and curators. Field searches were made in southern Iowa during the 2003 to 2011 field seasons at night with different combinations of lights and searching logs and tree trunks with flashlight; day collecting consisted of searching logs and under bark for specimens.

The following individuals listed in alphabetical order were queried for label data for this paper from their institutions, museums, or collections (abbreviations are those used in the text below): James Boone, Field Museum of Natural History, Chicago (FMNH); Ralph Holzenthal, University of Minnesota, St. Paul (UMSP); Paul Lago, personal collection, University of Mississippi, University (PKLC); Steve Krauth, Wisconsin Insect Research Collection, University of Wisconsin, Madison (WIRC); Serge Laplante, Canadian National Collection of Insects, Ottawa (CNCI), Serge Laplante, personal collection (SLC); Mark O’Brien, University of Michigan Museum of Zoology, Ann Arbor (UMMZ) Edward Riley, Texas A & M University, College Station (TAMU); Edward Riley, personal collection (EGRC); Kristin Simpson, Enns Entomological Museum, University of Missouri, Columbia (EEMC); Paul Skelley, Florida State Collection of Arthropods, Gainesville (FSCA); Charles Triplehorn, Museum of Biological Diversity, Columbus, Ohio (CATIC); Doug Veal, personal collection, Marion, Iowa (DAVC); James Zahniser, University of Illinois at Urbana/Champaign, Illinois Natural History Survey Collection, Urbana (INHS).

Results

Strongylium crenatum specimen records include those obtained from collections, published sources, and the internet by state; data as given to me by collection managers and curators or as gleaned from the literature; number of specimens per date and location in brackets.

[1], Clarke, Menard, and Riley, funnel trap hardwood bottomland, sample 186; Brazos Co., Koppe’s Bridge 5 mi. SW College Station, 3 June 1995 [1], E. G. Riley, sample 127; Brazos Co., College Station, Lick Creek Park, 14 May 1997 [2], E. G. Riley, uv light bottomland forest; Sabine Co., Mill Creek Cove, Beech Bottom, 8.8 mi. NE Hemphill, IV-28-V-10-2008 [1], E. G. Riley (TAMU; EGRC); Texas (Downie and Arnett 1996).


One specimen was reported collected in Great Smoky Mountains National Park but I was unable to obtain further information: #2442 *Strongylium crenatum*, Ciegler and Merritt 2000, ID = Adriean J. Meyer (GSMNP 2010).

Three good photos of *Strongylium crenatum* were found in the literature (Steiner, Jr. 2008; Triplehorn and Spilman 1973; Thomas and Okins 2011).

**Discussion**

*Strongylium crenatum* specimen records are reported from 17 states. The western edge of the distributional range is now marked by western Iowa, eastern Kansas, eastern Oklahoma, and eastern Texas; the northern edge is now marked by southern Iowa, southern Ohio, and Maryland. No label data were obtained from the following states that occur within the presumed range: Delaware, Illinois, Indiana, Kentucky, Nebraska, New Jersey, and West Virginia. No specimens were located in collections contacted in Wisconsin, Minnesota, and Michigan (Steve Krauth, Ralph Holzenthal, and Mark O’Brien, pers. comm.). Records from Arkansas, Iowa, Kansas, Louisiana, Missouri, and Oklahoma represent new state records (see map, Fig. 1).

The earliest collected specimen was 14 May in Brazos County, Texas; the latest collection was 1 September in Alachua County, Florida. Most specimens were collected in June (51) followed by July (19), May (7), August (1), and September (1). When mode of collection was provided the majority of specimens were collected using lights. Other methods of collection included malaise trap, funnel trap, canopy trap, sugar baits, beating dead branches, and reared from log litter; many labels indicated collection in wooded areas or forests or from bur oak, wild plum, hickory, ash, persimmon, haw, or Osage orange. These data indicate this species is a generalist preferring wooded areas and may be collected using a variety of methods.

The Sharon Bluffs State Park collection site is located in south central Iowa along the Chariton River in Appanoose County about nine miles from the Iowa-Missouri border. The first 25 acres for this 144 acre park was purchased in 1929 (Wolf 1991). Prior to Euro-American settlement the vegetation of this area was probably mostly prairie and savanna on the uplands with forest habitat along river corridors (Mutel 2008). Today the entire park is forest, except for the campground and picnic area, and dominated by white and pin oak and shagbark and kingnut hickory (Mark Leoschke, pers. comm.), with buckeye, basswood, and sugar and silver maple also present.

