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COVER PHOTO

*Scudderia furcata* Brunner von Wattenwyl (Tettigoniidae), the forktailed bush katydid.
Photo taken in Huron Mountains, MI by M. F. O'Brien.
THE MICHIGAN ENTOMOLOGICAL SOCIETY

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NEW DISTRIBUTION RECORD FOR THE ENDANGERED CRAWLING WATER BEETLE BRYCHIUS HUNGERFORDI (COLEOPTERA: HALIPLIDAE) AND NOTES ON SEASONAL ABUNDANCE AND FOOD PREFERENCES

Michael Grant¹, Robert Vande Kopple¹, and Bert Ebbers²

ABSTRACT

The Federally endangered beetle, Brychius hungerfordi, has been discovered at a new location in the Northern Lower Peninsula of Michigan. We also report preliminary data on a seasonal variation in relative abundance and on its possible food plants.

The crawling water beetle, Brychius hungerfordi Spangler, is known from only three sites in Michigan and from one in Ontario (Spangler 1954, Wils­mann and Strand 1990, Roughly 1991, Strand and Spangler 1994, Keller et al. 1998). We report the discovery of a fourth location in the Northern Lower Peninsula of Michigan. We can only speculate about the beetle's natural history since it is so rare, but details concerning its abundance and food preferences are beginning to emerge.

MATERIALS AND METHODS

Beetle collecting occurred in Van Hetton Creek, Montmorency County, Michigan (Twp. 31N, Rge. 2E, Sec. 5, SW ¼. Beetles were collected with a long handled D-net (30-cm diameter) using a sweeping motion across the current with the lip of the net held slightly above the bottom of the creek. After the initial pass the net was quickly moved back over the same area in a downstream direction, to catch beetles dislodged from the bottom during the first pass.

Collecting also occurred at a large pool, located on the East Branch of the Maple River, Emmet County, known to support a B. hungerfordi population. In order to assess the temporal variation in beetle abundance, we sampled the pool monthly from March through December, 1999, at the middle of the month. We divided the pool into three sections, head, midsection, and tail, and sampled each section equally for a total of one hour sampling. Immediately after counting the beetles were released back into the pool from which they had been collected. Sample removal error was considered insignificant given the length of time between sampling dates.

Algal samples were collected in the field and preserved in 4% formalin for later identification in the lab.

¹University of Michigan Biological Station, Pellston, MI 49769.
²Great Lakes Ecosystems, P. O. Box 156, Indian River, MI 49749.
RESULTS AND DISCUSSION

In July 1999, six adult beetles were captured. The creek drains wetlands, but also receives some groundwater based upon water temperature measurements made at the time of collection. The beetles were found dispersed along a stretch of creek several hundred meters in length and downstream from a pool, formed as the creek flowed from a culvert beneath a county road. This site differs from previously described locations in that the creek channel is composed of sand overlain with a thin layer of detritus (Roughley 1991, Wilsmann and Strand 1990, Strand 1989).

In addition to searching for new beetle locations, we have begun study of its basic biology and natural history. Initial observations suggest a seasonal component to its relative abundance and that its preferred food source may be filamentous green or blue-green algae.

The relative abundance of beetles in the pool, expressed as the number of adults captured per hour of sampling, is summarized in Figure 1. The relative abundance in November is probably underestimated due to partial ice cover, which prevented a complete search of the pool. The ice was gone by December, allowing a normal search pattern to resume. The data suggest that some *B. hungerfordi* adults may survive through the winter, which was confirmed on 10 February 2000 when five adults were captured from the pool beneath a 24 cm cover of ice. This is consistent with study of other halphilids. Hickman (1931) in laboratory studies reported that some adult halphilids survived as long as 18 months in captivity. He also reported finding some lentic species beneath ice cover. Our preliminary data also suggest that several generations may be present during a single season. The increase in relative abundance in May followed by a second increase in October suggest that a second brood of adults may emerge late in the season. If these observations are confirmed in additional studies, then an optimal period may exist in which to conduct survey work. Searching during less than optimal times would make the beetle that much more difficult to detect.

![Figure 1. Seasonal distribution of *B. hungerfordi* from E. Branch Maple River, Emmet County, Michigan.](image)
During sampling we observed that beetles were frequently found associated with dense growths of epilithic algae. Samples of cobble and rocks from areas in the pool containing beetles and from areas where they were absent were collected and brought to the lab for microscopic examination. Sites with beetles contained approximately 30% detritus with the remainder living biomass. There was no clearly dominant genus of algae, but a diverse assemblage of Cocconeis, Oedogonium, Cymbella, Gomphonema, Navicula, Calothrix, Lyngbya, Chroococcus, Oscillatoria, Nitzschia, Frustulia, Microspora and Amphora. Samples from sites without beetles consisted of approximately 60–70% detritus with the remainder being living biomass. The living algae were 50% Audovinella violacea (a red alga), 30% Epithemia (a N-fixing diatom) and 20% genera similar to the beetle group.

