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Cover photo
Serropalpus substratius (Coleoptera: Melandryidae).
Photo by James K. Liebherr
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A New Species of *Erioptera* Meigen Crane Fly (Diptera: Limoniidae) From Michigan With Notes on Closely Related Species

Stephen W. Taber

**Abstract**

A new Nearctic species of *Erioptera* Meigen crane fly was discovered in Michigan, USA. It belongs to the green *chlorophylla* species group of the nominate subgenus. *Erioptera michigana* Taber sp. n. is most closely related to *Erioptera subfurcifer* Alexander but their reproductive structures are different. Their close relative *Erioptera georgei* Alexander is illustrated for the first time.

The nominate subgenus of *Erioptera* Meigen includes 28 currently recognized Nearctic crane fly species (Catalogue of the Craneflies of the World; online resource, August 2015). The two most recently described Nearctic species are *Erioptera brauni* Taber (Taber 2014) from the southwestern United States (Utah) and *Erioptera georgei* Alexander (Alexander 1956, p. 183) from Michigan, on the Lower Peninsula in the Edwin S. George Reserve 225 kilometers southeast of the site in the Manistee National Forest where the material described and discussed here was collected.

A survey of the Nearctic taxa of the green *chlorophylla* species group of *Erioptera* crane flies suggests that Michigan is especially rich in those species but that impression follows from a coincidence instead. The entomologist J. Speed Rogers happened to work in Michigan, had an interest in the behavior and ecology of crane flies (Rogers 1942), collected many specimens in many years of fieldwork, and sent his unidentified material to C. P. Alexander who described more species of crane flies than anyone else. The five green species that were found in Malaise traps in summer during the present study were *Erioptera michigana* Taber, *Erioptera chlorophylla* Osten Sacken, *Erioptera chlorophylloides* Alexander and what is perhaps its subspecies *Erioptera chlorophylloides orthomera* Alexander, *Erioptera subfurcifer* Alexander, and *Erioptera georgei* Alexander.

**Methods and Materials**

The type locality of the new species is the edge of a jack pine forest (*Pinus banksiana* Lambert) near the southern limit of that tree’s distribution, next to a marsh bordered by leatherleaf (*Chamaedaphne calyculata* (L.) Moench) in Newaygo County, Michigan, USA, 7 km east of Brohman, at a site within the Manistee National Forest known as “Oxford Swamp”, approximately 0.5 km southwest of GPS coordinates 43.41° N, 85.44° W. The vegetation is mostly jack pine with a few eastern white pines (*Pinus strobus* L.) and paper birches (*Betula papyrifera* Marshall). Flies were collected with a large Malaise trap running from mid-March of 2015 when snow melt allowed access to the area until early November 2015.

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All specimens were collected dry, without killing agent, and frozen in Malaise trap canisters until removed and placed in Petri dishes for examination with a stereomicroscope. Those of interest were soaked overnight in a tissue culture dish with one drop of the wetting agent polysorbate to help submerge wings and dried appendages without breakage. The clearing ability of KOH isn’t needed because these flies are so pale in life and after collection that the relevant structures can be seen in material pointed dry on a pin, but a weak KOH solution was used to help spread terminalia.

Each fly was placed on a microscope slide with one or two drops of polyvinyl alcohol (PVA) as a mounting medium. Cover slips were not used because material must be viewed from more than one angle by applying additional mounting medium and waiting a few minutes for the previous application to re-liquefy so that dorsal, lateral, and ventral views are obtained. Type material will be provided with cover slips. The photographs shown here were taken with stereoscopic and high-power compound microscopes, (Olympus SZ40 Zoom and Olympus BH-2, respectively), provided with a digital SPOT idea camera (Diagnostic Instruments Inc., Sterling Heights, MI). Stacking software was employed to combine series of images differing only in the chosen plane of focus into a single merged image with improved clarity (Zerene Stacker Version 1.04), thus overcoming depth-of-focus problems with thick specimens.


Results

Erioptera michigana Taber new species

Diagnosis. Each gonapophysis of Erioptera michigana is arched in the opposite direction from that of its presumed closest relative E. subfurcifer (the outer edge bows outward or laterally instead of bowing inward or mesally; compare Fig. 1 herein to Fig. 52D, p. 455 of Alexander 1942/1966). Each gonapophysis of the new species also has two apical points rather than one, has all or nearly all of its serrations on the inner surface instead of having its most significant array on the outer surface, and its serrations are stronger than those illustrated for E. subfurcifer. The inner tip of the inner gonostylus of E. michigana is black whereas the tip is pale in E. subfurcifer (Alexander 1929, p. 51).

Type Material. Holotype. Adult male. Manistee National Forest, 7 km east of Brohman, Newaygo Co., MI, 27 June 2015, S. W. Taber, Saginaw Valley State University Insect Collection, University Center, MI; in canister of 6-meter Malaise trap hung between two large jack pines in jack pine forest adjacent to cattail marsh. Paratypes. 1 adult male with the same data as the holotype, 1 adult male collected 5 July 2015, and 1 adult male collected 12 July 2015. Other data the same as the holotype. Several paratypes will be deposited at the Smithsonian Institution.

Description. Holotype. Adult male. Length in PVA = 6.6 mm. As is typical for members of the chlorophylla group most of the body is pale green including the halteres and some of the wing veins but the large compound eyes are black and some wing veins are pale and the legs are tinged with yellow that might be the result of drying soon after death. Wing (paratype): Length = 6.8 mm, hyaline without pattern. The highly transparent condition of the wing makes it difficult to see and to successfully photograph its veins.

Genitalia (Figs. 1–2): The apex of the ninth tergite of the abdomen is excised concavely or is truncated into a nearly straight edge instead. Outer (posterior) gonostyles appearing as pale rods with blackened tips when lying parallel to one another at right angles to the body and touching each other along
their length. The inner (anterior) gonostylus forks at a distance from the base of the stylus equal to about 2/3 of its total length. The tip of each branch of the fork is black but the outer (posterior) branch is more extensively blackened, sharper, and bears a greater number of microscopically small setulae.

The pair of gonapophyses (parameres) forms a pincer-like shape when viewed from dorsal and ventral perspectives. Each gonapophysis is curved, black on the distal half, bears two points at the apex, and has a series of conspicuous teeth on the inner edge that form a serration along the blackened distal half of the structure. In specimens that were cleared slightly with KOH and mounted in polyvinyl alcohol (PVA) medium the proximal half of each gonapophysis grades from yellow at the base to brown at the midpoint where the black distal half is encountered.

A total of 18 male specimens of *E. michigana* were found in the present study. Average body length as measured in PVA = 6.3 mm (n = 18); average wing length = 6.1 mm (n = 12).

**Distribution.** The new species is known only from its type locality.

**Etymology.** The new species *E. michigana* is named for the state where it was discovered.
Biology. Unknown except that adult males appeared in Malaise traps from late June to late July.

Remarks. The combination of size, shape, and color of the gonapophyses of the new species allows it to be quickly distinguished from those of the other four *chlorophylla* species-group crane flies that were found in the present study. Their gonapophyses and their gonostyli have been illustrated before (Alexander 1942/1966, pp. 451 and 455), except for *E. georgei* which has never been illustrated until now (Fig. 3). The gonapophyses of *E. georgei* can be distinguished from related species as they are apically-blackened curved hooks that point straight down (ventral direction) or ventro-laterally. In addition, the gonostyli of *E. georgei* aren’t apically forked but are blackened at the tip, and the tip of the outer gonostylus is widely dilated and pointed. The specimen shown here was collected at Mount Desert, Maine, 12 July 1963. *Erioptera georgei* was previously known only from Michigan but two specimens on microscope slides from the United States National Museum increase the known distribution of the species to include Mt. Desert Island, Maine. The collection dates are 12 and 15 July 1963. I saw the holotype that was collected in Michigan at a trap-light on the E. S. George Reserve in Livingston Co. on 23 June 1947 (Alexander 1956, p. 183). It is pointed on a pin. The original green color has changed to a nearly uniform brown.

Discussion

All of my observations were made without cover slips so that the natural orientations of parts would not be distorted by pressure. It appears that C. P. Alexander’s custom or habit was to draw terminalia that were bearing the weight of a cover slip with the result that some parts were distorted when drawn. This has implications for those who seek to identify material. One example might be

Figure 2. *Erioptera michigana*; male paratype gonapophyses.
his illustration of *Erioptera villosa* Osten Sacken (Alexander 1942/1966, p. 455; Fig. 52G). Specimens that I collected and that I believe to be *E. villosa* show in dorsal view what appear to be sharp, slender gonapophyses that point down unlike the blunt, curved structures that he drew. But when I placed a cover slip on top of the fly and pressed down on it too, the gonapophyses were deflected to a lateral view that resembled those of the drawing.

*Erioptera chlorophylla* was the only species that was collected in Malaise traps and in emergence traps. Those emergence traps were erected in previous years in late winter or early spring over inundated soil in a black ash (*Fraxinus nigra* Marshall) swamp. Females can be associated with the males because all of the males were *E. chlorophylla*. The encompassing structure of the trap suggests that larvae develop in mud where snow covered the ground until late March or early April. Remarkably, this species was found in emergence traps in black ash habitat but wasn’t noticed in Malaise traps a few meters away while in the jack pine habitat the converse was true. *Erioptera chlorophylla* adults were collected in June, July, and August.

**Acknowledgments**

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Literature Cited


The Biogeography of a Disjunct Plant-Insect Relationship: Thimbleberry and Diastrophis kincaidii (Hymenoptera: Cynipidae) in the Great Lakes Region

Michael C. Rotter\textsuperscript{1,2} and Mac Strand\textsuperscript{1}

Abstract

The clonal shrub thimbleberry (Rubus parviflorus) ranges throughout western North America and is disjunct to the northern Great Lakes region. Diastrophis kincaidii (Hymenoptera: Cynipidae) is an obligate gall wasp of thimbleberry that has long been known from western North America but has only been reported from the Great Lakes region since the early 1990s. It has been suggested that Diastrophis kincaidii was only recently introduced into the Great Lakes region sometime in the 1980s. We conducted a survey to determine the distribution of D. kincaidii and its parasitoids within the thimbleberry range in the Great Lakes region. We found that D. kincaidii is restricted to the colder and more xeric habitats within the Great Lakes thimbleberry range. Additionally D. kincaidii was found to have colonized isolated micro-habitats in the region were it attained high population densities. The inquiline community inhabiting D. kincaidii in the Great Lakes Region was similar to past reports. This community included species from eastern and western North America as well as two undescribed species. We suggest that D. kincaidii and its inquiline community have long been a part of the insect fauna of the Great Lakes region and is likely a remnant of an original connected pre-glacial continental thimbleberry population.

Diastrophus kincaidii Gillette (Hymenoptera: Cynipidae), is the only known gall maker of the clonal shrub thimbleberry (Rubus parviflorus Nutt.) (Weld 1957). The natural history and lifecycle of D. kincaidii was first described in the Pacific Northwest where it was originally thought that the wasp’s range was restricted to the range of thimbleberry in western North America (Wangberg 1975). Diastrophus kincaidii females preferably oviposit on new first season thimbleberry shoots. Typically, eggs are communally deposited into the vascular areas of the plant stem. Galls form rapidly following oviposition, with the first evidence of swelling appearing in 5–7 days (Wangberg 1975). The occurrence of D. kincaidii in the Great Lakes region was confirmed by Kraft and Erbisch (1990). In their study, D. kincaidii was recorded from three counties in Michigan as well as Saint Louis county, Minnesota. Kraft and Erbisch (1990) also suggested, through the use of surveys by local botanists and berry pickers, that D. kincaidii arrived in the Great Lakes region sometime in the 1980s.

Although thimbleberry was first described from specimens collected from Mackinac Island, Michigan, Great Lakes thimbleberries are currently considered

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to be disjunct representatives of a larger population that extends from the coastal ranges of western North America into the Rocky Mountains (Voss 1985). In the Great Lakes region, thimbleberry has a fragmented distribution with clusters of plants occurring near Lake Superior and along the northern coasts of Lake Michigan and Huron (Marquis and Voss 1981). Many other Great Lakes disjunct plant species, for example black hawthorn (Crataegus douglasii), western fescue (Festuca occidentalis), and bilberry (Vaccinium membranaceum), exhibit similar distributional patterns (Marquis and Voss 1981). Thimbleberries are particularly abundant along Lake Superior’s southern coast, even supporting a small commercial jam industry in the Upper Peninsula of Michigan (Anderson 2003).

Thimbleberry galls, like those induced by other cynipid wasps (Wiebes-Rijks and Shorthouse 1992, Gordinier 2003, Hayward and Stone 2005), are also inhabited by complex communities of insects (Wangburg 1976, Jones 1983). The most common members of this community are parasitoid wasps that attack D. kincaidii larvae. Thimbleberry gall communities have been described from western North America include members of the Hymenoptera families Ichneumonidae, Eurytomidae, Pteromalidae, Torymididae, Eupelmidae, and Ormyridae (Wangburg 1976, Jones 1983). Jones (1983) found that parasitoid presence selected for deeper oviposition within a gall in D. kincaidii and an increase in the number of females contributing to the formation of each gall. Parasitoids and gall inquiline communitites can change over a host species range, but they may also “follow” their host organism revealing ecological and phylogenetic affinities (Wiebes-Rijks and Shorthouse 1992, Schönrogge et al. 1995). Landscape patterns, environmental gradients, interspecific interactions, and host plant variability can all influence inquiline community composition (Kruess 2003). Kraft and Erbisch (1990) collected three unidentified parasitoid species from thimbleberry galls from the Upper Peninsula of Michigan indicating that Great Lakes region thimbleberry gall communities may be less species rich than those in western North America.

As in other Rubus subgenus Anoplobatus species, thimbleberry stems exhibit biannual growth patterns, first forming “primocanes” which become increasingly woody during year one and transform into reproductive “floricanes” in year two (Voss and Reznicek 2012). Gravid female D. kincaidii prefer to oviposit in the relatively soft, rapidly growing shoots of primocanes, which often host clutches of eggs from multiple female wasps (Wangburg 1975). Green, irregularly shaped galls form as larvae begin to feed during the first season and adults emerge from woody galls early in the summer of year two. Jones (1983) found that D. kincaidii larvae within larger galls and those that were deeper in these galls, had lower rates of parasitism.

The objectives of the present study were: 1) determine the range of D. kincaidii in the Great Lakes region 2) identify regional and local factors that influence the distribution of D. kincaidii, 3) describe the thimbleberry gall inquiline community in the Great Lakes region and 4) use new evidence to evaluate a previously published hypothesis regarding the history of D. kincaidii in the Great Lakes region.

Methods

We conducted a survey for D. kincaidii over the thimbleberry range in the Great Lakes region using our knowledge of thimbleberry stand locations and published distribution information from Marquis and Voss (1981), Reznicek et al. (2011), and Voss and Reznicek (2012) (Fig. 1). Surveys were conducted during the summer of 2013 from July to October after gall formation became apparent. Due to thimbleberry being rare and sometimes un-accessible in parts of its range, natural resource personnel from Parks Canada and the Nature Conservancy were provided with pictures of D. kincaidii galls and asked to survey local populations of thimbleberry in Bruce Peninsula National Park, Pukaskwa National Park
At each stand (defined as a single clone separated by at least 10m from another nearby clone), we recorded the percentage of stems with galls and relative gall density. Variable width belt transects that ran the length of the thimbleberry stand were used to calculate the percent stems galled and relative density of galls for each stand. Each stem along the belt was recorded as either galled or ungalled and as either a floricane or a primocane. We also measured total stand area and calculated the ratio of floricanes to primocanes at each site.

A more intensive study of thimbleberry stands in a park in Marquette, Michigan was conducted to examine factors that influence local distribution of gall wasps. This area (46°33´12.03´´N, 87°24´22.08´´W) was surrounded by neighborhoods and a cemetery, forming an isolated forest remnant. The site is a 57 hectare area dominated by hemlock (Tsuga canadensis) and northern hardwood forests with several ruderal areas and recreational trails running throughout. We mapped and sampled all thimbleberry stands within the park to assess local variation in D. kincaidii abundance and density as well as to investigate spatial patterns on a local scale. Additionally, we mapped the recreational trails in the park to determine the influence of trails on local thimbleberry and D. kincaidii distribution.

A total of 88 galls were collected from the Michigan portion of the D. kincaidii range during August through October of 2013. These months covered the peak of thimbleberry growing season until the end of the growing season. Galls were cut from an individual thimbleberry stem when they had started to turn brown. Each gall was placed into a labeled jar, held at room temperature, and checked weekly for emerged wasps. Emerged wasps were identified as either parasitoid spp. or D. kincaidii. The gender of each emerged D. kincaidii
was recorded and then it was prodded with a dissection pin (in order to provide initiative to flee as in Jones 1983) to see if they would fly in the lab. Parasitoid wasps were sent out for identification to genus (Roger Burks, Ohio State University, and Alexey Reshikov Swedish Museum of Natural History). Voucher specimen of *D. kincaidii* and parasitoids were deposited in the Northern Michigan University Insect Collection.

**Data Analysis**

To determine factors that influence variation in galler distribution at the local scale, distance to a hiking trail, distance to the nearest thimbleberry patch, and total density of stems, primocanes and floricanes were used as predictor variables for total gall density, percent stems galled in a patch and presence and absence of galls. Data collected from the intensive sampling site in Marquette Michigan were analyzed using non-parametric multiplicative regression (NPMR). NPMR avoids the unrealistic assumption of a simple linear or non-linear response of a response variable to a predictor variable (McCune 2006). HyperNiche version 2 (McCune and Mefford 2009) was then used to find the models that predicted gall density, percent of canes galled within stands and presence or absence of galls within a patch. Models were evaluated using a 100 iteration Monte Carlo randomization test and using $x^2_r$. This metric uses a cross validation of the residual sum of squares in relation to the total sum of squares. Like $r^2$, $x^2_r$ can be used to evaluate model quality.

Region-wide patterns were analyzed with simple descriptive statistics. We used the locations of Kraft and Erbisch (1990) to determine a potential spread rate of *D. kincaidii* within the Great Lakes region. Although Kraft and Erbisch (1990) was not a comprehensive range-wide survey for *D. kincaidii*, their work provided the best available starting point for assessing possible range expansion.

**Results**

Galls of *D. kincaidii* were found throughout the upper Great Lakes region, expanding the known range of *D. kincaidii* in the region as reported by Kraft and Erbisch (1990) (Fig. 1). In addition to the known records, galls were recorded from Ontonagon, Menominee, and Marquette counties in Michigan; Iron and Bayfield counties in Wisconsin; Lake and Cook counties in Minnesota; and Thunder Bay and Algoma districts in Ontario (Table 1). Distribution of *D. kincaidii* within the Great Lakes thimbleberry range was clustered within the western portion of the Lake Superior watershed where galls were present in all stands surveyed. *Diastrophus kincaidii* was found as far east as Lake Superior Provincial Park in Algoma District, Ontario where two isolated occurrences were noted, and as far south as Menominee County, Michigan where a single isolated occurrence was detected (Fig. 1). Across the entire region in stands where galls occurred, an average of 16.7 ± 1.89% stems galled, and an average density of 1.62 ± 0.24 galls per square meter (n = 91). Only four (0.4%) of the 824 floricanes sampled were galled. *Diastrophis kincaidii* dispersal rate was calculated to be 19 km/year based on the presence of galls in the Duluth, Minnesota area in 1980, as reported by Kraft and Erbisch (1990), to the current location of Nipigon, Ontario, the furthest direct route of a new *D. kincaidii* record.

Nine parasitoid morpho-types (identified to genus) representing six Hymenoptera families were reared from the 88 field-collected galls (Table 2). These specimens represent parasitoid families previously collected from galls in in western North America (Wangberg 1976, Jones 1983). Wasps from these families also parasitize *Diastrophus nebulosus*, a gall former on *Rubus flagellaris*, which occurs in the lower peninsula of Michigan (Gordinier 2003).

Five parasitoid genera collected in this study have been previously collected from *D. kincaidii* galls from western North America (*Orthopelma*, *Eurytoma*, *
Torymus, Eupelmella, and Ormyrus); Five have been found in D. nebulosis galls in southern Michigan (Orthopelma, Eurytoma, Torymus, Eupelmella, and Ormyrus); and two have not been previously associated with Diastrophus galls (Xiphosomella and Pteromalinae). The two members of Pteromalinae (Pteromalidae) are most likely un-described species (Roger Burks, Ohio State University, personal communication).

Thimbleberry covered approximately one percent of the total area of the intensively studied area in Marquette, Michigan (Fig. 2). Disastrophus kincaidii occupied 88% of the 57 thimbleberry stands examined. Gall density per stand was 0.99 ± 0.27 per square meter and thimbleberry plants covered approximately 2% of the park area. Thus we estimate that there were approximately 0.59 galls per square meter, or 3,430 galls in the park. Based on Jones (1983) average of 45 insects per gall this would put the populations of D. kincaidii for the park at an estimated 154,350 individuals. Average gall density per stand was measured at 0.99 ± 0.27 galls per square meter and on average 13.31 ±2.36% galled stems within stands. The best fit NPMR model indicated that presence/absence per stand was a function of distance to a hiking trail, density of primo canes, and floricanes density (xr² = 0.25, p = 0.059). Sensitivity analysis showed presence
was influenced most by distance to a hiking trail (sensitivity = 0.48) followed by lower flora cane density (sensitivity = 0.43) and an increase in primo cane density (sensitivity = 0.31). The model explained some of the variation in gall distribution within this study area, although it was only marginally significant and had low explanatory power. Both male and female *D. kincaidii* flew readily in the lab.

**Discussion**

**Distribution of *Diastrophis kincaidii* in the Great Lakes Region.**

The results of our survey indicate that the present distribution of *D. kincaidii* in the Great Lakes region lies within the much larger range of its host plant, the thimbleberry, *Rubus parviflorus*, with most observations occurring in the western half of the Lake Superior watershed (Fig. 1). Following the regional micro-climate data from Fuller et al. (1995), the greatest densities of *D. kincaidii* galls, and the highest proportions of thimbleberry stems with galls, occurred in the coldest, driest habitats within the thimbleberry range, including apparently isolated gall wasp populations in relatively cold, dry environments in the eastern (Lake Superior Provincial Park, Algoma District, Ontario) and southern (Menomonee County, Michigan) parts of the survey area (Fig. 1). Interestingly, even within the heart of the *D. kincaidii* range along Lake Superior, a distinct density gradient was observed with greatest population densities occurring in the coldest, driest (more xeric) parts of the Keweenaw Peninsula, Isle Royale, and northeastern Minnesota, with densities decreasing where habitats within these areas become warmer and wetter (more mesic).
Table 2. Hymenopteran wasp communities found in *Diastrophus kincadii* galls in California (Wangburg 1976), and British Columbia (Jones 1983) and the present study. Also showing the hymenopteran gall community of *D. nubulosus* galls in southeastern Michigan (Gordinier 2003).

<table>
<thead>
<tr>
<th>Family</th>
<th>California</th>
<th>British Columbia</th>
<th>Southern Michigan (D. nubulosus)</th>
<th>Great Lakes Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ishncomonidae</td>
<td><em>Orthopelma californicum</em></td>
<td><em>Orthopelma californicum</em></td>
<td>c.f. <em>Orthopelma sp.</em></td>
<td><em>Orthopelma sp</em> Xiposomella sp</td>
</tr>
<tr>
<td>Eurytomidae</td>
<td><em>Eurytoma brevitergis</em></td>
<td><em>Eurytoma c.f. auriceps</em></td>
<td><em>Eurytoma diastrophus</em>, <em>Eurytoma rubrigalla</em>, <em>Tenuiptiulbs ruber</em></td>
<td><em>Eurytoma sp.</em></td>
</tr>
<tr>
<td>Pteromalidae</td>
<td><em>Habrocytus sp.</em> <em>Artholytus sp.</em></td>
<td><em>Eryhromalus sp.</em>, <em>Arthrolytus sp.</em></td>
<td><em>Habrocytus sp.</em></td>
<td><em>Pteromalinae nsp #1</em> <em>Pteromalinae nsp #2</em></td>
</tr>
<tr>
<td>Torymididae</td>
<td><em>Torymus fagopirum</em>, <em>Torymus solitarius</em></td>
<td><em>Torymus fagopirum</em>, <em>Torymus solitarius</em></td>
<td><em>Torymus flavicosa</em>, <em>Torymus advenus</em></td>
<td><em>Torymus sp. #1</em> <em>Torymus sp. #2</em></td>
</tr>
<tr>
<td>Eupelmidae</td>
<td><em>Eupelmella vesicularis</em>, <em>Eupelmella vesicularis</em></td>
<td><em>Eupelmella vesicularis</em></td>
<td><em>Eupelmella vesicularis</em></td>
<td><em>Eupelmella sp.</em></td>
</tr>
<tr>
<td>Ormyridae</td>
<td><em>Ormyrus sp.</em></td>
<td><em>Ormyrus sp.</em></td>
<td><em>Ormyrus labotus</em></td>
<td><em>Ormyrus sp.</em></td>
</tr>
<tr>
<td>Eulophidae</td>
<td><em>Tetrastichus sp.</em> 1 unknown</td>
<td><em>Tetrastichus sp.</em> 1 unknown</td>
<td><em>Synophromorpha sylvestris</em></td>
<td></td>
</tr>
<tr>
<td>Cynipidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total observed</td>
<td>10</td>
<td>8</td>
<td>19</td>
<td>9</td>
</tr>
</tbody>
</table>
Gall position along a xeric-mesic gradient has been shown to strongly influence the survival of gall-forming insects as a result of increasing parasitism and fungal disease as habitats become more mesic (Fernandes and Price 1992). For example, Williams et al. (2003) exposed overwintering larval Diplolepis wasps (Hymenoptera: Cynipidae) to conditions simulating unseasonably warm winter weather and found that energy reserves required for pupation were depleted, which suggests that wasps overwintering in galls can be very sensitive to deviations from their optimal thermal environment. Like Diplolepis species, the super cooling point of D. kincaidii is quite low (-31.0 C to -40.0 C) (Ring and Tesar 1981) which suggests that the combination of this cold/xeric thermal optimum and (or) the sparse distribution of thimbleberry outside of the western Lake Superior watershed may contribute to the regional distribution patterns observed for D. kincaidii.