The Waubonsie State Park collection site is an upland area located in southwestern Iowa about five miles from the Missouri River and about five miles from the Missouri-Iowa border. This site is dominated by chinquapin oak (John Pearson, pers. comm.) with bur and white oak, basswood, and paw paw also present. Pre-settlement vegetation of these loess hills was probably grassland and savanna (John Pearson, pers. comm.; Mutel 1989). The state of Iowa purchased lands and founded a park during 1926 (Wolf 1991).
Acknowledgments

First, a special thank you to my collecting buddy, Doug Veal, for sharing his interest in beetles and being a great friend. Another special thank you to Charles Triplehorn for his help and comments. I also thank all the curators, collection managers, collectors, and photographers listed above. Thank you to the following who contributed to this study: Paul Lago, Warren Steiner, Dan Young, John Pearson, Mark Leoschke, Betsy Betros, Becky Heth, Marlin Rice, Deb Lewis, and the contributors and creators at Bugguide.net and Biodiversitylibrary.org. Also thank you to the three reviewers for their constructive comments making this a better paper. And finally, a special thank you to my wife Janet, for her interest in nature, and thus understanding my interest in beetles.

Literature Cited


Recent Detections of a Rare Native Lady Beetle, *Coccinella novemnotata* (Coleoptera: Coccinellidae), in Minnesota

Robert L. Koch

Abstract

*Coccinella novemnotata* Herbst (Coleoptera: Coccinellidae) was once widespread and commonly collected in North America; however, its abundance and distribution decreased over the 1970s and 1980s. It has not been collected by recent surveys in some areas and in other areas is only rarely collected. Museum records were examined and a survey of Minnesota soybean fields was conducted via sweep-net sampling in July and August 2011. Results suggest that *C. novemnotata* is absent from or below the detection threshold in the majority of the state of Minnesota. However, there appears to be an area in east central Minnesota with at least sustained low, but detectable populations of *C. novemnotata* and it is active in agricultural crops.

The status of *Coccinella novemnotata* Herbst (Coleoptera: Coccinellidae) populations is of concern to conservation biologists (Harmon et al. 2007, Losey et al. 2007). This species was once widespread and commonly collected in North America (Gordon 1985). In Minnesota, Stehr (1930) wrote: “This is the commonest species of the genus *Coccinella* in the state. It is usually abundant wherever aphids are present. It is especially common on field crops and grass and must be rated among those species of greatest economic benefit.” However, the abundance and distribution of *C. novemnotata* decreased over the 1970s and 1980s to a point where it has not been collected by recent surveys in some areas and in other areas is only rarely collected (Wheeler, Jr. and Hoebeke 1995, Harmon et al. 2007, Losey et al. 2007, Hesler and Kieckhefer 2008, Hesler et al. 2009, Fothergill and Tindall 2010). The reasons for the decline of this species remain undetermined, but several factors have been proposed (Wheeler, Jr. and Hoebeke 1995). Of these, two potentially important factors for consideration are the establishment of adventive coccinellids and changes in land use and cropping systems (Harmon et al. 2007).

*Coccinella novemnotata* remains rare in the upper midwestern United States. For example, this species has not been recorded from Iowa since 1972 (Hesler 2009). However, there have been some recent detections of *C. novemnotata* in the region. Two adult *C. novemnotata* were collected near Madison, Wisconsin in 2000 (Harmon et al. 2007). In 2008, three adults were collected from western South Dakota and nine from western Nebraska (Hesler et al. 2009), but no detections were made in the eastern portion of South Dakota (Hesler and Kieckhefer 2008). More recently in Wisconsin, single adult *C. novemnotata* were collected from Buffalo County in 2009 and 2010 (Discover Life 2011). However, the status of this species in Minnesota has remained undocumented in the literature over recent years. Recent literature including coccinellids in Minnesota have not reported *C. novemnotata* (Wold et al. 2001, Galvan et al. 2005, Chacón