Calothrix, Lyngbya, Microspora, Oscillatoria and Oedogonium are filamentous blue-green or green algae. In Hickman's feeding experiments, he reported that some larva and adults of Michigan Haliplidae did well only on Spirogyra, also a filamentous green alga (Hickman 1931). It is not uncommon among herbivorous insects to exhibit a limited range of foods (Matthews and Matthews 1978). Until we know the specific food plants of Brychius we can only surmise that they might be as restricted as for other haliplids and thereby place constraints on beetle distribution.

Successful protection of Brychius hungerfordi depends upon expanding our knowledge of its natural history. It is our hope that this report adds to the understanding of the beetle's distribution and begins to address more fundamental questions regarding its seasonal abundance and food preferences.

ACKNOWLEDGMENTS

The authors thank Dr. Rex Lowe and Aga Pinowska of the Department of Biological Science, Bowling Green State University, Ohio for their assistance in identifying the algal samples, and for the comments from two anonymous reviewers. The U.S. Fish and Wildlife Service (PRT 839782) and Wildlife Division of the Michigan Department of Natural Resources (PN1304) provided sampling permits.

LITERATURE CITED


ARHYSSUS HIRTUS (HEMIPTERA: HETEROPTERA: RHOPALIDAE)
IN MINNESOTA: THE INLAND OCCURRENCE OF AN
EAST COAST SPECIES

John D. Lattin¹ and John Haarstad²

ABSTRACT

Arhyssus hirtus (Hemiptera: Heteroptera: Rhopalidae), is reported from the Cedar Creek Natural History Area, a Long-Term Ecological Research site, outside of Minneapolis, Minnesota where over 4000 species of arthropods have been collected. This species has previously been known only from a narrow zone along the sandy edges of the Atlantic Ocean (Maryland, Massachusetts, New Jersey and New York). The species is known on Hudsonia tomentosa at these ocean sites, but other hosts may be involved at Cedar Creek. This small species of Arhyssus occurs in both micropterous and macropterous forms, unusual for this genus. Thus far, only micropterous forms have been collected at the Minnesota site.

Corizus hirtus (Hemiptera: Heteroptera: Rhopalidae) was described by Torre-Bueno (1912) from Yaphank, Long Island, New York, based upon long- and short-winged adults. The specimens were taken at a sandy, grassy site in pine woods in 1911. Wheeler and Henry (1984) reported it from habitats from Massachusetts, Maryland, New Jersey, and New York (as Arhyssus hirtus). Henry (1988) summarized the taxonomic history of the species in North America.

Both sexes of this small species (ca 4.5 mm) occur in macropterous and micropterous forms (Torre-Bueno 1912). Chopra (1968) revised the genus Arhyssus. Later, Wheeler and Henry (1984) added information on the New Jersey specimens that had been collected “under Hudsonia” by H. G. Barber and “in and under Hudsonia” on Long Island by Nathan Banks. These specimens are in the U. S. National Museum in Washington, D. C. Wheeler and Henry also reported on the collection nymphs and adults of A. hirtus in and under the mats of Hudsonia tomentosa Nutt.

The specimens reported here are from the Cedar Creek Natural History Area, Long-Term Ecological Research (LTER) site, near Minneapolis, Minnesota, as part of a 25-year study of insects and other arthropods on this 2200 ha site. Over 4000 species of arthropods have been collected, chiefly by J. Haarstad, with additional species added annually. The Cedar Creek site has become one of a handful of well-known sites in North America that include the H. J. Andrews Experimental Forest, in western Oregon (about 3700 species known) and Central Plains Experimental Range, in Colorado (1649 species known), both LTER sites as well (Parsons et al. 1991, Kumar et al.

¹Department of Entomology, Oregon State University, Corvallis, OR 97331-2907.
²Cedar Creek Natural History Area, East Bethel, MN 55005.
1976). Some very interesting species, including *Arhyssus hirtus*, have been collected at this Minnesota site. This bug was known formerly from a narrow range along the mid-Atlantic coast (Wheeler and Henry 1984).

**COLLECTION RECORDS**


**RESULTS**

All eight specimens of *A. hirtus* from the Minnesota site were micropterous with collection dates ranging from 24 June to 24 September, 1985–1991. These specimens were swept from four different grassland sites, all of which contained *Lechea stricta*, and most contained *Helianthermum bicknellii*. Although *Hudsonia tomentosa* occurs at the Minnesota location, it was not found at the specific sites where the bugs were taken. It is of interest that the xeric sandy old fields at Cedar Creek contained several other plants showing disjuncts distributions including *Aristida tuberculosa* and *Polygonella articulata*. Other disjunction of insects may occur as well.