**Local Distribution of Diastrophis kincaidii.** The local distribution of D. kincaidii appeared to be random within and among thimbleberry stands in the intensively studied area. Predictive NPMR models showed mostly weak associations with different habitat variables, suggesting that within area groupings may be random for D. kincaidii on a local scale. Thimbleberry is a disturbance tolerating shrub (Camaeu et al. 2000) that can persist for long periods once established (Oleskevich et al. 1996). Many of the stands with galls present may have had very different characters when they were originally colonized by D. kincaidii. This could have masked some of the variables in the NPMR models.

Gall makers live in an intrinsically patchy environment, with preferred host plants often existing in a complex matrix of non-preferred plants and dispersal barriers. For instance, relative quality of plants may restrict cynipid gall wasps in local movements. Slight phenotypic difference in plants may create small “micro-populations” that are adapted to individual plants (Egan and Ott 2007). Since thimbleberry is a long-lived clonal shrub, D. kincaidii distribution may be highly influenced by between patch variability.

Despite the mostly random patterns of distribution there was still some explanatory power in the NPMR models. The model explaining presence/absence as a function of hiking trail distance and primocane and floricane density might also show how D. kincaidii patterns are influenced on a local scale. Hiking trails could affect colonizing D. kincaidii in several ways. First they may provide more areas on the outside of the thimbleberry patch that would make it easier for D. kincaidii to encounter a thimbleberry patch when dispersing. Secondly, these trails may provide a corridor for dispersal. Lastly, disturbance along the trails, such as trail maintenance, may cut canes back and encourage the growth of primo canes which are selected heavily by D. kincaidii in preference of the second year floricane.

Emergent D. kincaidii search for new non-woody oviposition sites (Wangberg 1975), thus the relative density of primocanes may determine overall patch suitability. A large proportion of floricanes in a stand may reduce available oviposition sites and lower chances of gall induction. While stand area may approximate “target size” for dispersing D. kincaidii, it seems likely that primocane density is a more important determinant of habitat quality providing overall, more oviposition sites.

With an estimated D. kincaidii larval population in the intensive study area of 154,340 individuals, the population has a large pool of individuals. This large population size may lend itself to greater ability to spread locally though sheer numbers, maintaining regional populations. Chance dispersal increases with an increase in individuals (Simberloff 2009) and is most likely an important component of local distribution patterns in D. kincaidii. Despite the erroneous claim by Jones (1983) that female D. kincaidii are flightless, both male and females fly as observed numerous times in the present study. This fact greatly increases the potential for population expansion because ovipositing females
are seemingly capable of short dispersal flights and also using flight to initiate passive atmospheric transport.

Community Ecology of the Great Lakes *Diastrophis kincaidii*. Gall making insects commandeer their host plant to produce large, nutritious organs (galls) that provide for larval development and in some cases, colonial existence. Like other forms of herbivory, the cost to plants of hosting gall makers can substantially reduce plant fitness by limiting the availability of resources required for growth and reproduction (McCrea et al. 1985, Abrahamson and Weis 1987). The effects of *D. kincaidii* galling on thimbleberries appear to include an additional structural constraint on sexual reproduction by limiting the future reproductive efficacy of the stems with galls.

The community of parasitoids found on *D. kincaidii* in the Great Lakes region have significant overlap with both the parasitoids found in the western North American part of *D. kincaidii* range and from the con-generic *D. nebulosus* in southern Michigan. In addition to this diversity of parasitoids from different geographic communities, the discovery of two undescribed species adds to the known diversity of the Great Lakes parasitoid community. Evidence gathered thus far indicates the *D. kincaidii* parasitoid community is a mix of a pre-glacial remnant community from a vicariance event with western North America, host switching from the southern Michigan associated species and possible (currently being described) endemism in the Great Lakes.

**How Long Has *D.kincaidii* Been in the Great Lakes Region?** Based on our estimate of the dispersal rate of 19 km per year, *D. kincaidii* should have been able to reach any of the areas within the Great Lakes thimbleberry range since Kraft and Erbisch’s (1990) study. Its occurrence on Isle Royale (Keweenaw County, Michigan) and several other seemingly isolated patches suggests that long-distance dispersal may frequently occur, perhaps by passive atmospheric transport initiated by dispersal flights.

Although little information exists about the dispersal rates of very small wasps, 19 km per year seems rapid when compared to other insects. For example, the invasion of a gall midge *Urophora cardui* (Diptera: Tephritidae) in Finland, proceeded at approximately 11 km per year (Jansson 1992). Although it impossible to rule out with currently available information, the present distribution of *D. kincaidii* appears to reflect a history in the Great Lakes region, perhaps similar to that of its host.

*Diastrophus kincaidii* is widely distributed in the Lake Superior watershed. Its relative abundance within the watershed creates a complex ecological system for studying multi-trophic interactions across biogeographical gradients. The interaction of *D. kincaidii* with one of the most recognizable plants of the Upper Great Lakes is a fascinating and important ecological relationship. Further studies will only reinforce our knowledge of plant insect interactions over broad and geographically disjunct regions, including studies to address niche shifts, interactions within and among trophic levels, environmental and biological factors that contribute to abundance, and how these factors influence that community composition.

**Acknowledgments**

Kevin Heynig and Lauren Tarr both assisted with work in the field. Alan Rebertus helped with research design and analysis. Parks Canada and the Nature Conservancy (Door Peninsula) provided records of wasp distributions and checked for galls in isolated stands. Roger Burks helped identify many of the parasitoid wasps and Alexey Reshikov provided the identifications for the Ichneumonidae. We thank three anonymous reviewers for their helpful insights.
Literature Cited


Associations Among *Serropalpus substriatus* (Coleoptera: Melandryidae) and *Sirex* (Hymenoptera: Siricidae) Communities

Tonya D. Bittner¹, Ann E. Hajek¹*, and James K. Liebherr¹

Abstract

*Serropalpus substriatus* Haldeman (Coleoptera: Melandryidae) develops within the same trees as *Sirex noctilio* F. and *Sirex cyaneus* F. (Hymenoptera: Siricidae). This species is now reported emerging from red pine (*Pinus resinosa* Sol. ex Aiton) and balsam fir (*Abies balsamea* (L.) Mill.) (Pinaceae) in eastern North America. Numbers of *Se. substriatus* emerging from pines were always much lower than numbers of *Sirex* in trees, and 18% of *Se. substriatus* required 2 years before emergence. During first years of emergence, *Se. substriatus* was found in only 12 of 41 sampled red pines infested by *St. noctilio*. Trees from which *Se. substriatus* emerged hosted higher densities of *Sirex* than trees without *Se. substriatus*. Comparing dually infested trees, *Deladenus siricidicola* Bedding, the parasitic/mycophagous nematode associated with *St. noctilio*, was found parasitizing one of 141 (0.7%) *Se. substriatus*. This is the first report of a non-target impact of *D. siricidicola* in North America, but parasitism was very low in this uncommonly encountered woodboring beetle. In Europe, a related species, *Serropalpus barbatus* Schaller, has also been reported to be parasitized by *D. siricidicola*.

Three species of *Serropalpus* Hellenius (Coleoptera: Melandryidae, Melandryinae) occur in North America while one, *Serropalpus barbatus* Schaller, occurs in central Europe (Mank 1939). Larvae of these beetles tunnel within the xylem of conifers (Hoebeke and McCabe 1977). More generally, beetles in the subfamily Melandryinae, including *Serropalpus*, are associated with wood infested with white rot fungi (Lawrence 1991). Thus, it is consistent that in Europe *Se. barbatus* is known as an associate of woodwasps of the genus *Sirex* L. (Hymenoptera: Siricidae), as *Sirex* females carry the white rot fungus *Amylostereum* Boidin (Basidiomycota: Russulales) in their mycangia, depositing it within the xylem of conifers while ovipositing. *Sirex* larvae cannot develop if *Amylostereum* is not present in wood (Ryan and Hurley 2012).

*Sirex* spp. are also native to North America (Schiff et al. 2012), where they generally live as forest decomposers. The native *Sirex nitidus* (T. W. Harris) is mostly associated with species of spruce, *Picea* A. Dietr., and the native *Sirex cyaneus* F. is associated with species of firs, *Abies* Mill. In northeastern North America, both the introduced *Sirex noctilio* F. and the native *Sirex nigricornis* F. are primarily associated with species of pines, *Pinus* L. (Schiff et al. 2012). The Eurasian *Sirex noctilio* is known as an aggressive pest where it has been introduced in the Southern Hemisphere, in some situations causing extensive pine mortality, especially under drought conditions (Ryan and Hurley 2012). *Sirex noctilio* was first collected in North America in New York State in 2004 (Hoebeke et al. 2005) and has now spread into six additional states to the west.

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Serropalpus species also prefer coniferous host trees. In Europe, *Se. barbatus* is associated with firs and spruce (Hoebeke and McCabe 1977). In North America, *Serropalpus coxalis* Mank has been reared from eastern hemlock, *Tsuga canadensis* (L.) Carr (Hoebeke and McCabe 1977). All published host records for *Serropalpus substratiatus* Haldeman are from western North America, where this species is associated with a long list of host trees including trees in the Pinaceae—pines, fir, and spruce—as well as redwood, sequoia and other members of the Cupressaceae (for details see Furniss and Carolin 1977, Hoebeke and McCabe 1977, Camilli et al. 2012). *Serropalpus substratiatus* was reared from Engelmann spruce, *Picea engelmannii* Parry ex Engelm., and white spruce, *Picea glauca* (Moench) Voss, in British Columbia and was noted for having an economic impact when producing holes in lumber (Ross 1968).

Nematodes in the genus *Deladenus* that are associated with woodwasps are also associated with *Amylostereum* spp., the white rot fungal symbionts carried within mycangia by female *Sirex*. *Deladenus* species associated with woodwasps have a dimorphic life history with a free-living mycophagous form (feeding on *Amylostereum* spp.) and a parasitic form that parasitizes siricid hosts (Bedding 1972). The mycophagous form increases and persists within trees whereas the parasitic form disperses to new trees via parasitized female wasps. The parasitic female nematodes within a wasp’s abdomen bear mycophagous juvenile nematodes. These are injected into a new tree during oviposition, either within the woodwasp female’s eggs and/or along with accessory fluids from the female reproductive tract. Several species and strains of *Deladenus* have been investigated as biological control agents (Bedding and Akhurst 1978) and a strain of *Deladenus siricidicola* Bedding that sterilizes *Si. noctilio* females has been used extensively in the southern hemisphere to control *Si. noctilio* (Bedding and Iede 2005, Hurley et al. 2007). In North America, a strain of *D. siricidicola* that parasitizes *Si. noctilio* does not sterilize eggs of the adult females (Yu et al. 2009). This non-sterilizing strain of *D. siricidicola* is associated with *Sirex*, with 27.9% of *Si. noctilio* parasitized in New York and Pennsylvania in 2011 (Kroll et al. 2013). This strain of *D. siricidicola* was probably introduced with *Si. noctilio*.

Many other species of organisms may be present in the same wood as *Sirex* larvae and free-living *Deladenus*, some feeding as parasitoids on *Sirex* larvae and many feeding on wood (e.g., Ryan et al. 2012), sometimes in association with the same type of fungus as *Sirex*. Due to living within the same environment, these other species can be in close proximity to the free-living forms of the nematodes. The only other species besides *Si. noctilio* known to be parasitized by *D. siricidicola* in North America is *Si. nigricornis* (Morris et al. 2013). In Europe and Asia, *D. siricidicola* is known to parasitize 5 native species of siricids (Bedding and Akhurst 1978) and in Europe, the native woodboring beetle *Se. barbatus* is parasitized by both *D. siricidicola* and *Deladenus wilsoni* Bedding (Bedding 1972, Bedding and Akhurst 1978). Levels of nematode parasitism in *Se. barbatus* are not known.

In North America, *Se. substratiatus* emerges from trees infested by both the invasive *Sirex noctilio* and a native species of *Sirex*. We report rearing *Se. substratiatus* (see cover) from red pines, *Pinus resinosa* Sol. ex Aiton, infested by *Si. noctilio*, and also from balsam fir, *Abies balsamea* (L.) Mill. infested with *Si. cyaneus*. These beetles are not commonly encountered, and are usually not abundant. They require 1 or 2 years to complete a generation. We also report an instance of parasitism of *Se. substratiatus* by *D. siricidicola*, demonstrating a very low level of non-target impact.
Materials and Methods

From 2007–2015, declining red pines in New York and north central Pennsylvania exhibiting resin beads created by *Si. noctilio* oviposition (Bordeaux and Dean 2012) were detected in fall and felled the following March or April. *Sirex*-infested parts of trunks were cut into 1 m long sections, ends were waxed and bolts were placed into fiber barrels (77.5 cm tall x 51.4 cm diam.), closed with window screening. Barrels were checked daily for insect emergence from 1 July to 30 September. All rearing was conducted in an unheated barn where the wood was also overwintered between 2014 and 2015.

Emerging *Se. substriatus* were only consistently collected during the 2014 season for 30 red pines collected from Pennsylvania: Tioga Co., Tioga State Forest. Based on timing of emergence of *Se. substriatus* adults, we assume that eggs were laid in trees during the same field season as *Sirex* oviposition. *Sirex* specialist parasitoids were also collected and counted, because each of these solitary parasitoids represents initial presence of one *Sirex*. The numbers of *Sirex* per tree were calculated as the numbers of adult *Sirex* emerging added to the numbers of emerged parasitoids *Ibalia leucospoides ensiger* Norton (Hymenoptera: Ibalidae) and *Rhyssa* spp. (Hymenoptera: Ichneumonidae). Densities of *Sirex* plus parasitoids were compared using Student’s t-test for trees from which *Se. substriatus* emerged or not. For trees from 2014 and 2015 from which *Se. substriatus* emerged, log-transformed count data were regressed. Wood from 2014 trees was retained for a second year to investigate whether some *Se. substriatus* require two years before emergence.

*Se. substriatus* emerging from trees were not consistently collected prior to 2014 but records were maintained for collections from various locations between 2007 and 2013. Representative reared specimens of *Se. substriatus* are deposited in the Cornell University Insect Collection and labeled as CUIC voucher lot no. 1274.

**Deladenus siricidicola Parasitism of Serropalpus substriatus.** Because *Se. barbatus* was recorded as a host for *D. siricidicola* in Europe (Bedding and Akhurst 1978), in 2012 and 2013 when we realized that *Se. substriatus* was emerging occasionally in our rearing, we began dissecting *Se. substriatus* to evaluate nematode parasitism. During 2014–15, all *Se. substriatus* emerging from wood were dissected and observed at 60–65x for presence of nematodes. In 2014, one *Se. substriatus* containing abundant nematodes was detected. DNA was extracted from several nematodes and also from nematodes found in two *Si. noctilio* that emerged from the same tree. DNA was extracted using a QIAamp DNA mini kit (Qiagen, Germantown, Maryland, USA) and then a portion of mtCOI was amplified using primers described by Yu et al. (2009, with modification of the annealing temperature to 52° C). We performed a clean-up using Shrimp Alkaline Phosphatase (GE Healthcare) and Exonuclease I (New England Biolabs) enzymes following manufacturers’ instructions. Cleaned products were primed with an internal forward sequencing primer to produce clean reads (5'- ATG TTA GGT TGT CCT GAT AT-3') on an ABI3730xl automated sequencer. We subsequently dissected all *Si. noctilio* wasps that emerged from the same tree as the parasitized *Se. substriatus* to quantify percent parasitism by *Se. substriatus* for the entire tree from which the nematode-parasitized *Se. substriatus* emerged.

In addition, because both *D. siricidicola* and *D. wilsoni* parasitized *Se. barbatus* in Europe, and North American species of *Rhyssa* are parasitized by *D. wilsoni* (Bedding and Akhurst 1978), all *Rhyssa* emerging in 2014 (n = 139) and 2015 (n = 21) were dissected to detect *Deladenus* infections, including *Rhyssa lineolata* Kirby (n = 101), *Rhyssa persuasoria* L. (n = 30) and *Rhyssa crevieri* Provancher (n = 29).
**Results**

**Association of Serropalpus substriatus with Sirex noctilio.** During 2014 and 2015, emergence of *Se. substriatus* occurred from 15 July–2 September, which is the same period when *Si. noctilio* emerged from trees. In 2014, *Se. substriatus* emerged from 6 of the 26 trees from which *Si. noctilio* emerged (23.1%) and did not emerge from the 3 trees from which single *Si. nigricornis* emerged (Table 1). In 2015, *Se. substriatus* emerged from 6 of 15 trees (40.0%) from which *Si. noctilio* emerged, with no *Si. nigricornis* emerging during that year. Although no *Se. substriatus* emerged from most trees, a maximum of 50 individuals emerged from one tree. During both years, numbers of *Si. noctilio* emerging per tree were always far greater than numbers of *Se. substriatus*.

Red pines from which *Se. substriatus* emerged during both 2014 and 2015 hosted higher densities of *Si. noctilio* than red pines from which no *Se. substriatus* emerged (2014: t = -2.59; P = 0.016, 2015: t = -2.37; P = 0.039) (Fig. 1A). For trees from which both *Se. substriatus* and *Si. noctilio* emerged, a positive trend in densities between the two species occurred (Fig. 1B). *Serropalpus substriatus* emerged from some red pines harvested in 2014 that were monitored a second year. Based on the total emerging over the 2 years, 18% of the *Se. substriatus* from those trees emerged the second year. The two trees with second-year emergence of *Se. substriatus* were among the trees hosting higher *Si. noctilio* densities.

**Deladenus siricidicola Parasitism of Serropalpus substriatus.** Over four years a total of 141 adult *Se. substriatus* (11, 5, 32, and 93 respectively in 2012–2015) were dissected. Only one (0.7 %) contained nematodes, and it was one of 13 *Se. substriatus* that emerged from one tree in 2014 (this tree had the highest *Se. substriatus* emergence in 2014). The sequences of the three unknown nematode samples (from the parasitized *Se. substriatus* and two randomly chosen *Si. noctilio* emerging from the same tree) matched each other and matched Genbank sequences of Morris et al. (2013) JX104282 and JX104276, which belong to the non-sterilizing *Deladenus siricidicola* clade present in North America. This is the first report of *Deladenus* parasitism in a North American *Serropalpus* species. We observed juvenile nematodes within the beetle, thus meeting the “successful” parasitism criterion of Bedding and Akhurst (1978).

The tree hosting the *Se. substriatus* with *D. siricidicola* infection had been divided into 1-m long bolts and placed into four different rearing barrels. The overall rate of nematode parasitism of the 109 *Si. noctilio* that emerged from this tree was 39.5% and the barrel from which the infected *Se. substriatus* emerged (which contained 3 bolts) had 50.0% parasitism of *Si. noctilio* by *D. siricidicola*. No nematode parasitism was detected in any of the *Rhyssa* emerging in 2014–15.

**Host Trees.** In 2014 and 2015, *Se. substriatus* was reared from red pines, *Pinus resinosa*, from Tioga State Forest, Pennsylvania, from which *Si. noctilio* also emerged. In 2008, we reared both *Se. substriatus* and the native woodwasp *St. cyaneus* from balsam firs from Huntington Wildlife Forest, Newcomb, Essex Co., New York, with *Se. substriatus* emerging from 22 July to 2 August.

**Discussion**

When rearing insects from pines infested by *Sirex noctilio* in northeastern North America, it is very common that woodboring beetles also emerge from the same wood (Ryan et al. 2012; AEH unpubl data). To date in New York and Pennsylvania, *D. siricidicola* has not previously been found parasitizing any of these *Sirex* associates (e.g., parasitoids of *Sirex* or beetles) (AEH and D.W. Williams unpublished data). When we discovered *Se. substriatus* emerging from pines, we particularly focused on this species because the congeneric species *Se. barbatus* has been reported as being parasitized by both *D. siricidicola* and
Table 1. Mean (+ SE) emergence of *Serropalpus substriatus*, *Sirex* spp. and parasitoids associated with *Sirex* from red pines in Tioga County, Pennsylvania over one year after trees were infested by *Si. noctilio*.

<table>
<thead>
<tr>
<th>Site</th>
<th>Total trees with <em>Sirex</em> &amp; <em>Sirex</em> parasitoids</th>
<th>Total trees with <em>Si. noctilio</em></th>
<th>Total trees with <em>Si. nigricornis</em></th>
<th>Total <em>Sirex</em> parasitoids/ tree</th>
<th>Total <em>Sirex</em> tree</th>
<th># trees with <em>Se. substriatus</em></th>
<th>Total <em>Se. substriatus</em> tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hills Creek State Park</td>
<td>26</td>
<td>46.4 + 10.8</td>
<td>0.1 + 0.1</td>
<td>31.4 + 8.0</td>
<td>77.9 + 18.1</td>
<td>6</td>
<td>1.2 + 0.6</td>
</tr>
<tr>
<td>Tioga State Forest</td>
<td>15</td>
<td>22.8 + 7.4</td>
<td>0</td>
<td>14.5 + 7.7</td>
<td>37.3 + 14.9</td>
<td>6</td>
<td>6.2 + 3.5</td>
</tr>
</tbody>
</table>

*a* Red pines in 2014 were from Hills Creek State Park and in 2015 were from Tioga State Forest.

*b* Total of both species of *Sirex* plus parasitoids, as each parasitoid parasitized one *Sirex* individual.
Figure 1. A. Mean (± SE) *Sirex noctilio*, *Si. nigricornis* and *Sirex* parasitoids emerging per red pine sampled from Tioga County, Pennsylvania from which *Serropalpus substriatus* also emerged or not. Years tested separately and differences were statistically significant (*P* < 0.05; see Results). B. Association between *Sirex noctilio*, *Si. nigricornis* and *Sirex* parasitoids and *Se. substriatus* emerging per red pine (number of *Se. substriatus*/tree (log) = 0.692*number of *Se. substriatus*/tree (log) - 0.5461; *R*² = 0.2956; *F* = 4.20; df = 1, 10; *P* = 0.0677), including 12 trees from which both *Sirex* and *Se. substriatus* emerged.
D. wilsoni in Europe (Bedding 1972, Bedding and Akhurst 1978). Although some reviews report Se. barbatus from North America (e.g., Baker 1972), as of 1939, Mank reported that no specimens of Se. barbatus are known from North America, and to our knowledge this remains correct (Hoebeke and McCabe 1977; E.R. Hoebeke, personal communication). We report that this relatively uncommon beetle, Se. substratiatus, can be parasitized by D. substratiatus but the percent parasitism determined over 4 years of collections was very low. In fact Se. substratiatus and Se. barbatus are the only non-targets, besides Sirex species (Morris et al. 2013), known to be parasitized by D. siricidicola. Regardless, from the standpoint of the beetle, being an associate of Si. noctilio could be positive due to the presence of the white rot fungus decomposing the wood, but it can also be negative when the beetles are parasitized by the nematode associated with Si. noctilio, although our study would suggest that this occurs rarely.

Members of the Sirex community are known to be attracted to the ecosymbiotic white rot fungus carried by Sirex. Fernández Ajó et al. (2015) demonstrated that Si. noctilio females are attracted to Amylostereum areolatum (Chaillet ex Fr.) Boidin, whereas Sarvary et al. (accepted) demonstrated that only mated Si. noctilio females were attracted to A. areolatum. Martínez et al. (2006) showed that females of Ibalia leucospoides (Hochenwarth), a hymenopteran parasitoid of Si. noctilio, are attracted to cultures of A. areolatum, and these parasitoids were found to use chemical cues derived from A. areolatum to locate Si. noctilio eggs and larvae (Madden 1968; Spradbery 1974). Alternatively, trapping studies conducted in an area of Ontario with diverse pine species demonstrated that a Serropalpus sp. (not identified to species) was attracted to monoterpenes and ethanol (Chénier and Philogène 1989). Sirex noctilio is also attracted to pinenes (Bashford 2008), so it is possible that Se. substratiatus is attracted to the same or similar compounds being emitted from trees that also attract Sirex. Therefore, Se. substratiatus could be attracted to trees infested with Sirex using volatiles from Sirex, Amylostereum, and/or the host tree, but this remains to be tested.

Utilizing trees also from Tioga State Forest Pennsylvania, Kroll et al. (2013) previously reported overall rates of D. siricidicola parasitism of Si. noctilio in 5 of 16 P. resinosa ranging from 0.8–2.3%. The highest previously reported nematode parasitism of Si. noctilio within one tree was 57.7% in a Scots pine (Pinus sylvestris L.) from central New York (Kroll et al. 2013). Thus, the nematode parasitism in the tree with the infected Se. substratiatus in the present study (39.5%) is considerably higher than previously reported in P. resinosa in this region, and within the upper range of known overall parasitism rates per tree for D. siricidicola in North America. One possible explanation for finding nematode parasitism of Se. substratiatus is that this unusually high load of nematodes increased exposure of this potential non-target to relatively high densities of nematodes within the wood, although only 1 of 13 Se. substratiatus from that tree became parasitized.