---

1Minnesota Department of Agriculture, 625 Robert Street North, Saint Paul, MN 55155. (e-mail: koch0125@gmail.com).
A survey of Minnesota soybean fields was conducted via sweep-net sampling in July and August 2011. Over 300 soybean fields were sampled throughout Minnesota, except the northeastern portion of the state where production of agricultural crops is minimal. In each field, three sets of 30 180°-sweeps were taken. The sweep contents were bagged and brought to the laboratory for identification of contents. Adult coccinellids were identified using Gordon (1985) and Gordon and Vandenberg (1991). From 978 adult coccinellids examined, two maculate *C. novemnotata* adults were found. On 10 August 2011, an adult *C. novemnotata* was collected from Anoka County. Other coccinellid adults collected from the sample (three sets of 30 sweeps) in the same field included seven *Harmonia axyridis* (Pallas). On 22 August 2011, an adult *C. novemnotata* was collected from Isanti County. Other coccinellid adults collected from the sample (three sets of 30 sweeps) in the same field included: 12 *Coccinella septempunctata* L., two *Cycloneda munda* (Say), 66 *H. axyridis*, and four *Hippodamia variegata* (Goeze). The identification of the two adult *C. novemnotata* was confirmed by Natalia Vandenberg (USDA ARS Systematic Entomology Laboratory) and these specimens were deposited in the University of Minnesota Insect Collection.

Examination of museum records showed that *C. novemnotata* has been collected periodically from the same general area of the state over the last 30 years (Table 1). There were no specimens from other areas of the state for the same time period. The majority of these records, all those from Anoka and Isanti counties in the University of Minnesota Insect Collection and Cedar Creek Ecosystem Science Reserve Insect Collection came from collections conducted at the Cedar Creek Ecosystem Science Reserve (Table 1). The specimens from Aitkin County in the Minnesota Department of Agriculture insect collection was collected from a cornfield during an autumn European corn borer, *Ostrinia nubilalis* (Hübner) (Lepidoptera: Crambidae), survey (Table 1).

The combination of published surveys, museum records and results of 2011 soybean survey suggest that *C. novemnotata* is absent from or below the detection threshold in the majority of the state of Minnesota. However, there appears to be an area in east central Minnesota with sustained low, but detectable populations of *C. novemnotata*. Unlike the relatively recent detections of *C. novemnotata* on milkweed (*Asclepias* sp.) in Wisconsin (Harmon et al. 2007) and on uncultivated plants, on roadside vegetation and in rangeland pasture in western South Dakota and western Nebraska (Hesler et al. 2009), the data presented here suggest that *C. novemnotata* in east central Minnesota is still active in agricultural crops (e.g., corn and soybean). Further, more focused, work is suggested to try to better determine the range, abundance and host and habitat utilization of *C. novemnotata* in Minnesota.

Acknowledgments

I am grateful to Tina Seeland, Sam Banks, Jerald Yourczek, Rich Kvols, Ardell Knudsvig, and Roy Mayeda (Minnesota Department of Agriculture) for assistance collecting field data, Colleen Satyshur (University of Minnesota) for checking the Cedar Creek Ecosystem Science Reserve Insect Collection, Natalia Vandenberg (USDA Agricultural Research Service) for confirming identifications, and Louis Hesler (USDA Agricultural Research Service) and Monika Chandler (Minnesota Department of Agriculture) for providing reviews of this manuscript.
Table 1: Recent records of *Coccinella novemnotata* occurrence in Minnesota based on museum records and a statewide soybean survey.

<table>
<thead>
<tr>
<th>Year</th>
<th>Aitkin County</th>
<th>Anoka County</th>
<th>Isanti County</th>
<th>Anoka/Isanti County</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>5&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>6&lt;sup&gt;bc&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>8&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>6&lt;sup&gt;bc&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>4&lt;sup&gt;bc&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td></td>
<td></td>
<td>1&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td></td>
<td></td>
<td>1&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td></td>
<td>1&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td></td>
<td></td>
<td>5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>1993</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td></td>
<td></td>
<td></td>
<td>1&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>1995</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td></td>
<td></td>
<td></td>
<td>1&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td></td>
<td></td>
<td>1&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td>2&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td></td>
<td></td>
<td>1&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td></td>
<td></td>
<td>1&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td></td>
<td>1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Location labels for individual specimens listed both counties.

<sup>b</sup> University of Minnesota Insect Collection.

<sup>c</sup> Cedar Creek Ecosystem Science Reserve Insect Collection.

<sup>d</sup> Minnesota Department of Agriculture Insect Collection.

<sup>e</sup> 2011 Minnesota Department of Agriculture soybean survey.