**DISCUSSION**

Voss (1985) discussed the distribution of *Hudsonia tomentosa* Nutt. in Michigan (family Cistaceae) and included a map (No. 824) of its distribution. The plant, known as beach-heather or false-heather, is found on sand dune ridges in open forests of pine, oak or other trees along the coast of much of Michigan. Ownbey and Morley (1991) listed *H. tomentosa* from Minnesota and included a map of its distribution. At least five other species of Cistaceae occur in Minnesota, two in the genus *Helianthemum* and three in *Lechea*, with species of both genera found at Cedar Creek and some found associated with the bug. Further study is needed to clarify the exact hosts at the Minnesota site. Skog and Nickerson (1973) provided additional information on *Hudsonia* in their study of this genus. Grigal (1985) and Woucha et al. (1995) provided detailed discussions of the unusual St. Croix River Valley and the Anoka Sand Plain in Minnesota—a landscape sure to surprise us again. Specimens of the Rhopalidae species, *Arhyssus hirtus* (Torre-Bueno), were found at the Cedar Creek Natural Area near East Bethel, Minnesota (a Long-Term Ecological Research site). All specimens were micropterous, although long-winged adults are known from sites from Maryland, Massachusetts, New Jersey, and New York, along the Atlantic coast. The host plant of this bug along the Atlantic coast is *Hudsonia tomentosa* and although this plant is found at Cedar Creek, the bug has not yet been found on it. There,
collection sites of the bug contained *Leachea stricta* and/or *Heliantherum bicknellii*.

One of us (JDL) has seen what appears to be suitable habitats for the bug in the vicinity of Pentwater, Michigan where *Hudsonia tomentosa* is said to occur. See Voss (1985) for the distribution of this plant in Michigan. While the presence of *A. hirtus* in Minnesota appears to be a major disjunction, careful field work throughout the Great Lakes region may disclose its occurrence at other localities.

ACKNOWLEDGMENTS

Our thanks to L. Parks for careful preparation of the manuscript. Support to J.D.L. from N.S.F. grant BSR-90-11663 is gratefully acknowledged.

LITERATURE CITED


SEASONAL OCCURRENCE OF THE SOD WEBWORM MOTHS
(LEPIDOPTERA: CRAMBIDAE) OF OHIO

Harry D. Niemczyk, David J. Shetlar, Kevin T. Power and Douglas S. Richmond

ABSTRACT

While nearly 100 species of sod webworms are known to occur in North America, the species complex and seasonal occurrence of these moths has been documented in relatively few states. For Ohio, there is little published record of the sod webworm species complex, and the seasonal occurrence of only a few economically important species has been documented. Using black light traps, sod webworm adult flight activity was monitored over the course of three to five years at four different locations throughout Ohio. In this paper we report the seasonal occurrence of sod webworm species captured at these locations. These data provide a historical benchmark of sod webworm species diversity, local abundance, and seasonal occurrence in Ohio.

Although far from complete, recent gains have been made in documenting the lepidopteran fauna of Ohio. Major contributions include documentation of the superfamilies Papilionoidea and Hesperiioidea (butterflies and skippers) (Iftner et al. 1992), and the moth family Noctuidae (Rings et al. 1992). The two prior groups have likely received more attention because of their relatively large size and colorful ornamentation (Scott 1986), while many of the Noctuidae are serious pests of agricultural crops (Rings et al. 1992). Conversely, many moth families are often overlooked simply because they are smaller, less visually appealing, harder to identify, and tend to be nocturnal. One such group, the sod webworm moths (Lepidoptera: Crambidae), comprise a cosmopolitan family of moths formerly classified as a subfamily of the Pyralidae. Adult sod webworms are similar to pyralid moths in having abdominal tympanal organs, and elongate, scaled labial palpi extending in front of the head to form a proboscis. However, sod webworm moths can be distinguished by their habit of holding the wings close around the body when at rest (Borrer et al. 1989). The larvae of these moths feed primarily on plants in the family Gramineae and, as a result, several species are considered economically important pests of turfgrasses (Cobb 1995), cereal, and forage crops (Ainslee 1922). Some species of sod webworms are also known to feed on tobacco (Bohart 1947), cranberries (Franklin 1950), and coniferous nursery stock (Kamm et al. 1983).

Both univoltine and multivoltine species are known and, although there are exceptions (e.g., the cranberry girdler, Chrysoteuchia topiaria(Zeller)), the univoltine species are generally somewhat less important economically. Of the six most economically important temperate sod webworm species, four

1Department of Entomology, The Ohio State University, Ohio Agricultural Research and Development Center, Wooster, OH 44691.
2Department of Entomology, The Ohio State University, Columbus, OH 43210.
are multivoltine (Vittum et al. 1999). The multivoltine species are believed to be more important economically primarily because of their numbers and prolonged period of activity.