The increasing abundance of Si. noctilio in North America may positively affect populations of Se. substratiatus over time although the potential mechanisms are unknown. Interestingly, Se. substratiatus was not found during an extensive study of Si. noctilio associates in Ontario (Ryan 2011). There are no records of Se. substratiatus being associated with Si. nigricornis when this native woodwasp was the major Sirex species in pines in northeastern North America, although siricids emerged from the same spruce as Se. substratiatus in British Columbia (Ross 1968). We hypothesize that during this study, Se. substratiatus did not emerge from the same trees as Si. nigricornis solely due to low densities of both Si. nigricornis and Se. substratiatus, rather than due to avoidance of co-habitation within the same trees.
Acknowledgments

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Spatiotemporal Patterns of Population Decline in *Oarisma poweshiek* (Hesperiidae) in Michigan and Minnesota Between 1990 and 2013

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Abstract

The recent contraction of the geographic range of *Oarisma poweshiek* (Poweshiek skipperling) (Lepidoptera: Hesperiidae) resulted in its listing as an endangered species in 2014 (USFWS 2014). However, changes in population density within sites associated with this contraction are still not understood. This range-wide contraction of Poweshiek skipperling appears to indicate a regional cause. Using population data from multiple sites in Michigan and Minnesota, we investigated the temporal and spatial patterns of population decline to determine if regional or site-specific factors likely contributed to the decline. We hypothesized that if regional factors caused the density declines, then the declines would be temporally synchronous and spatially correlated across sites. We found decline patterns to be temporally asynchronous and spatially uncorrelated, except for sites in west-central Minnesota. These results imply that regional factors may not be the main causes for the population density declines, and understanding multiple site-specific factors consistent with observed patterns of decline will be important for recovering Poweshiek skipperling populations.

*Oarisma poweshiek* (Parker, 1870) was once an abundant skipperling in north central North American prairies, especially in Minnesota (USFWS 2014). As recently as the 1970s, it was common for land managers and researchers keeping records of Poweshiek skipperling abundance to use qualitative terms such as “hundreds” and “very abundant” (McCabe and Post 1977). Surveyors frequently bypassed documenting Poweshiek skipperling entirely due to their profusion. Dana (2008) regarded Poweshiek skipperling to be “the most frequently and reliably encountered prairie-obligate skipper in Minnesota.” Once plentiful from Manitoba to Iowa with occurrences in Minnesota, Wisconsin, North Dakota, South Dakota, Illinois, Indiana, and Michigan, Poweshiek skipperling has been extirpated from most of its historical sites with a few exceptions in Wisconsin, Michigan, and Manitoba (USFWS 2014). Based on the severity and abruptness of this range contraction, which occurred primarily after 2003, Poweshiek skipperling was listed in the United States as an endangered species in 2014 (USFWS 2014). Poweshiek skipperling was listed as threatened in Canada under the Species at Risk Act (COSEWIC 2003), and endangered provincially under the Manitoba Endangered Species and Ecosystems Act (Manitoba Conservation 2012).

Often compared to other threatened or endangered skippers in the tall grass prairie, Poweshiek skipperling differs from these in several important respects. Poweshiek skipperling occupies a broader range of prairie habitats than some of the other rare skippers (USFWS 2014). In addition, other rare skippers,
such as *Hesperia dacotae* (Skinner, 1911), *Hesperia assiniboia* (Lyman, 1892), and *Hesperia ottoe* (Edwards, 1866), were historically considered uncommon or rare (Dana 1991), so while these populations have declined, the reduction has not been apparently as great or abrupt (USFWS 2014).

Several hypotheses for the causes of Poweshiek skipperling decline have been proposed (Swengel and Swengel 1999, Selby 2005, Mao and Cherkauer 2009, Ratajczak et al. 2012, USFWS 2014). These can be considered to act regionally on many sites at the same time, or locally in a site-specific manner. The fact that the loss of occupied sites seemed to occur after 2003 over the entire range of Poweshiek skipperling would appear to indicate some regional or range-wide factor was at work. For example, extreme weather events may cause temporal and spatial synchrony. However, it is also possible that site-specific factors were the main cause of their decline and post-2003 losses were coincidental. For example, variation in site-specific management may be as disruptive as regional factors. Leaving sites unmanaged should intensify encroachment by invasive species and woody vegetation (Ratajczak et al. 2011) potentially creating habitat unsuitable for Poweshiek skipperling. Disturbance regimes including fire and cutting (i.e., haying and grazing) may be altered from their historical tendencies in timing, frequency, and scale (Swengel 1996). This could interrupt flight and alter host plants to the demise of Poweshiek skipperling.

The USFWS (2014) considered the following factors as causes of decline of Poweshiek skipperling: habitat destruction and conversion (agricultural and nonagricultural development), wind development, flooding, invasive species, fire, grazing, haying/mowing, lack of management, small size and isolation, and herbicide and/or pesticide use. They identified habitat destruction/conversion, invasive species, grazing, and small size/isolation as the factors causing medium or high impact on about 75% of the sites analyzed, and the contribution of the other factors was much less. All of these could be considered site-specific factors, although there could be some temporal synchrony and spatial correlation in their action. For example, habitat destruction and conversion will occur from decisions by individual landowners to develop remnant prairies, but if landowners respond to economic incentives that occur simultaneously across a region, skipperling declines could appear to be temporally synchronous and spatially correlated. In this case, the ultimate cause of the decline would be regional (the economic incentives), while the proximate cause would be local.

The USFWS (2014) based their listing decision on the substantial reduction of sites known to be occupied by Poweshiek skipperling after 2003. Site-specific population data continues to be sparse, but to investigate the synchrony and spatial correlation of declines, it is necessary to consider how populations of Poweshiek skipperling fluctuate within sites. Moreover, population data from occupied sites would support the listing decision if large population declines occurred. We used the existing population data to examine if these data exhibit a large population decline. In addition, to determine if regional or site-specific factors have dominated the decline of Poweshiek skipperling we used site specific population data and examined the spatial and temporal patterns of decline to test if regional or local factors dominated the causes of decline. Regional factors would act across several sites, and the declines would be predicted to occur synchronously and correlate spatially. Conversely, temporally asynchronous, spatially uncorrelated declines would indicate local site-specific factors.

### Methods

We concentrated this study on Michigan and Minnesota because these states have sufficient and more consistently collected data than the other states with historic Poweshiek skipperling populations. In addition, Minnesota historically had the highest populations, and Michigan is known to harbor many of the few remaining populations. A database that was used in the listing of
Poweshiek skipperling as endangered in the United States (USFWS 2014) and contained range-wide Poweshiek skipperling abundance over time was acquired from Phil Delphrey of United States Fish and Wildlife Service (USFWS). The database contained population counts from many sites dating from 1995 to 2012. Each record could include information on the site (name, county, area), sampling method (observer, transect, date), and the number of Poweshiek skipperlings observed.

All of the records for Michigan and Minnesota were completed, corrected and verified against published sources, and additional records were added from published sources or via personal communication with the surveyors who sampled the sites. Minnesota records were comparable within sites as similar methods were used within sites (Schlicht et al. 2009). Several of the records in the USFWS database for Michigan originated from the Michigan Natural Features Inventory (MNFI), which we could not directly verify. Personal communications with surveyors and current land managers were integral to ensuring the accuracy of the database.

**Time of Population Decline.** Even with these additions, the database was sparse. We restricted our analyses to sites that had samples from at least three years. Relatively few sites met this modest standard, and those that did, typically did not have samples from consecutive years. Thus, it was not possible to pinpoint the year or years of decline for any site. We addressed these data gaps using an uncertainty analysis. We used the data from a site to identify the period of the largest population decline at the site, which was defined as the time period between the two sample with the largest decline in population size (at one site, we identified two almost equal, large population declines). This period was the time period during which the population decline would have had to have occurred. Although the exact year or years of decline were uncertain, the data would indicate the possible years during which one or more would be the year of the actual decline. It would not be possible to determine the synchrony of decline in two or more sites with such data, because the exact year or years of decline were uncertain. However, it was possible to determine that synchrony was possible by comparing the overlap of the time periods of decline among sites. If the time periods overlapped, then synchrony was possible, but if they did not overlap, then synchrony was not possible. In this paper, we used possible synchrony as a measure of actual synchrony of decline. This measure is biased toward synchrony because two sites may have overlapping periods of decline (possible synchrony) but the actual years of decline could be different (asynchronous). Thus, this analysis is biased toward identifying a regional cause of decline.

**Spatial Correlation of Decline.** A similar method was used to identify spatially correlated declines. Overlapping periods of decline in spatially proximate sites were considered to indicate spatial correlation, while lack of overlap indicated the lack of spatial correlation. This method was also biased, in this case toward finding spatial correlation, and therefore also biased toward evidence for a regional cause of decline.

**Michigan Poweshiek Skipperling Density.** The majority of the counts in Michigan were timed meander counts which are designed to take place during peak flight. Michigan counts were conducted by a single qualified individual in a consistent manner making the estimates comparable over time. Michigan survey data were completed and verified with help from David Cuthrell of MNFI, Michigan State University. Cuthrell provided information that was unavailable in reports and the USFWS database, including missing counts and survey methods. In the few instances where the count was unclear in a report (i.e., “several”, “hundreds”), he provided a likely interpretation, which we used.

We calculated the number of Poweshiek skipperlings per hectare at each MI site. Area sampled was calculated by multiplying the sampling time by a
likely walking speed of 2 mi/hr, +/- 10% (equals estimated distance walked) times the likely transect width of 10 m (viewing distance is 5 m in either direction) +/- 20%. Density was calculated by dividing the total count or estimate of skipperlings sampled by the area sampled to give the expected population density with an associated level of error (+/- 30%). The observed population density declines were all > 60%, so this error did not affect the determination of the time period of decline at any of the sites.

Poweshiek skipperling has been historically documented in 17 sites in Michigan (USFWS 2014), of which we used data from 12 sites with 72 total data points. Two of the sites were classified by the USFWS (2014) as unknown status, Bullard Lake in Livingston County and Grand River Fen (Liberty Fen) in Jackson County. Three of our sites are those where the species is presumed extirpated, Rattalee Lake Fen (Calla C Burr Preserve), Lamberton Lake Fen, and Whalen Lake Fen (USFWS 2014). The remaining eight sites are those where USFWS (2014) considers the species to be present.

**Minnesota Relative Population Size.** Historically, Minnesota held 48% of all known sites (144 sites), of which only one has the species present, 58 are unknown, and 21 are considered extirpated (USFWS 2014). Only eight sites were examined in Minnesota because they were the only ones that had at least three years of observations. At each of these Minnesota sites, data were collected using Pollard transects (Pollard 1977) with a few records included as presence/absence and a few as whole site surveys. Therefore, even though some of the sampling details were missing, the number of skipperlings observed within a site was a consistent relative population estimate, and changes over time could be interpreted within sites. The sites we considered included the Glacial Lakes site where Selby (2005) first noticed a sharp decline in the species population in 2003 compared to 2001. We also included the Prairie Coteau site, which along with the Big Stone County site, historically had the highest numbers of observed skipperlings.

**Spatial Pattern of Decline in Michigan and Minnesota.** We mapped the time periods of population decline in Michigan and Minnesota using ArcGIS. Locations of all of the sites were provided by Phil Delphrey of USFWS and Barb Hosler from the East Lansing USFWS in Michigan. Map symbols represented different time periods for the population declines. Points on the maps have been jostled to protect the locations of the remaining populations.

**Evidence for Statewide Population Decline.** To evaluate statewide population trends, we conducted regression analysis for each state using site as a categorical factor and year as the regressor on density (MI) or counts (MN). We first allowed the year regression to vary with site (site*year effect), and then we restricted the analysis to homogeneous year slopes (no site effect on slopes). In both analyses we allowed a site main effect, which would allow for different timing for the declines. The first analysis allowed us to determine if some sites trended differently than others, for example if some declined faster than others or if some trended up while others trended down. The second analysis allowed examination of a state-wide trend, assuming that all sites trended in the same direction at a similar rate. Analyses were conducting using Proc GLM in SAS 9.4.

**Results and Discussion**

**Michigan.** In Michigan, Brandt Road Fen, Buckhorn Lake, Grand River Fen, Halstead Lake Fen, and Long Lake Fen sites had the highest population densities among the twelve sites. The highest recorded skipperling density was 178 per hectare at Halstead Lake Fen in 2012. Five sites consistently had less than 10 skipperlings per hectare. Some sites showed an increase in density and many sites declined fairly recently, between 2005 and 2013. Rattalee Lake Fen (Fig. 1J) and Whalen Lake (Fig. 1L) sites show definite population decline, and
are considered extirpated by the USFWS (2014). Bullard Lake (Fig. 1C), Lamberton Lake Fen (Fig. 1F), and Grand River Fen (Fig. 1D) sites have evidence of decline however Bullard Lake (Fig. 1C), and Lamberton Lake Fen (Fig. 1F) have only one point with high density and therefore the observed “decline” might simply be a “normal” population fluctuation. Additional sites for Michigan, which are all sites where Poweshiek skipperling is present, did not show clear declines in Poweshiek skipperling populations. Little Goose Lake Fen (Fig. 1G) shows some periods of fluctuation in population density.

Despite these caveats, all populations in Michigan, except for the Halstead Lake Fen population, showed some evidence of decline. However, the Poweshiek skipperling population declines in Michigan were not synchronous (Fig. 1). Some occurred during 2008–2009 (Fig. 1A, 1C, 1G, and 1J), some occurred during 2012–2013 (Fig. 1A, 1B, 1D, 1H, and 1I), and three occurred before 2008 (Fig. 1F, 1K, and 1L).

The Michigan historical population trend across all sites varied significantly among the sites (significant site*year effect: $F = 10.59; \text{df} = 12, 44; P = 2.09 \times 10^{-9}$). The Halstead site was significantly different from the others (slope = $22.44 \pm 2.13$ skipperlings per hectare per year, $T = 10.52, P < 0.001$), where population densities increased significantly during the observation period. The cause(s) of this increase are not known, but understanding them may help with recovery. There was no difference among the other sites, and none of the other slopes were significantly different from 0. Consequently, there was no detectable statewide historical trend in population density (year slope; $F = 1.40, \text{df} = 1, 55; P = 0.242$). This is perhaps surprising as five of the 12 sites studied here either had populations extirpated or undetermined, but it indicates that the surviving populations in Michigan were not strongly affected by whatever factors caused the declines in other states and other sites in Michigan. This does not correspond to the USFWS (2014) finding of significant range contraction of
Poweshiek skipperling, which was based on site occupancy. It is possible that factors affecting the Michigan populations were different from those affecting populations in other parts of the historic range.

Minnesota. All populations in Minnesota showed evidence of decline. Poweshiek skipperling sites within Minnesota also showed asynchronous temporal declines between 1991 and 2013. The distribution of skipperling counts suggest at least two periods of decline for Poweshiek skipperling in Minnesota. The first period of decline was during 1996 (Fig. 2B, 2E, 2F, 2G, and 2H), and the second was probably between 2003 and 2005 (Fig. 2A, 2B, 2C, 2D, 2G, and 2H). Sites 2B, 2G and 2H could have declined in either period are listed in both. Even so, five sites definitely did not decline synchronously.

In Minnesota, the historical trends did not vary among the sites (site*year effect: $F = 1.17; \text{df} = 8, 19; P = 0.367$). There was a statewide historical trend

Figure 2. Minnesota Poweshiek skipperling population dynamics: A. Big Stone County; B. Prairie Coteau; C. Hole in the Mountain; D. Glacial Lakes; E. Lac Qui Parle (1); F. Lac Qui Parle (54); G. Prairie Marshes WMA NHR; H. Chanarambie Creek.
(year effect: $F = 9.31; df = 1, 26; P = 0.005$) of decreasing population counts (slope $= -2.13 \pm 0.70$ skipperlings per year, $T = 3.05, P = 0.005$). Population declines in eight Minnesota sites support the USFWS (2014) analysis of range contraction of Poweshiek skipperling based on site occupancy.

**Comparing Michigan and Minnesota.** The decline periods in Michigan and Minnesota were different (Fig. 3), in part because data were not collected during comparable time intervals. As our methods overestimated synchrony, the observed temporal asynchrony suggests that site-specific factors were contributing to the decline of Poweshiek skipperling across its range.

The maps of Michigan and Minnesota show different spatial patterns for the time periods of decline (Fig. 4). In Michigan, sites with similar decline peri-
ods were not near each other and were spatially uncorrelated. In Minnesota the west-central sites may have declined synchronously while southwestern sites did not. As spatial correlation was overestimated by our method, it is possible that regional factors contributed to decline in the west-central sites of Minnesota while site-specific factors of decline had a greater impact on southwestern sites in Minnesota and all sites in Michigan. Our study shows that the recent decline of Poweshiek skipperling has differed both temporally and spatially between sites found in Michigan and Minnesota.

Based on the challenges we had in compiling the dataset used in this analysis, we suggest that a minimum standard for data reporting will be crucial to advance recovery of Poweshiek skipperling. This standard should include measures or descriptions of the environment at the time of sampling, including host plant phenology, temperature, cloud cover, wind, and precipitation. The sampling method should be thoroughly described, including name and contact information of the data collector, transect method (e.g., Pollard, straight-line, or meandering), start time and duration of sampling, distance covered, and the estimated width of transect.

Our analysis of the data for Poweshiek skipperling suggests that local factors may be the primary causes of decline in southwestern Minnesota and all of Michigan, while both regional and local factors may be contributing to declines in west-central Minnesota. In contrast, analysis of Karner blue butterfly (Lycaeides melissa samuelis Nabokov) indicated that local factors were the primary cause of its decline (Andow et al. 1994). Many other threatened or endangered prairie and savannah butterflies and skippers show signs of local causes of decline. For example, Regal fritillary (Speyeria idalia Drury) has suffered decline in the eastern half of its range and is considered secure only in Kansas (Royer and Marrone 1992). Ottee skipper (H. ottoe) still occupies its historical range but many populations are missing (Dana 1991, Swengel and Swengel 1999). Dakota skipper (H. dacotae) may occur at only one quarter of the sites where it was previously recorded across its range (USFWS 2014).

The current challenge lies in determining the multiple causal factors consistent with observed patterns of spatial and temporal decline of Poweshiek skipperling populations. This requires resisting generalizations about the role of extreme weather events causing region-wide losses. While extreme weather events may have precipitated declines of Poweshiek skipperling, local factors may prime these populations to increase susceptibility to such events. Some possible local factors are habitat loss and fragmentation (Selby 2005), hydrological changes (Shull 1987, Selby 2005), fire timing and frequency (Swengel 1996, Swengel and Swengel 1999, Selby 2005), woody or exotic encroachment (Selby 2005), and cutting through overgrazing or haying (Dana 1991, Royer and Marrone 1992, Selby 2005). The difficult work to unravel these interacting factors remains, but is needed to provide scientific evidence in support of recovery activities.

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Consumption of Insect Pests by the Evening Bat (Nycticeius humeralis) in Southeastern Michigan

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Abstract

Diet of a colony of evening bats (Nycticeius humeralis Rafinesque) in Lenawee County, Michigan, was studied during 2006–2007, using standard fecal analysis. Of the 594 fecal pellets examined, the spotted cucumber beetle (Diabrotica undecimpunctata howardi Barber: Coleoptera), green stink bug (Chinavia hilaris Say: Hemiptera), and emerald ash borer (Agrilus planipennis Fairmaire: Coleoptera) were identified and occurred at a frequency of 15, 12, and 0.8%; respectively, over the two years combined. In some weeks, up to 64% of the pellets analyzed contained fragments of spotted cucumber beetles, and up to 43% contained green stink bugs—two of the most injurious pests to corn and soybean. Consumption of spotted cucumber beetle and green stink bug appeared to coincide with the life history of these species. Conservation and management of suitable bat habitat adjacent to agricultural lands would likely benefit farmers and bats alike.

Insectivorous bats provide an ecosystem service by controlling populations of insects, such as phytophagous pests, which has important economic and ecological implications for agriculture and forestry (Boyles et al. 2011, Kunz et al. 2011, Charbonnier et al. 2014). These flying mammals not only reduce density of arthropods in forests and on agricultural plants but also indirectly limit herbivory on plants (Kalka et al. 2008, Williams-Guillén et al. 2008). Ecosystem services provided by bats to agricultural systems include reduction of crop damage, reduced and delayed application of pesticides, abatement of pest-associated fungus and mycotoxin, and indirect enhancement of crop productivity (Cleveland et al. 2006, Classen et al. 2014, Maine and Boyles 2015). Estimated value of these ecosystem services provided by bats in the United States is upward of $53 billion per year (Boyles et al. 2011).

The landscape of Lenawee County in southeastern Michigan is dominated by agricultural lands, supporting primarily corn and soybeans, and only small remnants of forest occur in isolated stands and along waterways. Along one such riparian network approximately 5 kilometers south of the town of Palmyra, Kurta et al. (2005) documented a maternity colony of evening bats (Nycticeius humeralis Rafinesque), consisting of 40–50 female adults and young-of-the-year that roosted in tree cavities or under bark (Münzer 2008). Although common in parts of the Southeast and central Midwest, these bats are rare in the northern United States. The colony in Lenawee County is the most northern on the continent and the only colony known in the Great Lakes region (Kurta 2008). In this paper, we document the identity of some insect pests consumed by these bats and the frequency with which they appear in the diet.

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Foods eaten by the evening bat were ascertained by standard fecal analysis (Whitaker et al. 2009). Fecal pellets were collected from screens erected below the entrance to roosts and combined into weekly samples. Week 1 began on 15 May 2006 and 14 May 2007, and week 15 ended on 27 August 2006 and 26 August 2007. However, fecal pellets were not collected during weeks 1, 2, and 7 of 2006, and weeks 3 and 15 of 2007 because of restricted access to the study area, caused by flooding and other factors. If ≤ 30 pellets were in a sample, then all pellets were analyzed; if > 30 pellets were present in any weekly sample, then 30 were randomly selected for analysis. Pellets were soaked in 70% ethanol and teased apart under a dissecting scope (Whitaker et al. 2009), and the percent frequency of occurrence was calculated for insects identified to species.

Bats thoroughly masticate their prey, making it difficult to identify the species consumed, unless those prey are very distinctive post digestion (Whitaker et al. 2009). Consequently, only three species of insect pests were identifiable in the 594 fecal pellets that were analyzed: spotted cucumber beetle (*Diabrotica undecimpunctata* Barber: Coleoptera), green stink bug (*Chinavia hilaris* Say: Hemiptera), and emerald ash borer (*Agrilus planipennis* Fairmaire: Coleoptera). These insects were found in 15, 12, and 0.8%, respectively, of the fecal pellets from both years combined.

In 2006, spotted cucumber beetles (17%) and green stink bugs (13%) often were detected, but the emerald ash borer was uncommon (0.6%). Spotted cucumber beetles peaked in frequency in late summer (50%; Fig. 1). The frequency occurrence of the green stink bug was variable; nonetheless, it was found at greatest frequency late in August (25%; week 15), followed by mid-to-late June (23%; week 6) and end of July (17%; week 12) (Fig. 1). The emerald ash borer was detected in only two pellets, one at the end of May/early June and one at the end of August.

In 2007, spotted cucumber beetle, green stink bug, and emerald ash borer were identified in 14, 16, and 1% of fecal pellets, respectively. The frequency occurrence of spotted cucumber beetles in pellets peaked during late July (60%) and early August (64%), as in 2006, and fragments of green stink bugs were found at the greatest frequency (42%) in late June/early July (Fig. 1). Green stink bugs did not increase at the end of August, as they had in 2006 (Fig. 1) but collections ended a week earlier. The emerald ash borer was detected in three pellets during only week 12 (30 July–5 August).

Evening bats in Illinois and Indiana consume a number of agricultural pests (Whitaker and Clem 1992, Feldhamer et al. 1995), and the same appears true of evening bats in Michigan. The larval stage of the spotted cucumber beetle is also known as the southern corn rootworm, which tunnels through and feeds on the roots of soybean and corn, two of the most common crops in the study area. The adult beetles damage leaves and flowers of these plants (Meinke et al. 1985). Adult spotted cucumber beetles emerge in spring, feed on new foliage, and lay their eggs at the base of plants. In late July and early August, the larvae of spotted cucumber beetles pupate and ultimately become adults (Zandstra 1999), which coincides with the increased consumption by the bats in this study. Long et al. (2013) also identified spotted cucumber beetles in the diet of the big brown bat (*Eptesicus fuscus* Palisot de Beauvois) in Michigan, but at a lower frequency of 2.5%, although they did not investigate seasonal variation.

Like the cucumber beetle, the green stink bug often feeds on crops, such as the pods of soybeans, causing irreversible damage (Panizzi and Slanski 1985). In our study, fragments of green stink bug were found in 12% of pellets in both years combined but ranging from 20% to 43% in some weeks. Mating of green stink bugs occurs during the first warm days of spring. Throughout May and early June, a few adults may be active, but they become more common in mid-to-late June. A life cycle takes 30–45 days and, depending upon ambient temperature, a second generation may occur in July and August (Gomez and
Mizell 2013). Green stink bugs were less common in the diet than were cucumber beetles, and consequently, distinct trends were less apparent. Nevertheless, in 2006, green stink bugs occurred in the diet of evening bats primarily in late August and mid-to-late June, and during 2007, these bugs were detected most frequently in late June/early July (Fig. 1). These dates of higher consumption roughly correspond with the expected abundance of adult green stink bugs.