While nearly 100 species of sod webworms are known in North America (Bohart 1947), the species complex and occurrence of these moths has only been reported from Florida (Ainslee 1923, 1927; Kimball 1965), Iowa (Decker 1943), New York (Forbes 1923), North Carolina (Brimley 1938, 1942), Oregon (Prescott 1965), Tennessee (Matheny and Heinrichs 1975), and Virginia (Tolley and Robinson 1986). Like many of the Great Lakes States, there is little published record of the sod webworm species of Ohio. Therefore, the species complex and seasonal occurrence of this group is relatively unknown in this region.

The goal of this study was to document the species complex and seasonal flight activity of the common sod webworm moths of Ohio. In this paper, we consider the univoltine and multivoltine species separately because of the more evident economic significance of the latter. Using black light trap data collected from four different locations in Ohio, we identified the species complex and assembled seasonal flight activity profiles for all sod webworm species collected over the course of three to five years (16 total trap years). Supplemental data were gathered from the insect collection housed at The Ohio State University, Museum of Biological Diversity located in Columbus, OH. Together, these data provide a biological record of this common, but often overlooked group of insects, and clarify the seasonal occurrence of several species in this part of the Great Lakes region.

MATERIALS AND METHODS

Collection sites and dates. Collection sites represented the northern, central, and southern latitudes of the state (Figure 1). The northern Ohio collection site was established at the main campus of the Ohio Agricultural Research and Development Center (OARDC) in Wooster (Wayne Co.). Wooster lies within the Walhonding watershed and data were collected from the Wooster site from May, 1978 through October, 1982 (5 years) two central Ohio collection sites were used, both within the Upper Scioto watershed. The first site was located at Milford Center, in Union County. Data were collected from the Milford Center site from May through October of 1978, 1979, and 1982 (3 years). The second central Ohio site was located at the TruGreen Chemlawn research facility in Delaware (Delaware County). Data were collected from the Delaware site from May, 1986 through October, 1989 (4 years). The southern Ohio site was located at the Southern Branch of the OARDC in Ripley, OH (Brown Co.). Brown County lies within the Ohio Brush-Whiteoak watershed and data were collected from the Ripley site from May, 1978 through October, 1981 (4 years). No attempt was made to quantify the vegetation at any of the sites although all areas were predominantly surrounded by a matrix of agricultural fields and forest fragments. Additionally, the Delaware site was surrounded by 40 acres of managed turfgrass which was further surrounded by forest and agricultural land. Major agricultural crops include corn, soybeans, alfalfa, and wheat in the northern and central regions, and corn, alfalfa, and tobacco in the southern region.

Collecting methods and data management. Collection was performed using Ellisco® light traps with 15 W blacklight tubes. One light trap was placed at each of the collection sites and was on from dusk until dawn during all collecting seasons. At the Wooster, Millford Center, and Ripley locations, one insect strip (Vapona®) was used in each trap to kill captured
Figure 1. Map of Ohio showing location of collection sites used to assess sod webworm flight activity in Ohio (●). Collections were made at the Wooster site during 1978–82, at the Delaware site during 1986–89, at the Milford center site during 1978, 79, and 82, and at the Ripley site during 1978–81.

Moths and strips were replaced regularly. At the Delaware location, an open container of ethyl acetate was placed in the trap head as the killing agent and was refilled daily. Captured moths were collected daily (except weekends) and kept frozen until identification, sorting and counting could be performed. Sod webworm adult species identifications were verified by D. C. Ferguson (Systematic Entomology Laboratory, USDA, Washington, D. C.).
Voucher specimens were deposited in the insect collection at the OARDC. Data were organized by year, calendar date, and location, and comparisons between locations were based on the average total number of each species collected per year.

RESULTS AND DISCUSSION

Univoltine species. Seven species and three genera of univoltine sod webworm moths were collected during the course of the study although there were considerable differences in local abundance. Only four of the seven univoltine sod webworm species collected were regularly found at all four sites. These species include *Crambus laqueatellus* Clemens, *Crambus agitatellus* Clemens, *Chrysoteuchia topiaria* (Zeller), and *Agriphila vulgivagella* (Clemens). Based on the average total number of moths collected per year, *C. laqueatellus* was generally more abundant at the Milford Center and Ripley sites than at either of the other two sites (Figure 2). *Crambus agitatellus* was roughly equally abundant at the Milford Center, Delaware, and Ripley sites but was much less common at the Wooster site (Figure 3). *Chrysoteuchia topiaria* was most abundant at Delaware followed in order by Milford Center, Ripley, and Wooster (Figure 4). *A. vulgivagella* was most abundant at the Delaware and Ripley sites followed by the Milford Center and Wooster sites. Wooster recorded the lowest abundance of all four of these common species.

Figure 2. Seasonal flight activity of *Crambus laqueatellus* Clemens at four locations in Ohio as determined by the average number of moths caught in black light traps on each date.
Figure 3. Seasonal flight activity of *Crambus agitatellus* Clemens at four locations in Ohio as determined by the average number of moths caught in black light traps on each date.

Figure 4. Seasonal flight activity of *Chrysoteuchia topiaria* (Zeller) at four locations in Ohio as determined by the average number of moths caught in black light traps on each date.
Three of the seven species collected were found regularly only at the Delaware site (Figure 5). These species included *Crambus caliginosellus* Clemens, *Crambus luteolellus* Clemens, and *Agriphila ruricolella* (Zeller). Based on the average total number of moths collected per year, *C. caliginosellus* was by far the most abundant of these species followed in order by *C. luteolellus*, and *A. ruricolella*. Although all three of these species may have been collected at the other sites, their numbers were extremely low. This problem could have been exacerbated by handling practices. Because sod webworm moths tend to be small and delicate, excessive handling, freezing, and shipping made many specimens impossible to identify. Future efforts directed at collecting this group of moths should also explore alternative methods since blacklight traps may not be the most effective way to collect all species.

There appeared to be a trend of earlier to later emergence corresponding to latitude for *C. laqueatellus*, *C. agitatellus*, and *C. topiaria* but not *A. vulgivagella*. This observation implies that while development and adult flight of the prior three species is mainly temperature dependent, the later species may rely more heavily on other environmental cues such as photoperiod. Indeed, Tolley and Robinson (1986) determined that calendar date was a better flight peak predictor than degree-days for many sod webworm species in Virginia. Further research will be necessary to determine the relative importance of various environmental factors in determining seasonal flight activity for each species.

Based on seasonal flight activity profiles, there appear to be three dis-
tinct life-history strategies employed by these univoltine moths: early emergence, mid-season emergence, and late emergence. While the majority of species (four) can be considered mid-season emergers (C. agitatellus, C. topiaaria, C. caliginosellus, and C. luteolellus), one species, C. laqueatellus, falls into the early emergence category, and two species can be considered late season emergers (A. vulgivagella and A. ruricolella). These different emergence periods may result in a temporal partitioning of available resources between similar species thereby limiting interspecific competition.

**Multivoltine species.** Five species representing five different genera of multivoltine sod webworms were collected during the course of the study (Figs.7–11). However, numbers varied between sites and only four species were collected at all of the collection sites: *Parapediasia teterrella* (Zincken), *Pediasia trisecta* (Walker), *Fissicrambus mutabilis* (Clemens) and *Microcrambus elegens* (Clemens) (Table 2). *Crambus praefectellus* (Zincken) was notably absent from the Ripley site and was the least abundant species at both Wooster and Milford Center although it was far more abundant at the Delaware site. *P. teterrella, P. trisecta, and F. mutabilis* were most abundant at the Delaware site followed in decreasing order by Milford Center, Ripley, and Wooster. Although *M. elegens* was most abundant at the Delaware site as well, its abundance at Wooster was a close second followed by Milford Center and Ripley. Based on the average total number of moths collected per location per year, the most abundant species overall was *P. teterrella*, followed in decreasing abundance by *P. trisecta, F. mutabilis, M. elegens, and C. praefectellus.*
Figure 7. Seasonal flight activity of *Parapediasia teterrella* (Zincken) at four locations in Ohio as determined by the average number of moths caught in black light traps on each date.

Figure 8. Seasonal flight activity of *Pediasia trisecta* (Walker) at four locations in Ohio as determined by the average number of moths caught in black light traps on each date.
Figure 9. Seasonal flight activity of *Fissicrambus mutabilis* (Clemens) at four locations in Ohio as determined by the average number of moths caught in black light traps on each date.

Figure 10. Seasonal flight activity of *Microcrambus elegens* (Clemens) at four locations in Ohio as determined by the average number of moths caught in black light traps on each date.
Figure 11. Seasonal flight activity of *Crambus praefectellus* (Zincken) at three locations in Ohio as determined by the average number of moths caught in black light traps on each date.

<table>
<thead>
<tr>
<th>Species</th>
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<th>Delaware</th>
<th>Milford Center</th>
<th>Ripley</th>
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</table>

*Number of years varies with collection site; Wooster = 5 years, Delaware = 4 years, Milford Center = 3 years, and Ripley = 4 years.
Table 2. Average number of five different multivoltine sod webworm species collected per year* at four locations in Ohio (total number collected/number of years collected).

<table>
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<td>203</td>
<td>2,603</td>
<td>1,283</td>
<td>618</td>
</tr>
<tr>
<td>Fissicrambus mutabilis</td>
<td>11</td>
<td>241</td>
<td>113</td>
<td>87</td>
</tr>
<tr>
<td>Microcrambus elegens</td>
<td>116</td>
<td>149</td>
<td>92</td>
<td>23</td>
</tr>
<tr>
<td>Crambus praefectellus</td>
<td>6</td>
<td>196</td>
<td>4</td>
<td>—</td>
</tr>
</tbody>
</table>

*Number of years varies with collection site; Wooster = 5 years, Delaware = 4 years, Milford Center = 3 years, and Ripley = 4 years.