Although not an agricultural pest, emerald ash borers are exotic beetles from Asia that have killed or wounded more than 5 million ash trees (Fraxinus) in southeastern Michigan (Poland and McCullough 2006). Emerald ash borers are only a small component of the diet of evening bats (≤ 1%), probably because this insect is primarily diurnal (EMPOPO 2005). Evening bats either glean resting emerald ash borers from foliage at night or more likely consume the beetles as they fly during evening or morning twilight.

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**Figure 1.** Weekly summary of percent frequency occurrence of spotted cucumber beetle and green stink bug detected in the diet of evening bats during 2006–2007 in Lenawee County, Michigan. Fecal pellets were not collected during weeks 1, 2, and 7 of 2006, and weeks 3 and 15 of 2007. Week 1 began on 15 May 2006 and 14 May 2007, and week 15 ended on 27 August 2006 and 26 August 2007.
Evening bats potentially play a role in controlling some pests in Michigan, and the diet of these bats seems to reflect the life-history patterns of the spotted cucumber beetle and green stink bug, similar to other bat-insect interactions (Lee and McCracken 2005, McCracken et al. 2012). Future dietary studies using molecular techniques potentially can gain further insight into the role of evening bats in agroecosystems by identifying other prey to the species level, beyond those that are morphologically distinct (Whitaker et al. 2009, Clare et al. 2014). Since evening bats roost in wooded areas, conservation and management of suitable forested habitat close to agricultural lands may be economically beneficial to farmers (Federico et al. 2008).

Acknowledgments

We thank J. Eisenbach and J.O. Whitaker, Jr., for assistance with insect identification; R. Bricklin, S. Captain, C. Rockey, J. Stumpf, and R. Slider for assistance during the field season; and all the landowners in the study area for their generosity and access to their land. We thank the two anonymous reviewers for their time and valuable suggestions. Research was supported by Michigan Department of Natural Resources State Wildlife Grants T-9-T-1 to AK and a Hellwig Research Fellowship from the Department of Biology, Eastern Michigan University to OMM.

Literature Cited


The Caddisflies (Trichoptera) of an Undisturbed Lower Michigan Habitat

David C. Houghton

Abstract

The caddisfly assemblages of small streams, medium floodplain and forested rivers, and lakes within the Black River Ranch, a relatively undisturbed habitat in northern Lower Michigan, were sampled during 2014–2015 using ultraviolet light traps to establish a reference assemblage for the caddisflies of the region. A total of 117 species were collected including three—Hydropsyche amoena Ross, H. novicola Blickle and Morse, and H. quinola Ross—not previously reported from Michigan. All species and their habitat affinities are reported herein. Individual sampling sites all had high levels of species richness compared to similar habitat types throughout Michigan, Minnesota, and Wisconsin, and included the single most species-rich sample from any of the three states. Due to this high species richness, as well as a trophic functional composition indicative of undisturbed ecosystems, the Black River Ranch assemblage is probably the most appropriate assemblage to use as a regional biological monitoring reference site.

Quantifying the composition of aquatic organism assemblages in different habitats for the purpose of biological monitoring is a powerful technique for evaluating aquatic disturbances because it directly measures ecosystem function (e.g., Karr and Chu 1999). To be most effective, biological monitoring compares organismal assemblages from tested sites against ‘reference sites’, those known to be undisturbed. One challenge with this technique is locating truly undisturbed ecosystems for comparison. Thus, research that characterizes assemblages of known undisturbed habitats will be of great value in future biological monitoring studies. In Michigan, for example, basic studies on undisturbed aquatic habitats are ongoing in the relatively pristine Huron Mountains of the northeastern Upper Peninsula (Yanoviak and McCafferty 1996, O’Brien et al. 2003, Woods 2015).

The caddisflies (Trichoptera) are an integral component of aquatic ecosystems, as well as a valuable taxon for biological monitoring protocols, due to their taxonomic richness, ecological and trophic diversity, varying susceptibilities to different types of ecosystem disturbances, and abundance in virtually all types of freshwater ecosystems (Barbour et al. 1999, Dohet 2002, Houghton 2007, Houghton and Wasson 2013). In Michigan, the caddisflies are primarily known from Leonard and Leonard’s (1949) checklist, although there has been a recent effort to catalog the entire state fauna (Houghton et al. in press). Bright (2015) maintains a current checklist of known and suspected species.

The Black River Ranch is a ~3600 ha private preserve located in Cheboygan and Montmorency Counties (Fig. 1). The landscape is composed mostly of primary and secondary growth of eastern white pine (Pinus strobus L.) and other forest types, and has not been logged in > 100 years. Aside from a small

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airstrip, ~100 km of dirt trails, and a few buildings around Silver Lake, the property is relatively undisturbed, and is primarily used for elk hunting, trout fishing, and non-motorized recreation (http://www.blackriverranch.org/). The Ranch contains both the east and main branches of the Black River, as well as smaller streams and natural lakes. Both branches of the Black River arise in the Mackinaw State Forest and are protected throughout most of their continua to the Ranch (Fig. 1). Both branches support naturally-reproducing populations of native brook trout (*Salvelinus fontinalis* [Mitchill]); the upper main branch in particular has long been considered one of the best brook trout fisheries in the eastern U.S. (www.upperblack.org). The east branch joins with the main branch on Ranch property. Both branches of the river are known for periodic flooding after heavy rain events (waterdata.usgs.gov); thus, some low-lying riparian habitats constitute natural floodplain and do not support tree growth (Fig. 1).

The objective of this study was to document the caddisfly assemblage of the Black River Ranch as indicative of an undisturbed Lower Peninsula habitat. Eleven sites were chosen *a priori* as representative of the different habitats at the Ranch. These sites included forest and floodplain stretches of both the main and east branches of the Black River, 2 lakes, and 2 small tributaries of the Black River (Table 1, Fig. 1). All sites were within a ~16 km² area.
Table 1. The 11 sites of the Black River Ranch sampled for adult caddisflies during 2014–2015, showing months sampled. Mean (± SE) physicochemical measurements determined on 26 September 2015. DO = dissolved oxygen, k = specific conductance. N = 6 for each measurement at each site. Superscript letters denote statistically distinct means for each physicochemical parameter (1-way Analysis of Variance with post-hoc Tukey test).

<table>
<thead>
<tr>
<th>Site #</th>
<th>Site name</th>
<th>Location</th>
<th>Order</th>
<th>Site type</th>
<th>Date(s) sampled</th>
<th>Temp (ºC)</th>
<th>DO (mg/L)</th>
<th>K (μS/cm)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Black R.</td>
<td>N 45.219º, W 84.343º</td>
<td>4th</td>
<td>Forest</td>
<td>Jul, Sep 2015</td>
<td>16.2 (0.0)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>10.9 (0.3)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>368 (3.0)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.8 (0.0)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>Black R.</td>
<td>N 45.167º, W 84.337º</td>
<td>3rd</td>
<td>Floodplain</td>
<td>Jul 2014, Sep 2015</td>
<td>16.9 (0.0)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>10.8 (0.2)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>366 (2.1)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.9 (0.0)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>E. Br., Black R.</td>
<td>N 45.179º, W 84.289º</td>
<td>3rd</td>
<td>Floodplain</td>
<td>Jun, Jul 2015</td>
<td>15.7 (0.0)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>10.7 (0.3)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>360 (1.5)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.0 (0.0)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
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<td>N 45.181º, W 84.289º</td>
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<td>Forest</td>
<td>Jun, Jul 2015</td>
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<td>10.5 (0.3)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>361 (1.7)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.0 (0.0)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
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<td>3rd</td>
<td>Forest</td>
<td>Jun, Jul, Sep 2015</td>
<td>15.7 (0.0)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>10.7 (0.2)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>362 (1.8)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.0 (0.0)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>E. Br., Black R.</td>
<td>N 45.179º, W 84.289º</td>
<td>3rd</td>
<td>Floodplain</td>
<td>Jun, Jul 2015</td>
<td>16.1 (0.0)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>10.4 (0.2)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>363 (2.1)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.0 (0.0)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
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<td>E. Br., Black R.</td>
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<td>3rd</td>
<td>Forest</td>
<td>Jun, Jul 2015</td>
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<td>10.7 (0.3)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>361 (1.7)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.0 (0.0)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>8</td>
<td>Bush Lake</td>
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<td>Lake</td>
<td>Jul, Sep 2015</td>
<td>18.8 (0.0)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.8 (0.1)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>310 (0.9)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.5 (0.0)&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>Lake</td>
<td>Jul 2014, Sep 2015</td>
<td>19.6 (0.0)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8.0 (0.2)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>304 (0.8)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.5 (0.0)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
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<td>10</td>
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<td>N 45.186º, W 84.343º</td>
<td>1st</td>
<td>Stream</td>
<td>Jul, Sep 2015</td>
<td>14.5 (0.0)&lt;sup&gt;f&lt;/sup&gt;</td>
<td>12.2 (0.4)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>345 (2.2)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.1 (0.0)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>11</td>
<td>Beaver Creek</td>
<td>N 45.187º, W 84.349º</td>
<td>1st</td>
<td>Stream</td>
<td>Jul 2014, Sep 2015</td>
<td>15.2 (0.0)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.9 (0.3)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>343 (2.1)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.1 (0.0)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

\[ P = <0.001 \quad <0.001 \quad 0.01 \quad <0.001 \]
Materials and Methods

To characterize site conditions, 4 rudimentary physicochemical parameters were measured from each of the sites. Specific conductance (ECTestr Low, Vernon Hills, IL, www.eutechninst.com), pH (AccuMet AP61, Pittsburg, PA, www.fishersci.com), temperature (YSI-55, Yellow Springs, OH, wwwysi.com), and dissolved oxygen (YSI-55, Yellow Springs, OH, wwwysi.com) measurements were all made on-site. All parameters were tested on 26 September 2015. In all cases, six measurements were taken of each parameter and their mean determined. Differences between sites were assessed using 1-way Analysis of Variance with a post-hoc Tukey test.

Adult caddisflies were collected using light traps. Each trap consisted of an 8-watt portable ultraviolet light placed over a white pan filled with 80% ethanol. Lights were placed ~1 m from aquatic habitats at dusk and collected approximately 2 hours after dusk (Wright et al. 2013). Samples were collected only if the peak daytime temperature was > 25°C, dusk temperature was > 18°C, and there was no noticeable wind or precipitation at dusk (Houghton 2004). Since caddisflies collected within 40 m of a habitat accurately reflect the assemblage of that habitat (Sode and Wiberg-Larson 1993, Peterson et al. 1999, Sommerhäuser 1999, Houghton 2004, Brakel et al. 2015) dispersals of adults between sites, while certainly possible, were considered unimportant.

All 11 sites were sampled during mid-July, the peak period of adult species richness in northern Michigan (Houghton et al. 2011). Representative habitats were also sampled during June and September to document the early and late emergent species (Table 1). Specimens were identified to the species level using Houghton (2012), except for females of Hydropsychidae, Hydroptilidae, and Polycentropodidae, which lack the necessary characteristics to do so. Species were placed in trophic functional groups based on Merritt et al. (2008) and their relative abundances analyzed between habitat types using 1-way Analysis of Variance. Percentage data were transformed through an ArcSine function before analysis (Zar 2007). All identified specimens are stored in the Hillsdale College Insect Collection.

Results

Overall 38,248 specimens and 117 species were collected from the Ranch (Table 2). This species richness represents > 40% of all species known from Michigan (Bright 2015, Houghton et al. in press). Three species—Hydroptila amoena Ross, H. novicola Blickle and Morse, and H. quinola Ross (Hydroptilidae)—are reported from Michigan for the first time. While sample sizes were too low for statistical analysis, observed species richness was forested rivers > floodplain rivers > lakes > small streams and July > June > September (Table 2).

Caddisflies in the shredder trophic functional group were more abundant in small streams and forested rivers than in floodplain rivers. Scrappers were more abundant in floodplain rivers than in small streams and forested rivers. Filtering collector abundance was not different between habitat types (Fig. 2). Lakes were not analyzed due to a natural lack of filtering collectors and scrappers.

All individual Ranch sampling sites had species richness substantially greater than the mean of Michigan, Minnesota, and Wisconsin sites of the same habitat type sampled over the last 15 years (e.g., Houghton 2012, Houghton et al. in press) (Fig. 3). For example, Bush Lake was the second most species-rich lake for all 3 states and Beaver Creek was the second most species rich small stream for all 3 states. Most notably, Site 1 on the main branch of the Black River yielded 65 species in one mid-July sample, the most species caught from a single blacklight sample in all 3 states (n = 403).
Table 2. The 117 caddisfly species known from different habitat types and months based on the 11 sampling sites of the Black River Ranch. Species not previously reported from Michigan in boldface font.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Small stream</th>
<th>Floodplain river</th>
<th>Forested river</th>
<th>Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jul  Sep</td>
<td>Jun  Jul  Sep</td>
<td>Jun  Jul  Sep</td>
<td>Jul  Sep</td>
</tr>
<tr>
<td>BRACHYCENTRIDAЕ</td>
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<tr>
<td><em>Brachycerus americanus</em> (Banks)</td>
<td>x</td>
<td>x</td>
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<tr>
<td><em>Micrasema rusticum</em> (Hagen)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>GLOSSOSOMATIDAE</td>
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<tr>
<td><em>Glossosoma nigrior</em> Banks</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
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<tr>
<td><em>Protophila erotica</em> Ross</td>
<td>x</td>
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<tr>
<td><em>P. tennebrosa</em> (Walker)</td>
<td>x</td>
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<tr>
<td>GOERIDAE</td>
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<tr>
<td><em>Goera stylata</em> Ross</td>
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<tr>
<td>HELICOPSICHIIDAE</td>
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<tr>
<td><em>Helicopsyche borealis</em> (Hagen)</td>
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<tr>
<td>HYDROPSPICHIIDAE</td>
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<tr>
<td><em>Cheumatopsyche analis</em> (Banks)</td>
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<tr>
<td><em>C. aphantha</em> Ross</td>
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<tr>
<td><em>C. campyla</em> Ross</td>
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<tr>
<td><em>C. gracilis</em> (Banks)</td>
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<tr>
<td><em>C. oxa</em> Ross</td>
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<td>x</td>
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<tr>
<td><em>Hydropsyche alhedra</em> Ross</td>
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<td>x</td>
<td>x</td>
<td></td>
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<tr>
<td><em>H. betteni</em> Ross</td>
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<td><em>H. slossonae</em> (Banks)</td>
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(Continued)
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<thead>
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<th>Floodplain river</th>
<th>Forested river</th>
<th>Lake</th>
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<tr>
<td></td>
<td>Jul  Sep</td>
<td>Jun  Jul  Sep</td>
<td>Jun  Jul  Sep</td>
<td>Jul  Sep</td>
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<td>x</td>
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Water physicochemical measurements confirmed all sites as relatively undisturbed (Table 1) (Johnson et al. 1997). Lakes had higher temperature, and lower dissolved oxygen, specific conductance, and pH compared to streams. Temperature and specific conductance increased in larger rivers, whereas dissolved oxygen decreased. There was no difference in parameters between forested and floodplain streams.

Discussion

The Black River Ranch caddisfly assemblage appears typical of northern Lower Michigan; almost all of the individual species found at the Ranch have been previously collected in surrounding areas of the Lower Peninsula (Houghton et al. in press). Nonetheless, the Ranch assemblage was noteworthy due to its high species richness. This richness included a higher mean number of species per site than any other studied Michigan assemblage and some of the most species rich individual sites sampled in the northcentral U.S. during the last 15 years, including the single most species rich site. High taxonomic richness has been associated with low watershed disturbance levels for many aquatic taxa, including caddisflies (Kerans and Karr 1994, Berlin and Thiele 2002, Houghton 2004, DeWalt et al. 2005, Houghton and Holzenthal 2010). More specifically, Houghton (2007) found that caddisfly species richness explained > 75% of the variation in the level of upstream habitat disturbance in 4–10 m wide Minnesota streams. Thus, the high species richness of Ranch sites suggests a relatively undisturbed landscape.
Trophic functional group composition of Ranch habitats was as predicted by the River Continuum Concept (e.g., Vannote et al. 1980). The high abundance of shredders and low abundance of scrapers in small streams and forested rivers relative to floodplain rivers was almost certainly due to differences in riparian canopy cover and subsequent differences in available food sources. This pattern has been previously found in relatively undisturbed habitats throughout Michigan and Minnesota (Houghton 2015). Likewise, the low relative abundance of filtering collectors suggested no anthropogenic disturbance throughout the Ranch habitats (Houghton 2007).

Several unique species were caught during this study. The 3 species reported from Michigan for the first time, *Hydroptila amoena*, *H. novicola*, and *H. quinola*, have all been previously collected in Minnesota (Houghton 2012), and their presence is not surprising in the northern Lower Peninsula. *Banksiola dossuaria* (Say) (Phryganeidae) has previously been reported from only a single stream in Michigan ~180 km from the Ranch (Houghton et al. 2011). *Neureclipsis bimaculata* (L) (Polycentropodidae) hasn’t been reported from the Lower Peninsula since the 1940s (Leonard and Leonard 1949).

One of the challenges of establishing reference assemblages is finding habitats that are undisturbed. In the absence of data from several hundred years ago, it is not possible to establish if the Black River Ranch reflects truly natural conditions or appears pristine only due to its obvious contrast with the agri-
cultural landscape that dominates much of the northcentral U.S. (Pauly 1995). Deforestation, dam construction, and other land uses at the Ranch during the late 1800s may have altered stream conditions and affected biological diversity in ways that are difficult to detect now (Harding et al. 1998).

Despite the uncertainty, the high level of habitat protection, high species richness, and water physicochemistry and trophic functional group composition reflective of undisturbed habitats all suggest that aquatic habitats of the Black River Ranch constitute some of the least disturbed of northern Lower Michigan. Thus, the Ranch assemblage is probably the best available option for a reference caddisfly assemblage of the northern Lower Peninsula. Now that a reference assemblage for northern Lower Michigan has been established, future changes to regional faunas can be assessed with greater precision and confidence.

Acknowledgments

I thank the members and staff of the Black River Ranch, particularly Dorothy and Tim Michiels, for their hospitality and support. I thank Ben Albers, William Fitch, Joel Parker, Bilyana Petkova, Eleanor Smith, Mary Clare Smith, and Erich Steger for their assistance with collecting and sorting samples and other logistical support. Research costs were supported by the Hillsdale College biology department. This is paper #16 of the G.H. Gordon BioStation Research Series.

Literature Cited


The Family Mantispidae (Insecta: Neuroptera) in North Dakota

Eduardo I. Faúndez\textsuperscript{1,2}

Abstract

New records of mantidflies are given for the state of North Dakota. Climaciella brunnea (Say, 1824) is formally recorded, including the first precise locality records for the state. These records are for Barnes, Billings, Cass, Ransom, Richland and Slope counties. Dicromantispa sayi (Banks, 1897) is recorded for the first time in the state from Burleigh County. An illustrated key is provided to identify the species that occur in the state.

Members of the neuropteran family Mantispidae are usually called mantidflies because of their raptorial forelegs, elongate prothorax, triangular head and general resemblance to praying mantids (Mantodea). Mantispidae currently comprises nearly 400 species classified in 44 genera (Ohl and Oswald 2004). Adult members of this family are well known as predators of other insects. On the other hand, immatures (which undergo hypermetamorphosis) of several species are known parasites in the nests of aculeate hymenopterans and boarders in the egg sacs of spiders (Ohl and Oswald 2004). There is little information on most species of this family; additionally, there are several geographic areas from which we have limited information and records. The purpose of this contribution is to provide the new records for this family from the state of North Dakota.

Materials and Methods

The material examined belongs to the North Dakota State Insect Reference Collection (NDSIRC, Fargo, ND). Systematics and nomenclature follow Oswald (2016). Identifications were made with the keys and information in Hoffman (1992, 2002), Cannings & Cannings (2006) and Throne (1972). Photos were taken with a high resolution digital camera adapted to a stereoscopic microscope.

Results

The following mantispid species are here documented from North Dakota:

Mantispidae Leach, 1815

Mantispinae Leach, 1815

Climaciella Enderlein, 1910

Type species: Mantispa brunnea Say, 1824 by original designation.

Climaciella brunnea (Say, 1824) (Figs. 1, 3, 5)

\textsuperscript{1}Entomology Department, School of Natural Resource Sciences, North Dakota State University, Dept. 7650, P.O. Box 6050; Fargo, ND, USA. (e-mail: ed.faundez@gmail.com).

\textsuperscript{2}Departamento de Zoología Médica, Centro de Estudios en Biodiversidad (CEBCCh), Magallanes, 1979, Osorno, Chile.

Remarks: This is a widespread species in the U.S., where it has been recorded from Florida, Georgia, Pennsylvania, Illinois, Indiana, Kansas, Minnesota, Missouri, Nebraska, Nevada, New Mexico, North Carolina, Washington and Wisconsin (Throne, 1972). Outside of the U.S. it has been reported from southern Canada, Mexico and Central America down to Costa Rica (Cannings and Cannings, 2006). In Hoffman’s (1992) doctoral dissertation, it was mentioned from “North Dakota” but without specific data. Although information on *C. brunnea* is scarce for ND, it seems to be very common in both the eastern and western parts of the state. In addition to the records cited above, the author observed this species in the summer of 2014 and 2015 in urban areas in the city of Fargo (Cass Co.).

*Dicromantispa* Hoffman, 2002

Type species: *Mantispa sayi* Banks, 1897, by original designation.

*Dicromantispa sayi* (Banks, 1897) (Figs. 2, 4, 6)

Material examined: NORTH DAKOTA: Burleigh Co.: Bismarck, 2-VIII-1960, leg. A. Anderson 1 ♀, 1 w/o abdomen.

Remarks: In the United States this species has been recorded from throughout the eastern states south to Florida and west to South Dakota, Nebraska, Utah and eastern Arizona (Cannings and Cannings 2006). Outside the U.S., it is present in southern Canada and widely spread in Central America (Cannings and Cannings 2006). This is the first formal record of this species from ND. Although it seems not to be very common, this may be due to the lack of collecting. Another *Dicromantispa* species that may also be present in ND is *Dicromantispa interrupta* (Say, 1825). The latter species can be told apart from *D. sayi* because it has black spots in the tips of the wings; whereas wings of *D. sayi* are hyaline (Cannings and Cannings 2006).

**Key to the species of Mantispidae known occur in North Dakota**

1 Wings membrane with anterior portion infuscate (Fig 5), pronotum short and stout (Fig. 3) .................................................. *Climaciella brunnea*

1’ Wings membrane not infuscate (Fig. 6), pronotum long and slender (Fig. 4) ................................................................. *Dicromantispa sayi*

Conclusions

Mantispidae is represented in North Dakota by two species *C. brunnea* and *D. sayi*. *Climaciella brunnea* is this moment, the most abundant and widely distributed species within the state. However adults of this species are diurnal and easier to collect, explaining its abundance in NDSIRC; but in the field the situation may be different. Therefore, further collecting in the state may reveal new specimens of these species, and even other species not presently known from North Dakota. Adults of both of the above species seem to fly in the summer from June to August in the state.

Acknowledgments

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Literature Cited


Moths of the Douglas Lake Region (Emmet and Cheboygan Counties), Michigan: VII. Tortricidae (Lepidoptera)

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Abstract

Two hundred thirty-four species of Tortricidae are documented from Emmet and Cheboygan counties in Michigan, including 32 state records. This is the second major taxon of microlepidoptera inventoried from the area, and provides the first significant listing of a regional tortricid fauna from the state. Several additions are expected for this list as additional habitats and seasons are sampled more effectively.

The region around Douglas Lake in Emmet and Cheboygan counties including the University of Michigan Biological Station, at the tip of the Lower Peninsula of Michigan has a long history of work on the Lepidoptera. Early survey work by Welch (1915) documented several common species, and Voss worked extensively from the 1940s through the 1990s documenting the macrolepidoptera of the region (Voss 1954, 1970, 1981, 1984, 1991; Voss and Wagner 1956). Nearly all of the species listed in these efforts were macrolepidoptera. Since 1990, Scholtens has worked at surveying the microlepidoptera of the area, so far listing 187 species of Pyraloidea (Scholtens 1996). Voss also added 45 microlepidoptera by examining several smaller families (Voss 2002).

To date, only Welch (1915—2 species) and Moore (1922—3 species; 1930—16 species) have listed Tortricidae species from the northern Lower Peninsula. Here, we document 234 species of tortricids for the region, including 32 state records, based on over 20 years of collecting, with the most concentrated effort over the last decade. This listing brings the total known Lepidoptera species from the Douglas Lake area to 1167, still not including any of the smaller microlepidoptera. Based on our listed species, 41.8% of the entire state fauna is known from the region (Nielsen 1997, 1998a, b; Kriegel 2010), and Tortricidae make up 20% of the total fauna in the region.

The Tortricidae is a large family of moths including many economically important species (Brown et al. 2008). Larvae of these moths are common pests on trees as leaf tiers or rollers and shoot tip borers (e.g., Rhyacionia buoliana—European pine shoot moth (Gilligan et al. 2008); Ecdylophora insitica—locust twig borer (Adamski and Brown 2001); Choristoneura pinus—jack pine budworm). Several are also significant pests on fruits or seeds (e.g., Cydia pmonella—coding moth (Falcon and Huber 1991); Grapholita packardi—cherry fruit worm (Gilligan et al. 2008); Cydia latiferrea—filbert worm (Brown 1983)).