Table 3. Date/Locality records for sod webworm specimens in The Ohio State University insect collection—Columbus, OH.

<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
<th>Date (month/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriphila ruricolella</td>
<td>Granville, OH</td>
<td>August 1929</td>
</tr>
<tr>
<td>Agriphila vulgivagella</td>
<td>Granville, OH</td>
<td>August 1929</td>
</tr>
<tr>
<td></td>
<td>Columbus, OH</td>
<td>September 1942</td>
</tr>
<tr>
<td>Arequipa turbatella</td>
<td>Granville, OH</td>
<td>July 1930, July 1989</td>
</tr>
<tr>
<td>Crambus alboclavellus</td>
<td>Granville, OH</td>
<td>June, July and August 1930</td>
</tr>
<tr>
<td>Crambus agitatellus</td>
<td>Columbus, OH</td>
<td>July 1898</td>
</tr>
<tr>
<td>Crambus albellus</td>
<td>Granville, OH</td>
<td>June 1930</td>
</tr>
<tr>
<td>Crambus caliginosellus</td>
<td>Granville, OH</td>
<td>June 1930</td>
</tr>
<tr>
<td>Crambus girardellus</td>
<td>Granville, OH</td>
<td>June 1930</td>
</tr>
<tr>
<td>Crambus hortellus</td>
<td>Granville, OH</td>
<td>June 1930</td>
</tr>
<tr>
<td>Crambus laqueatellus</td>
<td>Columbus, OH</td>
<td>—*</td>
</tr>
<tr>
<td></td>
<td>Granville, OH</td>
<td>June 1930</td>
</tr>
<tr>
<td></td>
<td>Sugar Grove, OH</td>
<td>July 1920</td>
</tr>
<tr>
<td>Crambus zeelitus</td>
<td>Black Hand, OH</td>
<td>July 1930</td>
</tr>
<tr>
<td>Fissicrambus mutabilis</td>
<td>Granville, OH</td>
<td>June 1930</td>
</tr>
<tr>
<td>Microcrambus elegens</td>
<td>Granville, OH</td>
<td>July 1929</td>
</tr>
<tr>
<td>Parapediasia teterrella</td>
<td>Granville, OH</td>
<td>August 1929</td>
</tr>
<tr>
<td>Parapediasia decorella</td>
<td>Granville, OH</td>
<td>June 1930</td>
</tr>
<tr>
<td></td>
<td>Columbus, OH</td>
<td>July 1897</td>
</tr>
<tr>
<td>Pediasia trisecta</td>
<td>Granville, OH</td>
<td>August 1929, June 1930</td>
</tr>
<tr>
<td>Urola nivalis</td>
<td>Oak Harbor, OH</td>
<td>June 1925</td>
</tr>
<tr>
<td></td>
<td>Granville, OH</td>
<td>June 1929</td>
</tr>
<tr>
<td></td>
<td>Oak Openings, OH</td>
<td>July 1975</td>
</tr>
</tbody>
</table>

*— = no data available
Of the five species collected, four are considered important pest species: *P. teterrella*, *P. trisecta*, *F. mutabilis* and *C. praefectellus* (Vittum et al. 1999). Knowledge of the seasonal flight activity of pest species is particularly important for timing of monitoring and intervention. Flight activity profiles for some species illustrate differences in the number of generations occurring between sites. For instance, *P. teterrella* appeared to have at least a partial third generation at Wooster and Delaware while a third generation was obvious at Ripley. This same trend was true of *P. trisecta* with close to a full third generation appearing in some years at Ripley. These differences in voltinism are not overly surprising and may be due to local weather patterns or microclimate effects. Indeed, other authors have reported similar findings. For instance, *P. trisecta* is reported to have one generation per year in the Pacific Northwest, two generations in the Midwest, and three in Virginia (Ainslie 1927, Crawford and Harwood 1964, Robinson and Tolley 1982). Similarly, *P. teterrella* is reported to have two generations in Virginia and three generations in Tennessee (Robinson and Tolley 1982, Ainslie 1930). Our data indicate that both *P. teterrella* and *P. trisecta* may regularly have three generations in Ohio, a fact that was previously undetermined.

ACKNOWLEDGMENTS

The authors thank Keith Kennedy, Jeff Rodencal, Patrice Suleman, and Dan Chandler for technical assistance in handling, collecting and sorting moths. Funding for this work was provided, in part, by the Ohio Turfgrass Foundation, and by State and Federal funds appropriated to the Ohio Agricultural Research and Development Center.