Although no comprehensive treatment of the family exists for the area, several sources are available to aid in identification. Miller (1987) and Gilligan et al. (2008), following up on Heinrich (1923, 1926), cover nearly all of the

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Olethreutinae, with excellent images of adults and genitalia. Additionally, an excellent revision of the large genus *Eucosma* was just published (Wright and Gilligan 2015). Many Tortricinae are covered in Freeman (1958), with reasonable black and white images, and Powell and Brown (2012) have revised the Sparganothini. The Cochylini are the least well known, with Razowski’s (1997) treatment of Canadian species most comprehensive. Sabourin completed many of the identifications of specimens in this tribe. For the first time since the start of this series of papers on the Lepidoptera of the region, an excellent online resource is available to aid identification. The Moth Photographers’ Group (2012) provides both confirmed specimen photos and images of live individuals of many species. This resource continues to grow, and now includes range maps of most, and genitalic images of many Tortricidae. As with the Pyraloidea, Scholtens has reared only a handful of these species, and host plant information originates mainly from the previously listed sources, except where indicated.

**Methods**

Species are numbered using the Hodges et al. (1983) sequence, with species described subsequent to that list inserted as decimals in the sequence. The classification scheme follows that of Brown (2005) with updates presented in Gilligan and Wright (2013) and on Tortricidae.net (Gilligan et al. 2014). Plant names follow Voss and Reznicek (2012).

The conventions established in the previous lists are followed here, with all records confirmed based on specimens examined by the authors. The counties in which each species has been collected are listed, and we often give a preliminary indication of abundance based on collection frequency and field experience. Because most of the samples were collected during the summer session of the University of Michigan Biological Station, species that fly earlier or later are often missing from the listing. While the number of early flying species is insignificant in the Pyraloidea, the Tortricidae contains several late and early season moths, including some true winter moths, and these mostly remain to be sampled.

Records were gathered by examining material in the collections of the University of Michigan Biological Station, the University of Michigan, Michigan State University (including the Voss collection), and the Scholtens collection. Scholtens’ collecting in the Douglas Lake region has provided the largest number of records, where most specimens were collected at ultraviolet or mercury vapor light sheets or traps. Of the listed species, the Scholtens collection contains 90.1%, MSU 31.1%, and UMMZ 5.6%.

**Family Tortricidae**

**Subfamily Olethreutinae**

2701 *Episimus argutanus* (Clem.)—Cheboygan: 2 Jul–10 Aug. 3 specimens. One of a handful of Lepidoptera that use *Toxicodendron* (poison ivy) as a host (Heppner 1994).

2707 *Bactra verutana* Zell.—Cheboygan: 3–14 Aug. 2 specimens.

2713 *Paralobesia monotropana* (Heinr.)—Cheboygan: 31 Jul 2006. Single specimen taken in UV light trap near Carp Creek off Hogback Rd. Confirmed by dissection (BGS #1571). This species is known to feed in the seed capsules of Indian-pipe (*Monotropa*), an unusual parasitic plant (Heinrich 1926). This species is a state record for Michigan.

2714 *Paralobesia sambuci* (Clarke)—Emmet: 27 Jul 1992. Single male specimen from T36N R5W NW ¼ of Sec 8, confirmed by dissection, Sabourin #01206.
This species is known to feed on elderberry, *Sambucus canadensis*. This species is a state record for Michigan.

2738 *Endothenia hebesana* (Wlk.)—Cheboygan: 13‒29 Jun. 7 specimens. Larvae are seed feeders in a variety of herbaceous plants (Miller 1983, Gilligan et al. 2008).

2745 *Taniva albolineana* (Kft.)—Cheboygan: 16 Jun‒8 Jul. Known as the spruce needle miner, all specimens are from wetland areas where the spruce hosts grow (Tashiro 1974).

2749 *Eumarozia malachitana* (Zell.)—Cheboygan: 4‒21 Aug. 2 specimens. Larvae are known to feed on persimmon leaves (Heinrich 1926), but must use another host in our area.

2750 *Zomaria interruptolineana* (Fern.)—Cheboygan: 16 Jun‒13 Aug. 5 specimens, apparently 2 generations.

2753 *Apotomis capreana* (Hbn.)—Cheboygan, Emmet: 2‒24 Jul. Also taken by Sherman Moore from St. Ignace in Mackinac Co. The most common of our species of *Apotomis*. This genus ties the leaves of *Salix*, *Betula* and *Populus* (Adamski and Peters 1986, Miller 1987), all common in the area.

2755 *Apotomis funerea* (Meyr.)—Cheboygan, Emmet: 18 Jun‒21 Aug.

2765 *Apotomis deceptana* (Kft.)—Cheboygan, Emmet: 31 Jul‒26 Aug. Taken by both Mo Nielsen and Voss, with Voss’ specimens identified by W. E. Miller.

2767 *Apotomis infida* (Heinr.)—Cheboygan, Emmet: 2‒11 Jul. 4 specimens.

2768 *Apotomis remova*na (Kft.)—Cheboygan, Emmet: 6 Jul‒11 Aug. 3 specimens, also by Sherman Moore from St. Ignace.

2769 *Pseudosciaphila duplex* (Wlsm.)—Cheboygan, Emmet: 25 Jun‒13 Jul. A common and variable species, also taken by Sherman Moore at St. Ignace.

2770 *Orthotaenia undulana* (D. and S.)—Cheboygan. 22‒25 Jun. 5 specimens, also taken by Sherman Moore in Mackinac Co.

2775 *Olethreutes nitidana* (Clem.)—Cheboygan. 10‒22 Jul. 4 specimens. Species in the genus *Olethreutes* can be very difficult to identify, particularly if they are somewhat worn. Many of the specimens considered here have been dissected to confirm IDs.

2776 *Olethreutes furfurana* (McD.)—Cheboygan. 23 Jun‒6 Jul. 8 specimens, 6 confirmed by dissection, BGS #s 1580, 1573, 1581, 1583, 1637, 1638. Common as expected for a *Rubus* feeder (Miller 1979).

2777 *Olethreutes comandrana* (Clarke)—Cheboygan: 13 Jul 1990. A single male specimen taken at the UMBS light, confirmed by dissection, Sabourin #00542. This species is known to feed on bastard-toadflax, *Comandra umbellata*.

2778 *Olethreutes olivaceana* (Fern.)—Cheboygan. 27 Jun 2010. A single specimen taken at the UMBS MV light; confirmed by dissection, BGS # 1575. Larvae feed on *Fragaria* (Miller 1987).

2780 *Olethreutes subnubilum* (Heinr.)—Cheboygan. 11 Jul‒3 Aug. A common species, but difficult to distinguish from *O. permundana*. MS has seen specimens reared from *Salix* and *Corylus*. All males were confirmed by dissection, BGS #s 1617, 1620, 1622, 1624, 1627, 1629, 1625.

2782 *Olethreutes rusticana*num (McD.)—Cheboygan. 31 Jul 2006. A single specimen, confirmed by Sabourin (BGS diss #1628). This species is a state record.
2784 *Olethreutes footiana* (Fern.)—Cheboygan. 17 Jul 1998. 2 female specimens taken at Colonial Pt., confirmed by dissection, Sabourin #99174. The species feeds on *Hamamelis* and *Quercus*.

2785 *Olethreutes atroventana* (Fern.)—Cheboygan. 15 Jul–13 Aug. 2 specimens, both confirmed by dissection, BGS #s 1593, 1594.

2786 *Olethreutes punctana* (Wlsm.)—Emmet. 30 Jul 1945. A single specimen taken by Ed Voss in Mackinaw City and identified by W. E. Miller.

2787 *Olethreutes connectum* (McD.)—Cheboygan. 1 Aug 2013. A single specimen taken at the window lights of a cabin at UMBS.

2788 *Olethreutes inornatana* (Clem.)—Cheboygan. 13 Aug 2003. A single specimen taken at the jack pine plains south of Indian River. Known to feed on *Prunus*, but also reared from a larva on *Shepherdia* (buffalo-berry) from Keweenaw Co.

2790 *Olethreutes mediopartitus* (Heinr.)—Emmet: 7 Jul 1993. A single female specimen from the Pellston plains, confirmed by dissection, Sabourin #99307. This species feeds on ninebark, *Physocarpus opulifolius*. This species is a state record.

2791 *Olethreutes exoletus* (Zell.)—Cheboygan. 2 Jul 2010. A single specimen taken from Reese’s Swamp.

2794 *Olethreutes quadrifidus* (Zell.)—Cheboygan. 28 Jun–28 Jul. The host plant is *Cornus* (Heinrich 1926).

2795 *Olethreutes tiliarum* (Heinr.)—Cheboygan. 15 Jul 1999. One specimen taken at Colonial Pt. woods. The host, *Tilia*, is common in the area, and it is surprising that this species is not more abundant.

2799 *Olethreutes clavata* (Wlk.)—Cheboygan, Emmet. 2 Jul–4 Aug. Evidently a common species, the larvae are reported from *Corylus* (Miller 1979). Several males determined by dissection, Sabourin # 01204, BGS #s 1605, 1606, 1611, 1612, 1613, 1614.


2803 *Olethreutes merrickana* (Kft.)—Cheboygan. 18 Jun–1 Aug.


2805 *Olethreutes corylana* (Fern.)—Emmet. 18 Jul 2011. A single specimen, taken in Wilderness State Park in a UV light trap is presumably this species.

2809 *Olethreutes fagigemmacea* (Cham.)—Cheboygan. 16–17 Jul. 2 specimens, both taken in a UV light trap at Colonial Pt. woods, where its host *Fagus* is a dominant tree species. Determined by Sabourin.

2811 *Olethreutes melanomesum* (Heinr.)—Cheboygan, Emmet. 7 Jul–8 Aug. Several specimens taken by Ed Voss in Mackinaw City and identified by W. E. Miller.

2812 *Olethreutes valdana* (McD.)—Cheboygan. 13 Jul 2003. 4 specimens taken in a UV light trap at the jack pine plains south of Indian River. We would expect this to be more common because it uses the common shrub, *Spiraea*, as a larval host (McDunnough 1956).

2815 *Olethreutes brevirostratum* (Heinr.)—Cheboygan. 19 Jun–8 Jul 1969. Three specimens taken by Elaine and Ron Hodges at Ocqueoc Lake, reared from bearberry. Identification confirmed by dissection, Sabourin #s 97171,
Also from several specimens taken in two UV light traps at the jack pine plains south of Indian River and at the dunes at Bliss Beach in Wilderness State Park. This species is a state record for Michigan.

**Olethreutes galevora** (McD.)—Cheboygan. 20 Jun 2012. 2 specimens taken in a UV light trap at Mud Lake bog; confirmed by dissection, BGS #s 1634, 1635.

**Olethreutes permundana** (Clem.)—Cheboygan. 18 Jun–13 Aug. A common species, that is very similar to *S. subnubilum*; males confirmed by dissection, BGS #s 1631, 1633, 1628, 1619, 1621, 1618, 1616, 1615, 1577, 1578, 1576, 1572, 1574. The host is reported as *Rubus* (Heinrich 1926).

**Olethreutes nov. sp. ca. permundana**—Cheboygan. 31 Jul 1974. Single male specimen taken by Elaine and Ron Hodges at Ocqueoc Lake, and determined by Sabourin. This species is known to feed on ninebark, *Physocarpus opulifolius*. This species is a state record for Michigan.

**Olethreutes submissanum** (McD.)—Cheboygan, Emmet. 26 Jul–6 Aug. Taken twice in UV light traps, once at Colonial Pt. and once in Wilderness State Park, at Canada Goose Pond and once at the UMBS light. Confirmed by dissection, BGS #s 1600, 1601. Also taken in Mackinaw City by Voss and identified by W. E. Miller.

**Olethreutes appendicea** (Zell.)—Cheboygan. 22 Jun–28 Jul. A fairly common species that uses many different trees as hosts (Prentice 1966).

**Olethreutes concinnana** (Clem.)—Cheboygan. 26 Jun 1999. A single specimen taken in a UV light trap at Colonial Pt. woods. Confirmed by dissection, BGS # 1636.

**Olethreutes fasciatana** (Clem.)—Cheboygan, Emmet. 26 May–1 Aug. A common, distinctive species, presumably double brooded.

**Olethreutes astrologana** (Zell.)—Cheboygan, Emmet. 26 Jun–18 Jul. A pretty species with metallic bands on the forewing.

**Olethreutes coruscana** (Clem.)—Cheboygan. 20–29 Jun. Taken in UV light traps twice at Mud Lake bog; also known from Mackinac Co.

**Olethreutes polluxana** (McD.)—Cheboygan. 16 Jun 2014. Only a single specimen from Hogsback Rd. near Carp Creek. This species is a state record for Michigan.

**Olethreutes glaciana** (Mösch.)—Cheboygan, Emmet. 16 Jun–1 Aug. Larvae feed on several different common trees (Prentice 1966).

**Olethreutes bipartitana** (Clem.)—Cheboygan, Emmet. 20 Jun–11 Jul. 4 specimens.

**Olethreutes trinitana** (McD.)—Cheboygan, Emmet. 29 Jun–18 Jul. 3 specimens plus one known from Mackinac Co.

**Celypha cespitana** (Hbn.)—Cheboygan, Emmet. 22 Jun–29 Aug. An abundant species in the area, feeding on *Trifolium* and *Fragaria* (Bennett 1961).

**Metendothenia separatana** (Kft.)—Cheboygan. 30 May–9 Aug. 4 specimens.

**Hedya ochroleucana** (Frölich)—Cheboygan. 2 Jul–29 Aug. BGS has taken it only once, but Voss took several in Mackinaw City; also by Sherman Moore at St. Ignace.

**Hedya chionosema** (Zell.)—Cheboygan. 2 Jul 2010 and 2011. 3 specimens, taken in UV light trap in Reese’s Swamp in consecutive years on the same date.

**Rhynciona buoliana** (D. and S.)—Emmet. 6–18 Jul. Taken at several locations in Wilderness State Park. The European pine shoot moth was
introduced last century (Gilligan et al. 2008) but is not widespread in our area.

2892 *Retinia albicapitana* (Bsk.)—Cheboygan. 22 Jun 2003. A single specimen taken in a UV light trap at the jack pine plains south of Indian River.

2898 *Retinia gemistrigulana* (Kft.)—Cheboygan, Emmet. 18 Jun–31 Jul. A common species. Although the host plant is unknown, most congeners feed on pines (Gilligan et al. 2008).

2906 *Spilonota ocellana* (D. and S.)—Cheboygan. 20 Jun–27 Jul. The life history of this common species is well known because it feeds on the economically important apple (*Malus*) and cherry (*Prunus*) (Oatman et al. 1962, Chapman and Lienk 1971).

2913 *Eucosma umbrastriana* (Kft.)—Cheboygan. 1–3 Jun. 2 specimens at light near Douglas Lake and 1 during the day east of Wolverine. The taxonomy of this and the following species in *Eucosma*, *Eucopina*, and *Pelochrista* was recently revised by Gilligan and Wright (2013).

2916 *Eucosma formosana* (Clem.)—Cheboygan, Emmet. 28 May–21 Jun 2014. 4 specimens, also known from Mackinac Co. A relatively early flier, this species is known to feed on stems and leaves of *Solidago* (Putman 1942).

2925 *Eucosma autumnana* (McD.)—Cheboygan. 24 Aug–8 Sep 1989. This late-flying species has been taken at the UMBS UV light by Scholtens and near Cheboygan by Nielsen.

2927 *Eucosma ochrocephala* (Wlsm.)—Cheboygan, Emmet. 18 Jul–15 Aug. A common, late summer species. It is known to feed on cocklebur, *Xanthium strumarium* (Hare 1977).


2937 *Eucosma parmatana* (Clem.)—Cheboygan, Emmet. 27 Jun–20 Aug. Our most common member of this genus, it can be abundant at light. Also an aster feeder (Putman 1942). This species now includes as a synonym *E. marmontana* (Wright and Gilligan 2015).

2956 *Eucosma tarandana* (Mösch.)—Emmet. 24 Jul 2013. 2 specimens taken in a UV light trap on the dunes at Bliss Beach in Wilderness State Park.

2968 *Eucosma clavana* (Fern.)—Cheboygan, Emmet. 6 Jul–10 Aug. Taken only on dunes on the shores of Lakes Michigan and Huron, but common in this habitat.


3066 *Eucopina gloriola* (Heinr.)—Cheboygan. 23 Jun 1993. Taken only once at the UMBS UV light, surprising for a distinctive moth that feeds in pine shoots (DeBoo et al. 1971).


3009 *Pelochrista robinsonana* (Grt.)—Cheboygan. 17–24 Jun. 2 specimens, both at the UMBS UV light. This and the next species are very strikingly colored with shining white patterns that almost appear metallic.

3035 *Pelochrista morrisoni* (Wlsm.)—Cheboygan, Emmet. 6 Jul–10 Aug. A common species of dunes and sandy, jack pine areas.

3037 *Pelochrista agricolana* (Wlsm.)—Cheboygan. 21 Jun–7 Jul. Taken only at the UMBS light, but it should be expected on the dunes since it is known to feed on wormwood, *Artemisia* (Brown et al. 1983).

3079 *Pelochrista palabundana* (Heinr.)—Cheboygan, Emmet. 18 Jun–8 Sep. An abundant species throughout the summer, and surprisingly the biology is unknown (Gilligan et al. 2008).

3116.11 *Pelochrista similiana* (Clem.)—Cheboygan. 7 Aug 1995. Taken a single time at the UMBS UV light.


3133 *Pelochrista consobrinana* (Heinr.)—Cheboygan. 5–10 Aug 1989. 2 specimens, both from the UMBS UV light.

3141.12 *Pelochrista rindgei* (Miller)—Cheboygan, Emmet. 16 Jul–14 Aug. Confirmed by dissection (Sabourin). This species is a state record for Michigan.

3142 *Pelochrista cataclystiana* (Wlk.)—Cheboygan, Emmet. 2 Jul–1 Aug. 4 specimens. Likely more common that indicated by collection records, since the larvae use *Euthamia graminifolia* (flat-topped goldenrod) as host (Putman 1942), a very common plant in the area.

3151 *Pelochrista scintillana* (Clem.)—Emmet. 18 Jul 1945. Taken once by Voss in Mackinaw City and identified by W. E. Miller.


3173 *Epiblema abruptana* (Wlsm.)—Cheboygan. 2 Jul 2006. 2 specimens taken in a UV light trap on the jack pine plains south of Indian River. Confirmed by dissection, BGS #s 1659, 1660.

3186 *Epiblema scudderiana* (Clem.)—Cheboygan, Emmet. 20–28 Jun. Scholtens has taken 3 specimens and Voss 2 specimens. A gall former on goldenrod (Miller 1976).

3202 *Epiblema otiosana* (Clem.)—Cheboygan. 6 Jul–4 Aug. 2 specimens, both at lights at UMBS.

3205 *Epiblema resumptana* (Wlk.)—Cheboygan, Emmet. 25 May–12 Jun. This early season species has been taken 4 times in the area.

3211 *Notocelia culminana* (Wlsm.)—Cheboygan. 10–26 Aug. Taken once at UV light on the jack pine plains south of Indian River by Scholtens and twice at Eliot Creek marsh by Nielsen.

3218.11 *Sonia paraplesiana* Blanchard—Cheboygan, Emmet. 1–24 Jul 2013. A specimen from a UV light trap on the dunes of Bliss Beach in Wilderness State Park, and one taken by Voss at UMBS, identified by W. E. Miller as *S. constrictana* before *S. paraplesiana* was recognized as a distinct species.


3223 *Gypsonoma fasciolana* (Clem.)—Cheboygan, Emmet. 12–17 Jun. The two specimens probably don’t represent this species’ actual abundance because several are recorded by Sherman Moore from St. Ignace. Confirmed by dissection (Sabourin). This genus is common in the area, and all have
larvae that use *Populus* and *Salix* as hosts (Gilligan et al. 2008), both very common plants.

3226 *Gypsonoma haimbachiana* (Kft.)—Emmet. 1–12 Aug. One specimen taken by Scholtens in a UV light trap at the maintenance area in Wilderness State Park and one by Voss in Mackinaw City. Confirmed by dissection, BGS #1665.


3228 *Gypsonoma salicicolana* (Clem.)—Cheboygan, Emmet. 2–18 Jul. 3 specimens. Confirmed by dissection, BGS #1666.

3229 *Gypsonoma adjuncta* Heinr.—Cheboygan, Emmet. 22 Jun–7 Jul.

3230 *Proteoteras aesculana* Riley—Cheboygan, Emmet. 13 Jun–6 Jul. 2 specimens; this species is very similar to *P. obnigra*; one was confirmed by dissection, BGS #1668. Both of the first two members of this genus are known to feed on maple (*Acer*) (Gilligan et al. 2008).

3235 *Proteoteras moffatiana* Fern.—Cheboygan, Emmet. 22 Jun–9 Aug. This is the common summer species of the genus. Several confirmed by dissection, BGS #s 1669, 1678, 1675, 1679, 1677.

3237 *Proteoteras obnigra* Heinr.—Cheboygan. 29 Jun–5 Jul. 2 female specimens, both confirmed by dissection, BGS #s 1673, 1672.

3240 *Zeiraphera canadensis* Mutuura and Freeman—Emmet. 18 Jul 1950. A single specimen taken by Voss in Mackinaw City and identified by W. E. Miller.

3243 *Zeiraphera unfortunana* Ferris and Kruse—Cheboygan. 2 Jul 2011. 2 female specimens taken in a UV light trap in Reece’s Swamp; both confirmed by dissection, BGS #s 1680, 1681.

3252 *Pseudexentera haracana* (Kft.)—Cheboygan. 25 May 2015. A single female specimen taken at a cottage near Douglas Lake. This species closely resembles *Gretchenia delicatana* (Miller 1986b). Confirmed by dissection, BGS #2258.

3265 *Gretchenia delicatana* Heinr.—Cheboygan. 28 May–25 Jun. 2 specimens, taken in a UV light trap at Colonial Pt. woods and at a cottage near Douglas Lake; confirmed by dissection, BGS #s 1697, 2257.

3277 *Rhopobota dietziana* (Kft.)—Cheboygan. 16 Jun 2014. A single specimen taken at Mud Lake bog, where its larval host holly, *Ilex* (Heinrich 1923), is known to occur.

3278 *Rhopobota finitimana* (Heinr.)—Cheboygan. 20 Jun 2012. 2 specimens, both taken in a UV light trap at Mud Lake bog. Also feeds on *Ilex* (Ferguson 1975); confirmed by dissection, BGS #s 1708, 1709.

3283 *Epinotia solandriana* (L.)—Cheboygan. 31 Jul–14 Aug. 4 specimens.

3286 *Epinotia mediowiridana* (Kft.)—Cheboygan. 10–27 Aug. 3 specimens. Known to feed on *Rubus* as a larva (MacKay 1953).


3306 *Epinotia nisella* (Cl.)—Cheboygan. 8 Jun–8 Sep. A variable species, it is common in our area, as expected for a species that feeds on the catkins of quaking aspen (*Populus tremuloides*) (Miller 1986a).

3307 *Epinotia cinereana* (Haw.)—Cheboygan. 31 Jul–26 Aug. Only 3 specimens, one from a UV light trap near Carp Creek at Hogsback Rd., one from
Eliot Creek marsh near Cheboygan, and one from Douglas Lake in 1932. *E. criddleana* was found to be a synonym of *E. cinereana* (Mutonen et al. 2012).

3309 *Epinotia walkerana* (Kft.)—Cheboygan. 10 Aug 2000. One female specimen taken in a UV light trap at Colonial Pt. woods, confirmed by dissection, BGS #1713. This species is a state record for Michigan.


3335 *Epinotia nonana* (Kft.)—Cheboygan. 22 Aug 1990. A single specimen from the UMBS UV light. Identified by Sabourin.

3338 *Epinotia nanana* (Tr.)—Cheboygan, Emmet. 2 Jul 2011. 2 specimens, a female taken in a UV light trap from Reese’s Swamp, confirmed by dissection, BGS #1716, and one that emerged from a *Picea glauca* branch brought indoors by Voss in Dec. 2000 and IDed by Ron Priest.

3345 *Epinotia cruciana* (L.)—Cheboygan. 15 Jul 1989. A single specimen in a UV light trap on UMBS property. Identified by Sabourin. This species is a state record for Michigan.

3333 *Catastega timidella* Clem.—Cheboygan. 13 Jun 2015. Taken once at MV light at a cottage near Douglas Lake. Confirmed by dissection, BGS #2256.

3334 *Catastega aceriella* Clem.—Cheboygan. 8–29 Jun. This species can be common, and the characteristic trumpet-shaped larval tubes (Prentice 1966) may be very abundant on sugar maple leaves during the summer.

3354 *Ancylis nubeculana* (Clem.)—Cheboygan, Emmet. 13 Jun–7 Jul. A fairly common early summer species also taken by Sherman Moore at St. Ignace. The larvae feed on a variety of trees in the Rosaceae (Miller 1987).

3355 *Ancylis subaequana* (Zell.)—Cheboygan. 27 May–11 Jul.


3361 *Ancylis semiovana* (Zell.)—Cheboygan. 22 Jun–13 Aug. Taken 3 times at the jack pine plains south of Indian River.

3367 *Ancylis burgessiana* (Zell.)—Cheboygan, Emmet. 27 May–7 Jul. A common summer species that is part of a complex of forms (together referred to as the *spiraeifoliana* complex) that may represent several species (Gilligan et al. 2008). All of ours fit the coloration referred to *burgessiana*.

3372 *Ancylis brauni* (Heinr.)—Cheboygan, Emmet. 16 Jun–18 Jul. Two specimens, one from a UV light trap at Nebo Trail in Wilderness State Park and the other from a UV trap at Carp Creek at Hogsback Rd. This species is a state record for Michigan.


3375 *Ancylis divisana* (Wlk.)—Cheboygan. 13 Jun–13 Aug. 3 specimens.

3378 *Ancylis carbonana* Heinr.—Emmet. 23 May 1932. A single specimen taken by W. C. Stinson at Cecil Bay; identified by W. E. Miller.

3379 *Ancylis diminutana* (Haw.)—Cheboygan. 3 Jun–13 Aug. Two specimens, one in a UV light trap at the jack pine plains south of Indian River and one at a cottage near Douglas Lake.
Ancylis unquicella (L.)—Cheboygan, Emmet. 21 May—20 June. 3 specimens taken during the day on the dunes at Waugoshance Pt. in Wilderness State Park and one at UV light in Mud Lake bog.

Dichrorampha bittana (Bsk.)—Cheboygan. 24 Jul–7 Aug. 2 specimens, both identified by Sabourin, one confirmed by dissection #00543.

Dichrorampha sedatana (Bsk.)—Emmet. 28 May 2015. 3 specimens flying during the day at an opening in the woods at Wilderness State Park.

Pammene perstructana (Wlk.)—Cheboygan. 30 Jun 2011. Taken once at the UMBS MV light. A male confirmed by dissection, BGS #1723.

Larisa subsolana Miller—Cheboygan. 17 Jun–5 Jul. Taken 3 times at the UMBS light. First specimen identified by Sabourin. The larvae have been reared from pecan (Carya illinoinsensis) (Brown et al. 1983), but obviously use something else in our area, where that genus doesn’t occur.

Grapholita libertina Heirn.—Cheboygan. 10 Aug 2002. 2 specimens, one taken at the jack pine plains south of Indian River and one taken on the dunes of Sturgeon Bay. This species is a state record for Michigan.

Grapholita packardi Zell.—Cheboygan, Emmet. 22 Jun–18 Jul. Males are distinctive with a patch of dark scent scales on the hindwing. Larvae are known as the cherry fruit worm (Gilligan et al. 2008), and may cause damage to local cherry orchards.

Grapholita angeleseana (Kft.)—Cheboygan. 14–22 Jun 2014. 2 specimens taken flying during the day along the shore of Douglas Lake.

Corticivora clarki Clarke—Cheboygan. 29 Jun–29 Jul. A relatively common species, but small and easily overlooked; the larvae are known to feed on the bark of red pine (Clarke 1951).

Cydia multilineana (Kft.)—Cheboygan. 31 Jul 2002. A single individual taken at the UMBS MV light. Confirmed by dissection, BGS #1725.

Cydia populana (Bsk.)—Cheboygan, Emmet. 27 Jul–1 Aug.

Cydia fletcherana (Kft.)—Cheboygan. 29 Jun 1997. Taken once at the UMBS UV light. Identified by Sabourin.

Cydia toreuta (Grt.)—Cheboygan. 28 May–2 Jul. A fairly common early summer species. This is apparently part of a complex of species that feed on pine seeds and we may have different species on red pine and jack pine (Abrahamson and Kraft 1965).

Cydia pomonella (L.)—Cheboygan. 18 Jun–10 Jul. This species, a pest that feeds on the seeds of apples, pears, plums and walnuts (Falcon and Huber 1991), is certainly more common farther south in the apple growing areas of the state. It was also recorded from St. Ignace by S. Moore.

Cydia latiferreana (Wlsm.)—Cheboygan. 6 Jul–26 Aug. Very common in the mid and late summer. This is also generally considered a species complex, but the relationships are unresolved (Brown 1983, Miller 1987). It is a pest feeding on filberts and hazelnuts, but probably more commonly beech (Fagus grandifolia) in our area (Brown 1983).

Ectdytolopha insiticiana Zell.—Cheboygan. 30 May–12 Jul. Both this and the next species have larvae that feed on black locust (Robinia pseudacacia) (Adamski and Brown 2001), and have certainly increased in abundance as that species has spread in the area.

Gymnandrosoma punctidiscanum (Dyar)—Cheboygan, Emmet. 25 Jun–14 Aug. A very common species throughout the region.
Subfamily Tortricinae

3502 Acleris albicomana (Clem.)—Cheboygan, Emmet. 29 Jun–19 Aug. A fairly common species, also taken by S. Moore at St. Ignace.

3503 Acleris semipurpurana (Kft.)—Cheboygan. 30 Jun–24 Jul. One of several common summer species, first identified by Sabourin.

3504 Acleris curvalana (Kft.)—Cheboygan, Emmet. 27 Jun–4 Aug.

3506 Acleris macedonnoughi Obr.—Cheboygan. 9 Sep 1937. Taken once by Max Peet at Burt Lake. First described by Obraztsov (1963), this specimen identified by Sabourin.

3506 Acleris nivisellana (Wlsm.)—Cheboygan, Emmet. 25 May–20 Jun. 4 specimens. Many of our species of Acleris were treated by McDunnough (1934) under the genus Peronea, and this treatment includes several species that should occur in our area but have not been recorded, perhaps because they are difficult to distinguish and so many of these species fly during the fall and spring.

3514 Acleris cervinana (Fern.)—Cheboygan. 24 May 2015. A single specimen taken at MV light at a cottage near Douglas Lake. This species is a state record for Michigan.

3521.11 Acleris stadiana (B. and Bsk.)—Cheboygan. 27 Jun 1991. One specimen taken at the UMBS UV light. Identiﬁed by Sabourin. After distinguishing this species from A. semiannula, Sabourin et al. (1997) listed birch as the host plant of this species.

3525 Acleris forbesana (McD.)—Emmet. 3 Aug 1921. A single specimen in the UMMZ, taken by S. Moore on Waugoshance Island.

3527 Acleris schalleriana viburnana Clem.—Cheboygan. 3 Jun–10 Jul. Two specimens taken at a cottage near Douglas Lake, and two specimens reared from maple-leaved viburnum, Viburnum acerifolium; identiﬁed by Sabourin.

3532 Acleris fragariana Kft.—Cheboygan: 24 Aug–18 Sep. 4 specimens taken by M. C. Nielsen at UV light along Eliot Creek near Cheboygan.

3540 Acleris logiana (Cl.)—Cheboygan. 27 May, 22 Jun and 3 Aug. Three specimens, evidently of two different generations, all collected at light.


3565 Eulia ministrana (L.)—Cheboygan. 12–24 Jun. This distinctive, late spring species has been taken three times, at Grass Bay Nature Preserve, by Carp Creek at Hogsback Rd., and at a cottage near Douglas Lake. This species is a state record for Michigan.

3567.01 Cnephasia stephensiana (Doubleday)—Cheboygan. 20–29 Jun. All specimens have been taken in UV light traps at Mud Lake bog. Id conﬁrmed by Sabourin. This species is a state record for Michigan.


3584 Anopina ednana (Kft.)—Cheboygan. 26 Jun–6 Jul. 3 specimens, all taken in UV light traps at Colonial Pt. woods. This genus was treated by Obraztsov (1962). This species is a state record for Michigan.

3593 Pandemis lamprosana (Rob.)—Cheboygan. 9 Jul–10 Aug. A fairly common species that is quite similar to its congener. Several were conﬁrmed by dissection, BGS #s 1740, 1741, 1743, 1747, 1748. Feeds on several species of broad-leaved trees, including beech (Fagus) and oak (Quercus) in our area (Freeman 1958).
3594 Pandemis limitata (Rob.)—Cheboygan, Emmet. 18 Jun–16 Aug. A very common species in the region. Many confirmed by dissection, BGS #s 1745, 1742, 1744, 1746, 1750, 1752, 1753, 1755, 1756, 1757, 1751, 1758, 1760, 1762, 1763. This species has an even wider range of deciduous hosts (Freeman 1958).

3597 Argyrotaenia velutinana (Wlk.)—Cheboygan, Emmet. 29 Jun–1 Aug. Known as the red-banded leaf roller, it is an occasional pest on apple but it feeds on nearly any non-conifer (Freeman 1958).

3621 Argyrotaenia quadrifasciana (Fern.)—Cheboygan, Emmet. 2–16 Jul. First identified by Sabourin. The host plants include several rosaceous trees (Freeman 1958).


3624 Argyrotaenia alisellana (Rob.)—Cheboygan. 18 Jun–6 Jul. Several specimens taken at the UMBS light; also an oak feeder (Freeman 1958).

3625 Argyrotaenia mariana (Fern.)—Cheboygan. 24 May–13 Jun. This early season species is fairly common. Larvae apparently use Vaccinium in our area (Freeman 1958).

3632 Choristoneura fractivittana (Clem.)—Cheboygan. 16–25 Jun. Taken at Colonial Pt. woods and at Hogsback Rd. near Carp Creek. Host plants include Fagus and Quercus (Freeman 1958), both common at these localities.

3634 Choristoneura zapulata (Rob.)—Cheboygan, Emmet. 4–18 Jul. Quite common at the dunes of Wilderness State Park. It feeds on a wide variety of low growing shrubs (Freeman 1958).

3635 Choristoneura rosaceana (Heinr.)—Cheboygan, Emmet. 21 Jun–8 Sep. An abundant species. Scholtens has reared this species from Alnus incana, Vaccinium, Amelanchier, Fraxinus, Betula papyrifera, Shepherdia, Salix and Rhus. (Freeman 1958).

3637 Choristoneura conflictana (Wlk.)—Cheboygan. 16 Jun–12 Jul. A large, gray species known as the large aspen tortrix reflecting its host plant, Populus (Freeman 1958). It has also been recorded from St. Ignace by S. Moore.

3638 Choristoneura fumiferana (Clem.)—Cheboygan, Emmet. 18 Jun–5 Aug. A common species. Scholtens has reared it from Abies balsamifera, but it is also known from Picea, Larix and Pinus (Freeman 1958).

3643 Choristoneura pinus Free.—Cheboygan, Emmet. 30 Jun–9 Aug. Known as the jack pine budworm, it can reach outbreak proportions in the jack pine plains, as it did in 1991 when Scholtens collected it east of Indian River. Reared from Pinus banksiana.

3648 Archips argyrospila (Wlk.)—Cheboygan. 6–13 Jul. Taken only twice at the UMBS light. Recorded from many different host plants (Freeman 1958).


3652 Archips myricana (McD.)—Cheboygan, Emmet. 16–21 Jul. Taken at the UMBS light and at a wetland in the southern part of Wilderness State Park, but also collected it at Pt. Aux Chenes in Mackinac Co. Freeman (1958) reports it from Myrica, Salix and Spiraea. This species is a state record for Michigan.

3653 Archips semiferana (Wlk.)—Cheboygan. 22 Jun–22 Jul. Occurs with regularity here even though Freeman states it is restricted to the southern half of the continent (1958).
Archips fervidana (Clem.)—Cheboygan, Emmet. 9 Jul–11 Aug. The larva is appropriately referred to as the messy nest caterpillar. Scholtens reared several from such a “nest” on red oak, Quercus rubra, from the jack pine plains south of Indian River.

Archips purpurana (Clem.)—Cheboygan. 7 Jul–13 Aug. A distinctive species with an upwardly falcate wingtip. Scholtens reared it from Diervilla lonicera and Shepherdia, and it is known to feed on many different plants (Freeman 1958).

Archips grisea (Rob.)—Cheboygan. 22 Jun–16 Jul. This species is strikingly sexually dimorphic with males and females appearing to be different entities. Of the listed host plants (Freeman 1958), Quercus is the most likely in our area.

Archips cerasivorana (Fitch)—Cheboygan, Emmet. 15 Jul–9 Aug. Freeman (1958) records it from Prunus, Salix and Fraxinus.

Archips striana Fern.—Cheboygan, Emmet. 20 Jun–11 Jul. This and the next three species are very distinctly marked. A. striana is found primarily in wooded wetland areas and feeds on spruce (Picea) (Freeman 1958).

Archips alberta (McD.)—Cheboygan. 6–15 Sep. Taken twice by Max Peet at Burt Lake and also by Neilsen at the mouth of Eliot Creek in Cheboygan State Park.

Archips dissitana (Grt.)—Cheboygan. 31 Jul–21 Aug. Freeman (1958) simply says the foodplant is probably a conifer.

Archips packardiana (Fern.)—Cheboygan. 20–29 Jul. Found only at Mud Lake bog. Recorded from both Picea and Abies (Freeman 1958).

Syndemis afflictana (Wlk.)—Cheboygan. 24–28 May 2015. This early species has been taken only at a cottage near Douglas Lake, but is probably much more widespread and common.

Lozotaenia costinotana Franc.—Cheboygan. 2–11 Jul. Another species of wooded wetlands. This species is a state record for Michigan.


Clepsis persicana (Fitch)—Cheboygan. 17 Jun–22 Jul. Scholtens reared this species on Shepherdia from Keweenaw Co., and Freeman (1958) states it is a general feeder on many plants.

Clepsis clemensiana (Fern.)—Cheboygan, Emmet. 13 Jun–3 Sep. Only one specimen has been taken after 12 Jul, but it evidently represents a second brood. Freeman (1958) lists the hosts as grasses and goldenrod (Solidago).

Clepsis melaleucana (Wlk.)—Cheboygan. 8–25 Jun. Only 5 specimens, but also taken by S. Moore at St. Ignace. The hosts include Trillium, Polygonatum and Caulophyllum, all plants of the forest floor (Freeman 1958).

Clepsis peritana (Clem.)—Cheboygan, Emmet. 26 Jun–8 Sep. A very common species very similar to C. virescana; confirmed by dissection, BGS #s 1772, 1769, 1770, 1771, 1768, 1773. The host plant is wild strawberry, Fragaria (Freeman 1958).

Clepsis virescana (Clem.)—Cheboygan. 26 Jun–22 Jul. Also common; several confirmed by dissection, BGS #s 1778, 1776, 1775, 1777.

Xenotemna pallorana (Rob.)—Emmet. 1–16 Jul. Taken twice by Voss and identified by G. G. Lewis.
3695 *Sparganothis sulfureana* (Clem.)—Cheboygan, Emmet. 2 Jul–10 Aug. The form of this species known as *belfrageana* (Zell.) is included here, following the recent revision of Powell and Brown (2012).

3697 *Sparganothis lycopodiana* (Kft.)—Cheboygan. 26 Jun–31 Jul. A very pretty little species.

3699 *Sparganothis tristriata* Kft.—Cheboygan, Emmet. 2 Jul–21 Aug. Perhaps the most distinctive of our *Sparganothis* species, it is common in our jack pine plains.

3706 *Sparganothis xanthoides* (Wlk.)—Cheboygan, Emmet. 20 Jun–2 Jul. Only 3 specimens, but evidently a species of swamps.

3706.1 *Sparganothis boweri* Powell and Brown—Cheboygan, Emmet. 8–18 Jul. This recently described species has been found on two different dune systems, Grass Bay and Wilderness State Park. This species is a state record for Michigan.

3711 *Sparganothis unifasciana* (Clem.)—Cheboygan, Emmet. 2 Jul–13 Aug.

3717 *Sparganothis flavibasana* (Fern.)—Emmet. 18 Jul 2011. Taken in UV light traps at two nearby locations in Wilderness State Park. This species was reported from Michigan by Dwayne Badgero (2013).

3720 *Cenopis reticulatana* (Clem.)—Cheboygan, Emmet. 18 Jul–30 Aug. A common late summer species. This and the following 4 species were recently moved from *Sparganothis* (Powell and Brown 2012).

3721 *Cenopis mesospila* Zell.—Cheboygan. 6 Jul 2007. Taken only once near Carp Creek on Hogsback Rd. This species is a state record.

3722 *Cenopis directana* (Wlk.)—Cheboygan, Emmet. 2–13 Jul. Taken in a UV light trap in jack pines along Douglas Lake Rd. and at the jack pines south of Indian River.

3725 *Cenopis pettitana* (Rob.)—Cheboygan. 25 Jun–14 Aug. A common species, now including the form known as *acerivorana* (Powell and Brown 2012). Scholtens reared this form on *Acer saccharum* and the common form on *Tilia americana*.

3727 *Cenopis niveana* (Wlsm.)—Cheboygan. 5–17 Jul. A distinctive species collected only at the UMBS light.


3741 *Platynota semiustana* Wlsm.—Cheboygan. 6 Jul 2007. A single specimen taken in a UV light trap at Colonial Pt. woods. This is significantly farther north than the species has previously been reported (Powell and Brown 2012). Confirmed by dissection, BGS #1644. This species is a state record for Michigan.

3743 *Platynota exasperatana* (Zell.)—Cheboygan. 6–16 Jul.

3748 *Amorbia humerosana* Clem.—Cheboygan, Emmet. 8–12 Jun. An early-flying species taken by Scholtens at a cottage near Douglas Lake, and by Voss in Mackinaw City.

3755 *Aethes smeathmanniana* (F.)—Cheboygan. 8 Jul 1995. Single female specimen taken at Grass Bay Preserve. Taxonomy for the Cochylina follows the recent update by Metzler and Brown (2014). This species is a state record.

3755.1 *Aethes baloghi* Sabourin and Metzler—Cheboygan, Emmet. 27 May–4 Aug. A recently described species (Sabourin et al. 2002) and there listed for Michigan; dissected by Sabourin.
3758 *Aethes rutilana* (Hbn.)—Emmet. 2–18 Jul. Perhaps our most distinctive *Aethes*, with a pretty reddish pattern; several specimens taken at the dunes on Sturgeon Bay. The larva is known to feed on *Juniperus communis* (Razowski 1997), which is common in that habitat.


3758.31 *Aethes sexdentata* Sabourin and Miller—Cheboygan. 2 Jul 2006. Taken only once in a UV light trap at Reese’s Swamp. This species was not covered in Razowski (1997). This species is a state record for Michigan.

3807 *Aethes angulatana* (Rob.)—Cheboygan. 21 Jul 2012. Two specimens taken at UV light near the maintenance shed at UMBS.

3810 *Aethes atomosana* (Bsk.)—Cheboygan, Emmet. 27 Jun–14 Aug. Confirmed by dissection, Sabourin #3851, 00723.

3815 *Aethes biscana* (Kft.)—Cheboygan. 22 Jun–8 Sep. 4 specimens; first identified by Sabourin. Larvae feed on *Euthamia graminifolia* (Razowski 1997).

3832 *Aethes interruptofasciata* (Rob.)—Cheboygan. 13 Jul 1997. A single specimen collected by Margie Lepper at the UMBS light. Identification confirmed by Sabourin; not in Razowski (1997). This species is a state record for Michigan.

3850 *Aethes ca.* *seriatana* (Zell.)—Cheboygan. 8–16 Jun. Taken 3 times in the vicinity of Douglas Lake. This species is a state record for Michigan.

3851 *Aethes spartinana* (B. and McD.)—Cheboygan, Emmet. 10–30 Jul. Collected mainly on the dunes of Wilderness State Park, at both Waugoshance Pt. and Sturgeon Bay. A single specimen from 1934 in the UMMZ is labeled Douglas Lake. This species is known to feed on *Spartina*, with the life history described by Ainslie (1917); it is likely using another grass in northern Michigan. This species is a state record for Michigan.

3812 *Cochylis aurorana* (Kft.)—Cheboygan, Emmet. 18 Jul–14 Aug. This species is a state record for Michigan.

3819.32 *Cochylis dubitana* (Hbn.)—Cheboygan. 12–23 Jun. Taken twice, once at a cottage near Douglas Lake, and once at the UMBS UV light and dissected by Sabourin, #99143. Razowski (1997) reports this from various Asteraceae in Europe.

3828 *Cochylis hoffmanana* (Kft.)—Cheboygan. 31 Jul–14 Aug. Larvae have been reared from New England aster (*Aster novae-angliae*) (Razowski 1997).

3829 *Thyraylia hollandana* (Kft.)—Cheboygan. 1–14 Aug. Two specimens, collected at the UMBS light and Colonial Pt. woods. Not in Razowski (1997). This species is a state record for Michigan.

3864 *Thyraylia nana* (Haw.)—Cheboygan. 26 Jun 1997. A single specimen taken at the UMBS UV light, confirmed by dissection, Sabourin #3764. This species is a state record for Michigan.

3787 *Phtheochroa vitellinana* (Zell.)—Cheboygan. 18 Jun–9 Jul. A fairly common, pretty species with yellow and metallic markings.

3799 *Phtheochroa terminana* (Bsk.)—Cheboygan. 6 Jul 2007. A single specimen taken in a UV light trap near Carp Creek at Hogsback Rd.

3801 *Phtheochroa birdana* (Busck)—Cheboygan. 18 Jul 1998. Single female specimen taken at the UMBS light, confirmed by dissection, Sabourin #99417. This species is known to feed on tall coneflower, *Rudbeckia laciniata*. 
3836 *Phalonidia lepidana* (Clem.)—Cheboygan. 3 Jun–31 Jul. Two specimens taken at the UMBS MV light and one at a cottage near Douglas Lake. This species is a state record for Michigan.

3852 *Phalonidia straminoides* (Grt.)—25 Jun–3 Aug 1997. Two female specimens taken at UMBS light, confirmed by dissection, Sabourin #s 99144, 99156. This species is a state record for Michigan.

3842 “*Conchylis* oenotherana” Riley—Cheboygan. 31 Jul–10 Aug. A distinctive species with pink markings. Scholtens reared this from evening-primrose, *Oenothera biennis*, near the boatwell at UMBS. We follow Gilligan et al. (2014) and use the original genus because this species needs a new genus.

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Description of the Nymph of *Ophiogomphus smithi* (Odonata: Gomphidae), With a Key to the Species of *Ophiogomphus* in the Western Great Lakes Region

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Abstract

*Ophiogomphus smithi* Tennessen & Vogt is a gomphid dragonfly with restricted distribution which includes northeast Iowa, southeast Minnesota, and central to northwestern Wisconsin. The nymph is described and illustrated based on 173 specimens (66 exuviae of reared specimens plus 107 nymphs) from throughout the species’ range. The nymph of *O. smithi* is very similar to nymphs of *O. carolus* Needham, *O. colubrinus* Selys, and *O. rupinsulensis* (Walsh). Nearly all (99%) of *O. smithi* sampled can be distinguished from *O. colubrinus* by prementum terminal width less than or equal to 2.97 mm (98% of *O. colubrinus* greater than 2.97 mm), and from *O. carolus* and *O. rupinsulensis* by the ratio of metatibia length to abdominal segment 10 width being greater than 1.66 (96% of *O. smithi* vs. less than 1.66 (98.5% of *O. carolus* and *O. rupinsulensis*). Several characters and character combinations previously unused for *Ophiogomphus* nymphs were found to be of taxonomic value, including color pattern on dorsal hooks and dorsum of abdomen, shape of abdominal mid-dorsal punctae, length and shape of fronto-clypeal ridge setae, and ratio of metatibia length to width of abdomen on segments 9 and 10. An illustrated quantitative key to the 7 species of *Ophiogomphus* occurring in the western Great Lakes region is provided, along with a separate, more qualitative key enabling species identification in the field. *Ophiogomphus smithi* is regularly syntopic only with *O. rupinsulensis*, rarely with *O. carolus* and *O. colubrinus* and not with *O. anomalus*, *O. howei*, or *O. susbehcha*; nymphs inhabit small to medium-sized, sandy, cool to warm stream segments with patches of pea-sized gravel.

The genus *Ophiogomphus* Selys, 1854, is represented by seven species in the western Great Lakes region (defined in the Materials and Methods section): *O. anomalus* Harvey, 1898 (nymph described by Walker 1933, 1958), *O. carolus* Needham, 1897 (nymph—Needham 1901, Walker 1933, 1958), *O. colubrinus* Selys, 1854 (nymph—Hagen 1885), *O. howei* Bromley, 1924 (nymph—Kennedy and White 1979, Louton 1982), *O. rupinsulensis* (Walsh), 1862 (nymph—Walker 1933, 1958; Louton 1982), *O. smithi* Tennessen and Vogt, 2004 (nymph undescribed), and *O. susbehcha* Vogt and Smith, 1993 (nymph—Vogt and Smith 1993). The purpose of this paper is to describe and illustrate the nymph of *O. smithi* based on associated exuviae and nymphs, and to provide diagnostic characters by which it can be separated from the six other sympatric species of *Ophiogomphus*. Using the most recent comprehensive key to nymphs of *Ophiogomphus* (Needham et. al. 2014), *O. smithi* keys to *O. colubrinus*. *Ophiogomphus smithi* is considered by NatureServe (2014) as globally imperiled to vulnerable; in the

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least, it is a local species throughout its range, although it can be relatively common at a handful of sites. From a conservation perspective, facilitating the identification of *O. smithi* nymphs has been a critical need to date.