LITERATURE CITED


LEUCANTHIZA DIRCELLA [LEPIDOPTERA: GRACILLARIIDAE]: A LEAFMINER OF LEATHERWOOD, DIRCA PALUSTRIS

Toby R. Petrice¹, Robert A. Haack¹, William J. Mattson² and Bruce A. Birr²

ABSTRACT

Leatherwood, *Dirca palustris* (Thymelaeaceae), is an understory shrub ranging throughout most of the eastern and central United States and adjacent Canada. During 1997–1999, we conducted studies to identify and assess the impact of a leaf miner that was causing significant damage to leatherwood plants in eastern Gogebic County, Michigan. *Leucanthiza dircella* was identified as the only insect responsible for the leaf mining activity on leatherwood. In northern Michigan, *L. dircella* completed one generation per year. Adult moths were captured on yellow sticky panels suspended from leatherwood branches. In 1997 and 1998, most adults were captured during the first sampling period of each year: 6–12 June 1997 and 3–19 May 1998. In 1999, no moths were collected during 5–29 April but adults were collected between 30 April and 22 June 1999. In 1999, initiation of adult flight coincided with *D. palustris* leaf flush. In 1997, leaf mines were very noticeable by 30 June. The mean number of live *L. dircella* larvae per mine was 3.5 on 17 July 1997 and then decreased as the season progressed, with most larvae having exited the mines by late August to pupate in the soil. In late August 1997, the mean surface area of a single leaf was 17.8 cm² and the mean surface area of a single mine was 5.9 cm². At the end of the 1997 growing season, 31% of the leatherwood leaves contained *L. dircella* mines, and 11% of the total leaf surface area had been mined. In 1999, only 8% of the leaves in the study area contained *L. dircella* mines. No leatherwood mortality was evident as a result of *L. dircella* leaf mining. Seven species of hymenopteran parasitoids were reared from *L. dircella* larvae, including one braconid in the genus *Pholetesor* and six eulophids in the genera *Chrysocharis*, *Closterocerus*, *Pnigalio*, and *Sympiesis*. Three coleopterans that were commonly observed on leatherwood plants during all years included: *Glyptina brunnea* (Chrysomelidae), *Phyllobius oblongus* (Curculionidae) and *Polydrusus sericeus* (Curculionidae).

Leatherwood, *Dirca palustris* L. (Thymelaeaceae), is an understory shrub that grows to a height of 1–3 m and ranges throughout most of the eastern and central United States and adjacent Canada (Fernald 1950, Vogelmann 1953). Leatherwood is most often found growing in nutrient rich, mesic hardwood stands (Britton and Brown 1970, Cleland et al. 1993, Kotar et al. 1988, USDA Forest Service, North Central Research Station, 1407 S. Harrison Rd., Michigan State University, East Lansing, MI 48823.

2USDA Forest Service, North Central Research Station, 5985 Highway K, Rhinelander, WI 54501.
Radford et al. 1979). The common name leatherwood is earned from the plant's tough fibrous bark, which Native Americans utilized as a source of fiber for making items such as mats, bags, cords, and rope (Whitford 1943).

Leatherwood contains toxins that cause irritation and blistering when contacted by skin, and gastrointestinal discomfort when swallowed (Fuller and McClintock 1986, Muencherc 1964). Because of these properties, there has been some preliminary research exploring the potential of leatherwood extracts as deterrents for vertebrate herbivores (Ramsewak et al. 1999, Zasada et al. 1999). Interestingly, there are some references of leatherwood being used by early settlers for medicinal purposes (Fielder 1975). An ointment was made with leatherwood bark and sarsaparilla (Aralia sp.) for treating severe skin diseases, and a tea made from the leatherwood roots was used for treating kidney problems. Moreover, a study was conducted during the early 1900's, testing the efficacy of leatherwood extracts as a purgative (Lecours 1924).

Leatherwood has been planted as an ornamental shrub because its early spring bloom, tree-like appearance, and tolerance to full sun make it very suitable for shrub beds and rock gardens (Esson 1949, Tredici 1983). Tredici (1983) also noted that leatherwood is easily germinated from seeds that have been subjected to a cold period.

Although uncommon throughout most of its range, when leatherwood does occur in the forest understory, it frequently grows in dense patches (Nevling 1962). This is often the case in mature hardwood forests in northern Wisconsin and the western Upper Peninsula of Michigan, where leatherwood may be an important understory component (Curtis 1959, Kotar et al. 1988, John C. Zasada, USDA Forest Service, Rhinelander, WI, pers. obs.). During 1997–1999, we conducted a study to identify and determine the impact of any insects that were causing significant leaf mining damage to leatherwood plants in eastern Gogebic County, Michigan.