The nymphs and exuviae of *O. anomalus*, *O. howei*, and *O. susbehcha* are relatively easy to separate from each other and from their regional congeners; presence/absence of dorsal hooks and lateral spines and the shape of antennal segment 4 are readily used to identify these three species (Needham et al. 2014). The four remaining species, *O. carolus*, *O. colubrinus*, *O. rupinsulensis* and *O. smithi* (hereafter the “four similar species”) are very similar and difficult to identify. Previous keys to *Ophiogomphus* nymphs, including the most recent treatments of North American species by Carle (1992) and Needham et al. (2014) are difficult to use and can lead to misidentifications. Variation in character states and paucity of illustrations are among the challenges in using these works. Characters that yielded reliable differences, some of which have not been previously studied or discovered to be taxonomically useful for the genus, were used to diagnose the four similar species and to construct keys to the regional species.

### Materials and Methods

#### Study Area.

For the purposes of this paper the Western Great Lakes Region includes Wisconsin, Michigan, adjacent Ontario, Illinois, Ohio, and the eastern halves of Minnesota and Iowa. This area excludes the ranges of *O. westfalli* Cook & Daigle and *O. severus* Hagen, both of which occur in western Iowa (Abbot 2006–2014). An effort was made to collect fresh specimens of the four similar species within the current known range of *O. smithi*. Additional specimens were used from existing collections from the Western Great Lakes as well. We analyzed large series (a total of 684 specimens) of these four similar species. We measured or scored 144 morphological characters, plus we generated 25 additional characters based on ratios and sums of measurements and scores for analysis.

#### Odonata Rearing and Specimen Preparation.

The seven *Ophiogomphus* species addressed in this paper were reared to adults from selected nymphs, mainly F-0 stadia, collected in the field in both fall and spring. Live nymphs for rearing were placed in mesh cages in aquaria with fine gravel/sand substrate and aeration. Water temperature was maintained between 10ºC and 16ºC; day length was ambient for southern Wisconsin until emergence. The mesh enclosures extended well above the water level and provided support for emergence.

Fall collected nymphs were induced to enter diapause (necessary for subsequent completion of development to adults) by placing the aquaria near a window in a room receiving natural day length. Diapause was broken (usually after winter solstice) by heating the room or aquarium such that water temperature reached approximately 17–19ºC and providing day lengths with artificial white light about the same as that of normal emergence dates in late May or early June in Wisconsin. Emergence of adults usually followed breaking of diapause in 4–6 weeks.

Spring collected teneral adults were carefully moved to a dark container and kept alive for at least a day to allow color patterns to develop. The associated exuviae were wetted, carefully removed and placed in vials containing 70% ethyl alcohol. Since a number of specimens sometimes emerged at the same time, we removed tenernals with their exuviae as soon as possible to prevent mistaken associations and to avoid teneral adults falling into the water and drowning before they completed their color development. The vial with associated exuvia was kept with the teneral adult until final preservation and labeling.

#### Data Collection and Analysis.

A total of 173 *O. smithi* (IA, MN, WI), 165 *O. carolus*, 164 *O. colubrinus*, and 182 *O. rupinsulensis* final instar nymphs
and exuviae (all from WI) were measured and characterized using previously published characters for the genus plus a number of additional characters we suspected might reveal specific differences. We also numerically scored character states for several categorical features like degree of arching and coloration of dorsal hooks. Nymphs and unassociated exuviae were identified by direct comparison with reared material or when two or more important characters compared favorably. We left specimens of questionable identity out of the analysis, as hybrid adult specimens of *Ophiogomphus* have been reported (Tennessen 2014). A number of F-1 specimens were subjectively evaluated as well.

Collection data for *O. smithi* specimens examined are given under the Description Section; data for the other 3 species are given in Appendix 2. Measurements were made using a 10 to 30X binocular microscope equipped with an eyepiece micrometer to the nearest 0.1 mm. Setae on the frontoclypeal ridge were measured at 25X, all other characters at 12.5X. Figures illustrating the mid-dorsal punctae and cuticular granules were made from images captured with a JVC KY-F75U digital camera attached to a Leica Z16 APO dissecting microscope with apochromatic zoom objective and motor focus drive, using a Synchroscopy Automontage System and software. Multiple images for a given subject, generally 10 to 20 images, were used to construct the final figure. Specimens were illuminated with either an LED ring light attached to the end of the microscope column, with incidental light filtered to reduce glare, or by a gooseneck illuminator with bifurcating fiber optics. Specimens were immersed in water to help view setal characters. All other figures were made from images captured with a camera lucida mounted on a Wild-Heerbrug microscope.

Classification and Regression Tree Software (CART version 7.0.0.470 by Salford Systems, San Diego, CA) was used to determine which of the 169 characters analyzed showed some degree of utility in discriminating among the four similar species. The CART variable importance function looked at every value of every potentially discriminating independent variable (169 variables X 685 specimens of the four species) and ranked them based on the least classification error in the subsequent trees. CART then used a subset of the variables found important to construct final potential classification trees. Different permutations of final trees were used to generate potential character thresholds and contextual placement of couplets for the two taxonomic keys similar to the analysis by Fisher (1936) for three species in the vascular plant genus *Iris*. Characters found useful in separating the four similar species are given in Table 1; other characters we evaluated but found too variable to differentiate between species are presented in Appendix 1.

**Definitions and Abbreviations.** Acute was defined as sharply tapered (< 90 degrees) to a point; acuminate is similar but with apex more elongate/tapered. Mid-dorsal punctae are the medial paired dark depressions found on S2 to 8 of the abdomen. The punctae are surrounded by a darkly pigmented area generally matching the shape of the punctae. Additional definitions used in the keys below are summarized below.

Syntopic species were defined as breeding populations of different species found together in the same stream segment as delineated by junctions with nearest upstream and downstream confluence.

Antm = antennomere; DH = dorsal hook(s); FCR = frontoclypeal ridge; L = length; W = width; S = abdominal segment; CTH = county trunk highway; STH = state trunk highway.

**Results**

**Description of Ophiogomphus smithi Nymph.** Body overall pale yellow-brown often with dark markings on dorsum of S6; outer margins of head,
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Figure 1. Habitus of *Ophiogomphus smithi* nymph, F-0, dorsal view.

Thorax, legs, and abdomen beset with many long, pale, hair-like setae; dorsal hooks on S2–S9, lateral spines on S7–S9 (Fig. 1).

Head.—Nearly ovate in dorsal view, outer margins of eyes and postocular lobes broadly rounded, posterior margin incurved (Fig. 1), ca. 1.3 (exuvia 1.2) times as wide as long; small dark granulations on most of dorsal surface. Labrum with dense row of distal setae about 0.3–0.5 mm long. Antm3 longest of the 4 antennomeres, 1.3–1.45 mm long (mean 1.34 mm), slightly more than twice length of antm1 and 2 combined, 0.45–0.60 mm wide, (mean 0.53), (L/W ratio 2.2–3.1 (mean 2.6)), inner margin straight, outer margin broadly and evenly convex; antm4 triangular, apex bluntly triangular to rounded, 0.1–0.2 mm long, 0.1–0.25mm wide (Fig. 2). FCR 0.25–0.5 mm long with numerous (10–14) slender, slightly curved setae from 0.1 to 0.3 mm long (mean length 0.14 mm), plus a few shorter cylindrical setae (Fig. 3). Prementum length 2.85–3.30 mm, mean length 3.1 mm, distal width 2.40–3.00 mm (mean width 2.7 mm; mean L/W ratio 1.14), on average lateral margins slightly convex, prementum usually widest proximal to bases of palpal lobes, margins with scattered, fine setae (Fig. 4); ligula convex with 24–36 quadrate teeth weakly developed and separated. Palpal lobe with 10 or 11 low subquadrate teeth on inner margin, apex rounded, lateral margin of lobe with several pale setae near base; movable hook 0.85–1.05 mm long, same length as lateral margin of palpal hook (Fig. 4). Apical margin of labial hinge lies between procoxae approaching posterior margin of prosternum. Mandibles biramous, incisors with 4 stout cuspids, molar crest
with either 4 (right) or 6 (left) smaller cuspids: formula L 1234 0 a (m1 to 4)b, R 1234 y a (m1,2)b (Figs. 5a–5b).

Thorax.—Pro- and meso-tibiae with apical burrowing hook; pro- and meso-femora, on well-preserved and live nymphs banded, on others faintly banded to apparently not banded; hind femur length 4.1–5.0 mm (mean 4.4 mm), 0.3 times ventral abdomen length (incl. paraprocts); apex of hind femur extending to anterior margin of S4, dark band at 3/4 length; apex of hind wing pad at mid-length of S4 to posterior margin of S4.

Abdomen.—evenly tapered from S5 to acute apex (Fig. 1). Length (measured ventrally) 1.73–2.6 (exuviae 2.3–2.6) times maximum width, widest across S5 or S6. Mid-dorsal hook on S2–S9 in lateral view low, arched, degree of arch decreasing from S5–S9 (Fig. 6), distal half of DH 8 and 9 generally parallel to

Figure 6. *Ophiogomphus smithi* nymph mid-dorsal hooks, lateral view.
or slightly elevated in relation to longitudinal axis of abdomen; DH 7–9 apices generally lighter in color than dorsum (Fig. 1). Dorsum of S2–S9 each with two shallow, darkly pigmented depressions (punctae) on each side of median line, oblong and diagonally-oriented on S2–S4, more rounded on S5–S8 (Fig. 1), in some individuals faint to barely detectable; S6 dorsum with pair of median dark triangular markings (Fig. 1), sometimes fainter markings on segments posterior to S6–S8. Postero-lateral spine on S7 to S9, often decreasing in size posteriorly (L = 0.20–0.50 mm on S7, 0.14–0.40 mm on S8, 0.20–0.40 mm on S9), S9 spine 0.3–0.5 times dorsal length of S10. Lateral margins of S7–S9 with 6–12 very small, pale spicules. S9 lateral spines twice as wide as S8 lateral spines; S9 2.7–2.9 times wider than its mid-ventral length, S10 2.1–3.0 times wider than its mid-ventral length. Paraprocts acutely tapered, cerci and epiproct more acuminately tapered, cercus lateral margins straight to slightly concave (Fig. 7); epiproct 1.50–2.10 mm long (1.4–2.1 times S10 ventral length), male tubercles at 0.55 (0.5–0.63) times length of epiproct from base; cercus 1.05–1.60 mm long, 0.56–0.90 (avg. 0.74) length of epiproct; paraprocts extend slightly beyond epiproct (Fig. 7). Vulvar lobes at base of female S9 sternum cylindrical with rounded apex, gap between the two lobes approximately equal to width of a lobe at its mid-length, lobes parallel to each other or very slightly divergent (Fig. 8d).

Measurements (mm): Total L 22.0–29.0; head W 5.0–5.8; hind femur L 4.1–5.4; abdomen L 13.5–18.9; maximum abdomen W 6.8–8.8.

Specimens examined (all F-0 unless otherwise noted): [Abbreviations used for collectors below: AA= A. Achterhoff; AR=A. Reynolds; BWS=B. W. Smith; CCS=C. C. Smith; CMK=C. McKee; DEJ=D. E. Johnson; GB=G. Balwierz; GS=G. Schuurman; JA=J. Arthur; JHJ=J. H. Janacki; JMK=J. McKee; KJT=K. J. Tennessen; KLS= K. L Schmude; MB=M. Balwierz; MG=M. Garcia; MP=M. Payne; NAS=N. A. Sievert; RB=R. Bautz; RBD=R. B. DuBois; RL=R. Ladenburger; TEV=T. E. Vogt; WAS=W. A. Smith.]

IA, Buchanan Co., Bear Creek, above outlet of Koutny Pond, Public Access and I-380, 42.3025N, 91.9594W, 21 May 2010, WAS, GS and JHJ, 6 nymphs, (6 reared exuviae); IA, Buchanan Co., South. Fork. Maquoketa River, Hwy 187, N of Lamont, lat 42.6137, long -91.6467, 24 June 2011, KJT, 2 nymphs (1 F-0 and 1 F-3); IA, Clayton Co., Volga River, Hwy 13, Osborne, lat 42.7953, long -91.4414, 23 June 2011, KJT, 5 nymphs (F-0 and smaller); IA, Clayton Co., Volga River, above bridge, Hwy. 13, lat 42.7954, long -91.4420, 19 April 2013, KJT and WAS, 7 nymphs; IA, Delaware Co., Honey Creek, 180th St. N of Manchester, 24 June 2011, KJT, 1 nymph; IA, Jones Co., Plum Creek, NE corner of Rd/stream intersection, 285th Ave., lat 42.3827, long -91.2333, 1 June 2010, WAS, GS and JHJ, 1 nymph; IA, Winneshiek Co., Turkey River, nr. Ft. Atkinson, lat 43.1468,

Figure 7. *Ophiogomphus smithi* nymph anal appendages: a) male, dorsal view; b) female, dorsal view; c) male, lateral view.
long -91.9306, 23 June 2011, KJT, 5 nymphs (F-0 and smaller); IA, Winneshiek Co., Turkey River, Co. Rd. A46, lat 43.2990, long -92.0363, 23 June 2011, KJT, 2 nymphs (F-0 and smaller); IA, Winneshiek Co., Turkey River, below bridge, HWY 24, lat 43.1469, long -91.9306, 19 April 2013, KJT and WAS, 2 nymphs; MN, Dodge Co., South Fork Zumbro River, upstream of bridge about 30m, MN Hwy 13, lat 43.9042, long -92.7376, 13 September 2011, WAS, 10 nymphs; MN, Dodge Co., South Fork Zumbro River, Vernon, MN, Hwy 13, lat 43.9045, long -92.7386, 11 June 2011, RBD, AA, JA, GB, MG, MG, RL, CMK and JMK, 1 nymph, 5 exuviae; WI, Chippewa Co., Paint Creek, Jct. CTH K and Stillson Rd., 26 April 1983, KJT, 1 nymph; WI, Dunn Co., Hay River, just below bridge, CTH FF, lat 45.1060, long -91.9259, 18 August 2011, WAS, 19 nymphs; WI, Dunn Co., Hay River, canoe access below bridge, off 450th St and CTH FF, lat 45.1058, long -91.9260, 31 May 2012, WAS, 3 exuviae; WI, Dunn Co., Hay River, upstream of bridge, CTH N, lat 45.0688, long -91.9439, 31 May 2012, WAS, 8 exuviae; WI, Dunn Co., South Fork Hay River, at mouth of Tiffany Cr., CTH N, lat 45.0687, long -92.0102, 31 May 2012, WAS, 1 exuviae; WI, Eau Claire Co., Eau Claire River, canoe landing, Channey Rd., lat 44.7297, long 90.9898, 10 November 1989, WAS, TEV, CCS and BWS, 7 exuviae (all reared); WI, Eau Claire Co., Eau Claire River, S. bank of Eau Claire R. near Chimney Campsite, Channey Rd., lat 44.7292, long -90.9924, 26 May 2009, WAS, DEJ and NAS, 1 exuviae; WI, Eau Claire Co., Eau Claire River, at bridge, CTH K, lat 44.8908, long -91.2724, 17 July 2006, RBD, 6 F-0 nymphs; WI, Eau Claire Co., Eau Claire River, below mouth of Bridge Cr., CTH HHH, lat 44.7398, long -91.1672, 1 June 2012, WAS and DEJ, 1 exuviae; WI, Eau Claire Co., Eau Claire River, off Horse Creek Rd., 3 June 1993, KJT, 3 exuviae; WI, Eau Claire Co., Eau Claire River, immediately below confluence of So. Fk. Eau Claire R., Horse Creek Rd., lat 44.7284, long -90.9793, 1 June 2012, WAS, KJT
and DEJ, 2 exuviae; WI, Eau Claire Co., Lowes Creek, above and below bike trail bridge to mouth, Jopke Rd., 44.7791N, 91.5433W, 20 August 2009, WAS and DEJ, 5 nymphs; WI, Eau Claire Co., CTH H, 11 October 2005, KJT, 40 F-0 nymphs, >12 F-1 and smaller nymphs; WI, Eau Claire Co., West Creek, 0.08 mi ESE of HWY 85 bridge on West Cr., STH 85, lat 44.7560, long -91.6228, 20 August 2009, WAS and DEJ, 4 nymphs; WI, Jackson Co., Halls Creek, above bridge, Garage Rd., lat 44.4052, long -90.8051, 19 August 2011, WAS, 1 nymph; WI, Jackson Co., Halls Creek, canoe launch at mouth, CTH E, lat 44.3593, long -90.7844, 11 June 1997, RB, 3 exuviae; WI, Jackson Co., Perry Creek, at Perry Cr., lat 44.2667, long -90.8593, 10 June 1997, RB, 1 exuviae; WI, Jackson Co., Robinson Creek, at Robinson Rd. bridge, lat 44.2079, long -90.8662, 9 June 1995, WAS, 2 exuviae; WI, Polk Co., McKenzie Creek, CTH W, 22 May 2006, RBD, 1 nymph; WI, Polk Co., McKenzie Creek, CTH W, 26 June 2006, KJT, 3 F-0 nymphs, numerous smaller nymphs, 1 exuvia; WI, Polk Co., McKenzie Creek, just below bridge, CTH W, lat 45.6399, long -92.2985, 18 August 2011, WAS, 24 nymphs; WI, Portage Co., Plover River, downstream of foot bridge, STH 66, lat 44.5735, long -91.5433, 20 August 2009, WAS, 2 nymphs; WI, Portage Co., Plover River, mostly below bike bridge, about 91m on left and about 422m on right, STH 66, lat 44.5735, long -91.6228, 18 August 1999, WAS, 2 exuviae; WI, Portage Co., Tenmile Creek, downsteam of bridge, Evergreen Ave., lat 44.2905, long -89.6826, 21 September 2012, KJT, 1 nymph; WI, Saint Croix Co., Tenmile Creek, below bridge, 130th Ave., lat 45.0499, long -92.6095, 19 September 2007, WAS, 3 nymphs; WI, Saint Croix Co., Willow River, above and below bridge, 140th Ave., lat 45.0640, long -92.6149, 23 September 2007, WAS, 3 nymphs; WI, Trempealeau Co., Trempealeau River, along River Rd., lat 44.2079, long -91.5433, 20 August 2009, KLS, MP, AR, 1 exuvia; WI, Washburn Co., Potato Creek, above bridge, Ninth St., lat 45.8578, long -91.7427, 23 May 2012, WAS, 1 exuvia, 1 F-0 nymph; WI, Washburn Co., Potato Creek, above culvert, Ninth St., lat 45.8579, long -91.7423, 18 October 2011, WAS, 3 nymphs; WI, Waushara Co., White River, first 75m below dam, CTH YY, lat 44.0201, long -89.2471, 4 October 2007, KJT and WAS, 5 nymphs, 3 smaller; WI, Waushara Co., White River, immediately below dam downstream about 150m to next bend, CTH YY, lat 44.0200, long -89.2473, 16 June 2008, KJT, 12 exuviae.

**Diagnosis.** No single character was found to separate all *O. smithi* specimens from *O. carolus*, *O. colubrinus*, or *O. rupinsulensis*, but presented below are characters that split the greatest portion of each species in this difficult group. Determinations should be confirmed using a combination of characters presented in Table 1.

F-0 nymphs of *Ophiogomphus smithi* are generally separated from *O. colubrinus* by prementum terminal width < 2.97 mm, and from *O. carolus* and *O. rupinsulensis* by the ratio of the metatibia length to S10 W > 1.66. A very low percentage of *O. smithi* specimens (2% of sample) had a ratio of metatibia length to S10 width ≤ 1.66 but these can be separated from *O. rupinsulensis* by S9 width being ≤ 5.05 mm and from *O. carolus* by cercus L being > 1.25 mm. In addition, the ratio of femur length to abdominal segment width, as presented in the keys and Table 1, helps separate these species. *Ophiogomphus smithi* is reliably separated from *O. anomalus* and *O. susbechca* by having antm4 narrower and not continuous with antm3 (Fig. 2) and some DH usually at least moderately arched. *Ophiogomphus smithi* reliably differs from *O. howei* by head W being less than greatest abdominal W, DH usually distinct, projecting posteriorly over intersegmental membrane, lateral spines developed on S7–S9, and F-0 nymph > 21 mm in length. Fresh or well-preserved *O. smithi* specimens can often be distinguished from other sympatric *Ophiogomphus* species by the presence of paired dark triangular-shaped patches on the otherwise light-colored dorsum of S6 (Fig. 1), and by apices of DH 7–9 lighter than base color of same segments.
(Fig. 1). *Ophiogomphus smithi* also may be distinguished from *O. colubrinus* by the mid-dorsal punctae rarely being oblong on S7 or S8 (Figs. 1, 9b), and the lateral margins of cerci being relatively straight instead of recurved (Figs. 7, 10a). Well-preserved *O. smithi* nymphs and some exuviae can be reliably separated from congeners by the presence of relatively long, hair-like setae at anterior margin of the FCR in contrast to relatively short, thickened setae of the other species (Figs. 3, 11). In lateral view, the distal half of DH 7 and 8 of *O. smithi*, in relation to the longitudinal axis of the abdomen, vary from being directed slightly upward or parallel to the axis, while in the other three similar species DH 7 and 8 apices are distinctly depressed (Figs. 6, 12).

Figure 9. Mid-dorsal punctae shape (light arrow) and cuticular granule size (dark arrow) of four *Ophiogomphus* species: a) *O. carolus*, b) *O. colubrinus*, c) *O. rupinsulensis*, d) *O. smithi*.

Figure 10. *Ophiogomphus* left cercus, dorsal view: a) *O. colubrinus*; b) *O. rupinsulensis*. 
Discussion

**Characteristics Evaluated.** We made an effort to evaluate as many characters as possible, including those used in published keys to the genus as well as several that seemed at least subjectively useful, in separating *O. smithi* from the similar *O. carolus*, *O. colubrinus*, and *O. rupinsulensis*. The variable importance analysis provided in CART analysis proved to be very useful in this regard. Some of the more reliable characters revealed are presented in the Diagnosis and Key Sections and include some characters not previously used in *Ophiogomphus*. These include the ratio of metafemur and metatibia lengths to S9 W and S10 W. Also useful were the color patterns of various abdominal features like the tip of DH 7–9, markings on the dorsum of S6, plus the shape of the mid-dorsal pair of punctae on S5–S8. The dorsal to ventral inclination of the distal end of arching DHs, especially on S7-9, can often help separate *O. smithi* (Fig. 6) from the other three similar species (Fig. 12). The shape of the terminal setae of the FCR was also useful in separating *O. smithi* (Fig. 3) from congeners (Fig. 11). However, because of variation in all these characters among individuals, it should be emphasized here that no one character was found to consistently separate these four species, and final determination should be
Based on consideration of several characters, comparison with reared material, and review of Table 1.

Discussed below are characters used prominently in previous keys that we found unreliable for the material we evaluated. Both Walker (1958) and Needham et al. (2014) use the ratio of the cercus L to the L of S10 to separate *O. carolus* and *O. rupinsulensis* (cercus L = 2X S10 L) from *O. colubrinus* (cercus L = 2.5X S10 L). Our results show a great degree of overlap in this ratio (mean in parentheses): *O. carolus* = 1.4–2.4 (2.0), *O. rupinsulensis* = 1.5–2.8 (2.1), and *O. colubrinus* = 1.8–3.8 (2.8). The ratio of L to W of antm 3 was used to separate *O. carolus* (L 2X W) from *O. rupinsulensis* (L 3X W) by Walker (1958) and Needham et al. (2014). The 148 specimens scored for this character showed a wide range of overlap: *O. carolus* = 2.2–3.2 (2.5) and *O. rupinsulensis* = 2.1–3.6 (2.6). The ratio of cercus L to epiproct L is another character used by Walker (1958) to separate *O. carolus* from *O. rupinsulensis*. The cercus L of *O. carolus* was given as two-thirds the length of the epiproct, while for *O. rupinsulensis* it was three-fourths. Based on 344 specimens from Wisconsin, the range (mean in parentheses) for *O. carolus* was 0.5–0.8 (0.6) and for *O. rupinsulensis* 0.5–0.9 (0.7), rendering this character useless. We found that by expanding the definition of cuticular granule size used by Walker (1958) and utilizing photographic images (Fig. 9), this feature can be useful not only in separating *O. carolus* and *O. rupinsulensis*, but *O. colubrinus* and *O. smithi* as well. Briefly, *O. carolus* has relatively large, dark, even-sized granules, *O. rupinsulensis* has both coarse and fine dark granules, *O. colubrinus* has mostly fine granules with some large granules present, and in *O. smithi* almost all the granules are fine and dark.

Figure 12. *Ophiogomphus* DH profiles, S5–S9: a) *O. carolus*; b) *O. colubrinus*; c) *O. rupinsulensis*. 
Walker (1958) compared the W of the cercus at mid-length to the L of its inner margin to separate *O. carolus* and *O. rupinsulensis* from *O. colubrinus*. We found this character difficult to use and instead looked at the shape of each lateral margin and overall shape. The majority *O. carolus* cerci are relatively acute in shape with inner margin straight and outer margin evenly curved inward. *Ophiogomphus rupinsulensis* cerci tended to be less acute with margins relatively straight; *O. colubrinus* cerci were even more acuminate in shape with both margins concavely curved. Of the four similar species of *Ophiogomphus* discussed here, *O. smithi* had the greatest similarity to *O. colubrinus* in general appearance and proportions.

**Distribution.** *Ophiogomphus smithi* is sympatric with *O. anomalus*, *O. carolus*, *O. colubrinus*, *O. howei*, *O. rupinsulensis*, and *O. susbehcha*. However, it is regularly syntopic only with *O. rupinsulensis* and rarely with *O. carolus* and *O. colubrinus*. *Ophiogomphus smithi* is currently known only from northeast Iowa, southeast Minnesota, and central to northwestern Wisconsin. We know of no Iowa records for *O. anomalus*, *O. carolus*, *O. howei*, or *O. susbehcha*, although *O. severus* and *O. westfalli* Cook & Daigle occur in western Iowa (Abbott 2006–2014). *Ophiogomphus anomalus* and *O. susbehcha* are restricted to northern Wisconsin and Minnesota in the area delimited in our study. *Ophiogomphus smithi* scarcely overlaps the range of *O. colubrinus* in northern and central Wisconsin and scarcely overlaps *O. carolus* in northwest Wisconsin. Its distribution by ecoregions (Omernick and Gallant 1988) is centered on the Driftless Area of Wisconsin, Iowa, and Minnesota with most of the sites located in the adjacent North Central Hardwood Forest, Western Corn Belt Plains in Iowa, and the Northern Lakes and Forest ecoregions of Wisconsin (Fig. 13).

**Habitat.** While more detailed analysis of *Ophiogomphus* habitat is planned for a future paper, preliminary analysis based on statewide modeling of 249 potential stream habitat variables in Wisconsin show *O. smithi* presence positively correlated with stream segments of 4th and 5th order with some 2nd, 3rd, and 6th order segments used as well. Presence was also positively correlated with at least some conifer forest in the watershed, stream segments with gradient greater than 0.0027%, and riparian zone with low amounts of fine materials and high permeability. Also, correlated in the riparian zone were low levels of carbonate bedrock and high levels of sandstone bedrock. Similar modeling in Iowa using stream variable data provided by Loan-Wilsey et al. (2005) showed correlation of *O. smithi* presence with 2nd to 4th order streams with moderate gradient, limited to the Eastern Broadleaf Forest Subregion, and loamy soil texture. Generally throughout its range *O. smithi* is restricted to small to medium-sized, cool to warm, sandy stream segments with patches of pea-sized gravel.

**Keys to *Ophiogomphus* nymphs of the Western Great Lakes**

The following keys address the seven *Ophiogomphus* species known from the western Great Lakes region including *O. smithi* described herein. The primary key below is based on mostly quantitative characters in a context suggested by CART analysis for the four similar species and generally follows Needham et al. (2014) for the remaining three species. As an aid in assessing couplets for the four similar species, we provide the percent of the sample the ultimate couplets represented based on the CART analyses. This key is primarily for F-0 nymphs or exuviae and use requires access to a microscope equipped with an eyepiece micrometer capable of measurement to the nearest 0.1 mm.

A second more qualitative ‘field’ key is also given that focuses on characters which allow identification with a hand lens. It also should allow identification of some younger nymphs. Note that exuviae, in comparison to nymphs, have length measurements often inflated slightly due to telescoping of segments, while widths-to-length ratios are slightly decreased. F-0 nymphs of the four similar species generally can be distinguished from younger nymphs by having
Figure 13. Distribution of four *Ophiogomphus* spp. of the western Great Lakes Region. ● = *O. smithi*; gray dashed line = combined southern boundary of *O. carolus* and *O. colubrinus* within the study area; diagonal lines = range of *O. rupinsulensis* within the study area.
a head width greater than 4.65 mm and front wing pads > 4.0 mm long which usually terminate no less than 1.0 mm from the lateral margin of the abdomen.

### Definitions of Characters Used in Keys

<table>
<thead>
<tr>
<th>Character</th>
<th>Description</th>
<th>Reference</th>
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<tbody>
<tr>
<td><strong>S7,8,9</strong></td>
<td>Degree of arching of dorsal hooks in lateral view: ranging from flat, to slightly, moderately, and strongly arched; i.e. Fig. 12b more strongly arched than 12a.</td>
<td>Figs. 6, 12.</td>
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<tr>
<td><strong>S7,8,9 W</strong></td>
<td>Maximum ventral width of abdominal segment specified (lateral spines not included)</td>
<td></td>
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<tr>
<td><strong>Antm3 Width</strong></td>
<td>Widest either near the middle (Fig 14d) or in the distal half (Fig. 14c)</td>
<td>Figs. 2, 14.</td>
</tr>
<tr>
<td><strong>Cercus L</strong></td>
<td>Length along median, dorsal view. Position nymph at slight angle to make sure cercus is viewed perpendicularly.</td>
<td></td>
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<tr>
<td><strong>Cercus W</strong></td>
<td>Basal width, dorsal view. Position nymph at slight angle to make sure cercus is viewed perpendicularly.</td>
<td></td>
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<tr>
<td><strong>Cuticular Granule Size</strong></td>
<td>Relative size on dorsum of S5-9. Refer to photographic figures to judge relative size. Figs. 9a and 9c show mostly coarse and 9b and 9d show mostly fine granules.</td>
<td>Figs. 9a-9d.</td>
</tr>
<tr>
<td><strong>Metatibia and metafemur L</strong></td>
<td>Base to apex length as shown.</td>
<td>Fig. 15.</td>
</tr>
<tr>
<td><strong>Mid-dorsal Punctae Shape on S3–S8</strong></td>
<td>Ranging from lenticular (Fig. 9b), and oblong to oval and orbicular (Figs. 9a, 9c, 9d). A second lateral pair of punctae are also evident on these segments, but are not used here.</td>
<td>Fig. 9.</td>
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<tr>
<td><strong>Prementum Max W</strong></td>
<td>Usually same as the prementum terminal width, but in some <em>O. smithi</em> specimens the prementum tapers slightly near terminal end.</td>
<td></td>
</tr>
<tr>
<td><strong>Prementum Terminal W</strong></td>
<td>Distal end width at base of movable hooks.</td>
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<tr>
<td><strong>Ratio of S8 W to S10W</strong></td>
<td>Maximum abdominal segment widths measured ventrally</td>
<td></td>
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<tr>
<td><strong>Ratio of Cercus L to W</strong></td>
<td>Ratio of length to basal width as measured viewing cercus perpendicularly.</td>
<td></td>
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<tr>
<td><strong>Ratio of Metatibia L to S10W</strong></td>
<td>Ratio of metatibia length to S10 ventral width</td>
<td>Fig. 15.</td>
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<tr>
<td><strong>Convergence of Vulvar Lobes</strong></td>
<td>Longitudinal midlines being convergent, parallel, or divergent relative to each other.</td>
<td>Fig. 8.</td>
</tr>
</tbody>
</table>
Primary Key to *Ophiogomphus* species of the Western Great Lakes Region

1. Head W greater than maximum abdomen W; lateral spines absent or greatly reduced on S7; antm4 small, width < 0.3 times maximum width of antm3 (Fig. 16a); F-0 nymph < 22 mm long; DH absent or vestigial (if vestigial hooks, not projecting posteriorly over intersegmental membranes) .................................................. *howei*

1’. Head W less than maximum abdomen W; lateral spines developed on S7; antm4 usually larger, width at least 0.3 times width of antm3 (Figs. 16b and 16c); F-0 nymph > 21 mm in length; DH usually distinct, projecting posteriorly over intersegmental membrane, sometimes vestigial ......2

---

Figure 14. Antm 3 and 4 of four *Ophiogomphus* species: a) *O. carolus*, b) *O. colubrinus*, c) *O. rupinsulensis*, d) *O. smithi*.

Figure 15. Measurement method of metafemur and metatibia.
2. Antm4 nearly as wide as adjacent portion of antm3, forming a more or less complete cap, lateral margin appearing continuous (Fig. 16b, 16d); DH vestigial or low, usually not prominently arched (can be slightly arched in O. anomalus) ..............................................................3

2'. Antm4 distinctly narrower than antm3 and not completely capping segment, terminal end of antm3 forming at least one distinct shoulder at base of antm4 (Fig. 16c); DH usually raised and slightly to greatly arched (usually appressed in O. carolus) (Figs. 6, 12) .............................................................................. 4 (also couplet 1 of Field Key below)

3. Apex of antm4 smoothly convex (Fig. 16b); F-0 nymph < 26 mm in length; cercus L ≥ 0.64 L of paraprocts .................................. anomalus

3'. Apex of antm4 with center raised into a papilla-shaped tip (Fig. 16d); F-0 nymphs ≥ 27 mm long; cercus L < 0.64 L of paraproct ........................................... susbehcha

4. Prementum maximum W > 3.03 mm; mid-dorsal punctae on S6 usually lenticular to oblong in shape (Fig. 9b); medial and lateral margins of cercus concave, lateral margin usually markedly concave from base, inner margin with distinct basal shoulder (Fig. 10a)........... 95% of all colubrinus

4'. Prementum maximum W ≤ 3.03 mm; mid-dorsal punctae on S6 generally oval to orbicular in shape (Fig. 9a, 9c, 9d); medial and lateral margins of cercus straight, or only lateral margin slightly concave (Fig. 10b)......5

5. Ratio of metatibia L to S10 W ≤ 1.66 ................................................................. 6

5'. Ratio of metatibia L to S10 W > 1.66 ................................................................. 8

6. S9 W > 5.07 mm; vulvar lobes generally convergent distally, minimum gap < lamina W at half-length (Fig. 8a) ....... 95% of all rupinsulensis

6'. S9 W ≤ 5.07 mm; vulvar lobes generally parallel or divergent distally, minimum gap ≥ lamina W at half-length (Fig. 8b, 8c) .............................. 7

7. Cercus L < 1.23 mm; antm3 widest near middle of segment (Fig. 14a); S7 DH in lateral view appressed to very slightly arched (Fig. 12a); cuticular granules large and black (Fig. 9a) .......... 96% of all carolus

7'. Cercus L > 1.23 mm; antm3 widest in distal half or near middle of segment (Fig 14b, 14c, 14d); S7 DH in lateral view moderately to heavily arched (Fig. 6, 12b, 12c); with cuticular granules variable (Fig. 9b, 9d) ................................................................. 9

8. Prementum terminal W ≤ 2.97 mm; one or more DH on S7–S8 in lateral view with tip pointing up or parallel to the long axis of the body (Fig. 6) ......................................................... 94% of all smithi

Figure 16. Ophiogomphus antm 4 (and apex of antm 3): a) O. howei; b) O. anomalus; c) O. rupinsulensis; d) O. susbehcha.
8'. Prementum terminal W > 2.97 mm; DH on S7–S8 in lateral view with tip pointed variably (Figs. 6, 12a, 12b, 12c.) .................................................10
9. Apex of DH on S7–S9 not notably lighter than rest of DH base color. .................................................................3% of all *rupinsulensis*

9'. Apex of DH on S7–S9 notably lighter than rest of DH base color (Fig. 1) .................................................................4% of all *smithi*

10. Mid-dorsal punctae on S6 usually lenticular to oblong (Fig. 9b); DH on S7–S9 in lateral view with distal portion generally all declined relative to the long axis of the body (Fig. 12a) .....................3% of all *colubrinus*

10'. Mid-dorsal punctae on S6 usually orbicular to oval (Figs. 9a, 9c, 9d); one or more DH on S7–S9 in lateral view with distal portion generally parallel or inclined relative to the long axis of the body (Fig. 6) ...............................................................................<1% of all *smithi*

Semi-Qualitative (Field) Key to *Ophiogomphus* species of the Western Great Lakes Region

To separate *O. anomalus*, *O. howei*, and *O. susbehcha*, use couplets 1–3 of Primary Key above; if you are directed in that key to couplet 4, then move to couplet 1 below.

1. Coarse cuticular granules large, moderate to fine granules may be present (Figs. 9a, 9c); cercus usually more acute than acuminate (Fig. 10b); S7–S9 DH in lateral view flat (Fig. 12d) or moderately to strongly arched (Fig. 12c) mid-dorsal punctae on S6 usually orbicular to oval (Figs. 9a, 9c, 9d.) .................................................................2

1'. Cuticular granules mostly fine to fine-moderate in size, coarse granules rare (Figs. 9b, 9d.); cercus more acuminate than acute (Fig. 10a); S7–S9 DH in lateral view moderately to strongly arched (except for *O. carolus*) (Fig. 12); mid-dorsal punctae on S6 variable in shape ........................................4

2. DH on S7–S9 in lateral view appressed or very slightly raised (Fig. 12b) .................................................................3

2'. DH on S7–S9 in lateral view definitely raised and with some degree of arching (Figs. 12a, 12c) .................................................................*rupinsulensis*

3. Antm3 widest in distal half, usually near apex (Fig. 14c); inner and outer margin of cercus relatively straight with no distinct shoulder at base (Fig. 10b) .................................................................*rupinsulensis*

3'. Antm3 widest near middle (Figs. 14a, 14d); inner margin of cercus with tiny to distinct shoulder at base, outer margin concave ..........*carolus*

4. Mid-dorsal punctae on S6 lenticular to oblong in shape (Fig. 9b); cercus generally acuminate (Fig. 10a); DH on S7–S9 generally strongly and at least moderately arched (Fig. 12a) ..................................................*colubrinus*

4'. Mid-dorsal punctae on S6 orbicular to oval in shape (Figs. 9a, 9b, 9d); cercus acute or acuminate; DH on S7–S9 slightly to moderately arched (Figs. 6, 12b) ............................................................................5

5. DH on S8 with apex distinctly lighter than base color of same segment, apices of DH on S7 and S9 often lighter as well (Fig. 1); cercus generally acuminate with both medial and lateral margins straight or not generally curved (Fig. 7); dorsum of abdomen often darker on S6 than rest of segments, usually taking the shape of a saddle or paired triangles joined at the base (Fig. 1) ............................................................................8

5'. DH on S8 with apex as dark or darker than base color of segment; cercus acute or acuminate, generally with at least one of the lateral margins
curved (Fig. 10a); dorsum of abdomen dark/light color pattern absent or variable, but not as above .............................................................. 6

6. DH on S7–S9 in lateral view moderately appressed or barely arched (Fig. 12b); cercus generally acute (Fig. 10b); cuticular granules large. .............................................. carolus

6′. DH on S7–S9 in lateral view mostly raised and moderately to strongly arched (Figs. 6, 12a); cercus generally acuminate (Fig. 10a); cuticular granules fine to moderate sized .............................................. smithi

7. One or more DH on S7–S9 in lateral view with distal portion generally parallel or inclined posteriorly relative to the long axis of the body (Fig. 6); mid-dorsal punctae on S6 orbicular to oval; FCR setae mostly hair-like (Figs. 3, 11a). ........................................................................ smithi

7′. DH on S7–S9 in lateral view with distal portion generally all declined posteriorly relative to the long axis of the body (Fig. 12a); mid-dorsal punctae on S6 lenticular; FCR setae mostly short and stout or flattened, not hair-like (Figs. 11b, 11c, 11d) ............................................ colubrinus

Acknowledgments

We gratefully acknowledge the University of Wisconsin-Madison Insect Research Collection and Dr. Daniel Young, Director, for allowing us free use of the Auto-Montage imaging system in the Department of Entomology. The late Dr. William H. Hilsenhoff provided access to unidentified WI *Ophiogomphus* nymphs in the U.W. Insect Research Collection and was the first to collect nymphs of this species in 1969. A. Bartos, R. Bautz, M. Berg, T. J. Doolittle, C. Dovchin, R. DuBois, M. Griesbach, D. Johnson, R. Lillie, S. Melrose, G. Miller, G. Schuurman, C. C. Smith, B. W. Smith, M. Smith, M. Swift and J. Van Tatenhove all provided field support in searching for *Ophiogomphus* specimens. D. Cuthrell, J. Dimick, W. Hilsenhoff, C. T. Hubbard, K. Mead, S. Hummel, and K. L. Schmude generously provided specimens and or data for regional *Ophiogomphus* species. The Wisconsin Dept. of Natural Resources-Bureau of Natural Heritage Conservation generously provided support of staff time, laboratory space and page costs for this project. The Bureau’s Julie Bleser provided help finalizing the layout of various Figures and Tables. Karen Jankowski generously provided statistical advice on numerous occasions. We especially thank Bob DuBois for providing consult and moral support in addressing the troublesome members of this genus (which he dubbed “Awfulgomphus”) and for critical review of this paper.

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**Carle, F. L. 1992.** *Ophiogomphus* (*Ophionurus*) *australis* spec. nov. from the Gulf Coast of Louisiana, with larval and adult keys to American *Ophiogomphus* (Anisoptera: Gomphidae). Odontologica 21: 141–152.


Appendix 1. Ophiogomphus characters evaluated that did not yield differentiating character states

Appendix 2. *O. carolus*, *O. colubrinus*, and *O. rupinsulensis* specimens measured (Number of Specimens - N=nymphs, E= exuviae)

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>O. carolus</em></td>
<td>WI: ASHLAND CO., Brunsweiler River, 24N; White River, 2E; BAYFIELD CO., Marengo River, 23N; FLORENCE, CO., Popple River, 3E; IRON CO., Potato River, 43N; IRON CO., Potato River, 38N; LINCOLN CO., Pine River, 4N; MARATHON CO., Wisconsin River, 1E.</td>
</tr>
<tr>
<td><em>O. colubrinus</em></td>
<td>WI: ASHLAND CO., Brunsweiler River, 3N; ASHLAND CO., Marengo River, 1N; BAYFIELD CO., Eighteenmile Creek, 7N, Marengo River, 49N, DOUGLAS CO., Eau Claire River, 22N, Porcupine Creek, 1N; FOREST CO., Peshtigo River, 1N; O. colubrinus, MARINETTE CO., South Branch Pike River, 4N, Wausau River, 1E; MENOMINEE CO., South Branch Oconto River, 14N; ONEIDA CO., Wisconsin River, 1E; POLK CO., Saint Croix River, 1E; PORTAGE CO., Plover River, 1N; VILAS CO., Plum Creek, 48N; WASHBURN CO., Potato Creek, 2N; WOOD CO., Tenmile Creek, 6N.</td>
</tr>
<tr>
<td><em>O. rupinsulensis</em></td>
<td>WI: BARRON CO. Red Cedar River, 30E; CLARK CO., Black River, 1N; DOUGLAS CO., Eau Claire River, 4N; DUNN CO., Hay River, 31E, 18N; IRON CO., Potato River, 1E; LINCOLN CO., Pine River, 2N; MARATHON CO., Plover River, 2E, Plover River, 49N; MARINETTE CO., South Branch Pike River, 1N; PORTAGE CO., Plover River, 27N; RUSK CO., Flambeau River, 3N; TAYLOR CO., Black River, 1N; VILAS CO., Plum Creek, 8N; WASHBURN CO., Potato Creek, 2N; WAUSHARA CO., White River, 1N.</td>
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First Record of *Eurypogon niger* (Melsheimer) (Coleoptera: Artematopodidae) in Illinois

Jordan D. Marché II

Abstract

The elateroid species, *Eurypogon niger* (Melsheimer) (Coleoptera: Artematopodidae), is recorded for the first time from Illinois. This brings to 10 the number of U.S. states (plus the District of Columbia) from which the species has been reported. Its occurrence has also been noted in Canada.

A single specimen of the elateroid beetle, *Eurypogon niger* (Melsheimer) was taken during the mid-to-late afternoon from a leaf of northern red oak (*Quercus rubra*) on 25 May 2013 at Cave-in-Rock State Park, Hardin County, Illinois. This finding represents a new state record for the species. Approximate coordinates (of the park’s entrance) are as follows: 37° 28.1´, −88° 9.5´. The park is located in extreme southern Illinois, just north of the Ohio River, and contains a mixture of hardwood forests, grass-covered recreational areas, abundant limestone cliffs, and adjoining aquatic habitats.

Three species of the genus *Eurypogon* are currently recognized from North America, including *E. californicus* Horn, *E. harrisii* (Westwood) and *E. niger* (Hinson and Buss 2015). While occurrence of the first species is restricted to California, the latter two species are widely distributed in the eastern U.S. Previously, *E. niger* had been reported from the District of Columbia, Indiana, Kansas, Massachusetts, New York, North Carolina, Ohio, Pennsylvania, South Carolina, and Virginia, along with the Province of Québec in Canada.

Little is known about the life history of the species, or of the family as a whole, which is generally regarded as a basal group of the Elateroidea (Young 2002). Larvae of several species and genera within the family have been found in association with moss mats, growing on granitic boulders (Lawrence 2010). While no granitic bedrock occurs near Cave-in-Rock State Park, the abundant limestone cliffs and exposures found alongside the Ohio River seemingly provide a comparable habitat upon which such mosses can grow and thus sustain the species. Blatchley (1910) reported *E. niger* as having been beaten from leaves of hickories and oaks, the latter of which is in accord with my experience.

My initial identification of the Illinois specimen, along with an earlier specimen collected on 13 June 1994 near the author’s former residence of Bloomington, Monroe County, Indiana, was not that of *E. niger*, but rather that of *E. harrisii*. This was because character attributes in the taxonomic key provided by Downie and Arnett (1996: 711–712) for distinguishing between *E. niger* and *E. harrisii* are thought to have been reversed (Hinson and Buss 2015). Based on the clarification of the principal distinguishing traits, especially the presence of larger elytral punctures on *E. niger* in relation to the intervals between them, and side-by-side photographs of the two species, including the newly-designated lectotype of *E. niger* (Hinson and Buss 2015), it was readily apparent that both

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my Illinois and Indiana specimens are *E. niger*. Photographs of my two specimens have confirmed their identities (K. R. Hinson, personal communication, 30 Dec. 2015). As it turns out, a correct identification and description of *E. niger* was given by Blatchley (1910: 689), who made no mention of the occurrence, or even probable occurrence, of *E. harrisii* within that state, as has since been established (Young 2002).

The voucher specimen of *E. niger*, from Cave-in-Rock State Park, has since been deposited in the collection of the Illinois Natural History Survey (INHS).

**Acknowledgments**

I am grateful to Kevin R. Hinson for confirming the identity of both specimens of *E. niger*. Thanks are also due to Joseph L. Spencer, Steven J. Taylor, and Sam W. Heads, of the Illinois Natural History Survey, for their encouragement to prepare this scientific note, and to the two reviewers.

**Literature Cited**


First Report of *Retocomus wildii* (LeConte, 1855) (Coleoptera: Anthicidae) From Nebraska

Edwin L. Freese

The beetle species *Retocomus wildii* is reported from Nebraska for the first time with three specimens collected at Indian Cave State Park, which is located adjacent the Missouri River, in the southeast corner of Nebraska. The first specimen was collected 9 June 1992 in Nemaha County by C. A. Springer and deposited in the University of Nebraska State Museum, Lincoln. The second specimen was collected 30 June 2011 in Richardson County, no collector given. Both specimens were identified by Matt J. Paulsen during 2011 (Paulsen, pers. comm.). The third specimen was first located as a photo posted at http://bugguide.net/node/view/969717. This third specimen was collected 24 June 2014 in Richardson County by Junsuk Kim using mv-light (40°14.789´N, 95°31.056´W, 285m, Nebraska 64F Recreation Road) and is also deposited in the University of Nebraska State Museum (Kim, pers. comm.).

John L. LeConte (1855: 270) originally described this beetle species as *Eurygenius wildii* which at that time was included in the Pyrochroides. The type specimen is from Kentucky and housed at Harvard (#4868); the species is named after the collector Mr. J. P. Wild of Baltimore (LeConte 1855: 270). LeConte (1862: 264) later included *Eurygenius wildii* in the Anthicidae under the Tribe Pedilini and Group Eurygenii. Later, Thomas L. Casey, Jr. (1895: 628) moved this species to his new genus *Retocomus* in the Tribe Eurygeniini, where it stands today (Chandler 2002; Chandler, pers. comm.). The most recent revision of the genus *Retocomus* was published by Mohammad Abdullah (1965).

Willis S. Blatchley (1910: 1328) considered this species scarce in Indiana. Abdullah (1965) examined 102 specimens from 16 collections representing 12 states (Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Missouri, Ohio, Oklahoma, Tennessee, and Texas). No specimens were located from Wisconsin, Minnesota, and Mississippi during a recent search of collections (Kraith, Tinerella, Lago, Skelley, Riley, pers. comm.). Also, no specimens were located in the Iowa State University insect collection (ISIC), Ames (Gregory Courtney, curator), and the Iowa Wesleyan University insect collection (IWUC), Mt. Pleasant (Donald Wick, curator). In the literature, specimens have been reported collected from mid-March through mid-July and collected from oak and elm (Abdullah 1965). During the last decade, only six Iowa specimens have been collected, all at Waubonsie State Park, Fremont Co., Iowa, from late-May to late-June; four specimens were collected at uv-light and two specimens were hand-picked from black oak branches (*Quercus velutina*) (Veal, pers. comm.).

**Acknowledgments**

The author would like to thank Matt J. Paulsen and Junsuk Kim for help with the Nebraska specimens and data. Also thank you to Doug Veal for access to Iowa specimen label data from his personal collection. Thank you also to Steven J. Krauth (University of Wisconsin, Madison), Paul Tinerella (University of Minnesota, St. Paul), Paul K. Lago (University of Mississippi, University), Paul Skelley (Florida State University, Gainesville), and Edward G. Riley (Texas A & M University, College Station) for searching their respective insect collections for specimens from Wisconsin, Minnesota, and Mississippi.

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The following also contributed to this paper: Donald S. Chandler, Daniel K. Young, Kevin L. Thorne, Mark Hoffman, Gregory W. Courtney, Donald Wick, Becky Heth, Jeanette Andrews, the creators and contributors of Biodiversity Heritage Library, and the late Richard L. Hoffman. Also thank you to reviewers who provided constructive comments making this a better paper.

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Cover photo
Serropalus substratiatus (Coleoptera: Melandryidae).
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