MATERIALS AND METHODS

Studies were conducted during 1997–1999 on the Ottawa National Forest, Watersmeet Ranger District, near Taylor Lake in eastern Gogebic County, Michigan (Fig. 1). The area selected was classified as mature hardwood forest and was composed primarily of sugar maple (Acer saccharum), yellow birch (Betula alleghaniensis), and American basswood (Tilia americana). Leatherwood was abundant in the understory and had undergone heavy leaf mining damage during the early 1990's (John C. Zasada, pers. comm.). In 1997, from 6 June through 25 August, we attached one double-sided yellow sticky panel (15 cm by 30 cm) on each of six leatherwood plants, 1 to 2-m tall, to capture adult leafminers. Sticky panels were collected at two-week intervals, with the exception of the first two sample periods which were collected at six-day and four-day intervals, respectively. Each sticky panel was placed in a plastic bag, and frozen for later inspection. During each site visit, we visually examined leatherwood foliage for ovipositing insects and leaf mining activity. We collected specimens of suspect insects that belonged to leaf mining families. We also collected leaf samples from ten leatherwood plants at two-week intervals beginning 17 July 1997. Each sample consisted of one branch tip per plant, ca. 20-cm in length. Each branch tip typically had 6 to 12 leaves and included 2 to 3 year's growth. We selected a branch tip that appeared to represent the leaf mining activity currently found on each individual plant being sampled. Leaf samples were placed in-
individually in plastic bags, and stored on ice for later processing in the laboratory.

On 25 August 1997, after leaf mining had ceased and most larvae had exited the mines, we collected leaf samples in a 200-m by 100-m area surrounding the central study site. We sampled 110 leatherwood plants, taking one branch sample from each plant that was 1 m in height or taller. Each branch sample was chosen to be representative of the leaf mining damage level for the particular plant being sampled.

In the laboratory, the 1997-collected leaves that contained mines were held over a strong light, allowing the number of larvae inside of each mine to be counted. We also recorded if mines contained holes through which larvae could have exited to pupate in the soil. In addition, we noted if leaves pos-
essed fungal rust spots and if the section of branch sampled had evidence of other insects such as scale insects. After the leaves were examined, they were photocopied so the total leaf surface area and total mined area could be determined. Photocopying allowed for a simple means of leaf "preservation" and it accurately depicted mined and non-mined areas of each leaf. Using scissors, we cut out each photocopied leaf and passed it through a leaf area meter to determine total surface area. Each paper "leaf" was measured twice and the average surface area recorded. We then removed and measured the mined area of each photocopied leaf. The same procedure was followed for the leaf samples collected from the 110 plants on 25 August 1997.

The number of larvae per mine and percent of mines with exit holes were analyzed for differences among sample dates using a one-way-ANOVA (PROC GLM, SAS Institute 1990). For certain statistical analyses, leaves were first placed in 10-cm² leaf size classes. A one-way-ANOVA (Proc GLM) was used to test for differences in percent of leaves mined and percent of leaves with rust spots among leaf size classes. Arcsin square-root transformations were performed on all percentage data prior to analyses. Tukey's Studentized Range Test was used to separate means when ANOVA was significant. A significance level of $P \leq 0.05$ was set for all analyses.

Leaves containing larvae were placed on moistened paper towels inside of plastic bags in 1997. We used a pin to make small holes in the upper surface of the bags to reduce molding. The bags were examined at least twice weekly for insects emerging from the leaf mines. Leafminer pupae were removed and placed in petri dishes on moistened paper towels. Hymenopteran parasitoids emerging from the leaf mines were placed in vials containing 70% ethyl alcohol and were later sent to specialists for identification. Leafminer pupae were overwintered at 4°C for 120 days. Adult leafminers emerging from overwintered pupae were pinned and used as reference specimens for identifying insects captured on the sticky panels. The number of adult leafminers captured on each sticky panel was recorded. Voucher specimens of leafminer adults and hymenopteran parasitoids are currently stored in the USDA Forest Service insect collection, Michigan State University, East Lansing, Michigan.

In 1998, we placed one sticky panel (15 cm by 30 cm) on each of 20 leatherwood plants from 3 May through 3 November. Sticky panels were collected on 19 May, 1 June and 7 July. We replaced sticky panels on 7 July to monitor any mid- to late-season adult leafminer activity; these traps were collected 3 November 1998.

In 1999, we placed one sticky panel (15 cm by 30 cm) on each of 12 leatherwood plants from 5 April through August and samples were collected on 12 April, 22 April, 29 April, 10 May, 17 May, 27 May, 4 June, 15 June, 22 June and 4 August. The last sample period was longer than earlier periods in 1999, and was meant to monitor any mid- to late-season adult leafminer activity. On 25 August 1999, we sampled one branch from each of 22 leatherwood plants in the study area. For each branch, we recorded the number of mined and unmined leaves. Samples were collected from the same area sampled in 1997 and branches were selected following the same protocol as used in 1997.

Also in 1999, leatherwood shoot and leaf development were monitored on three leatherwood plants. On each plant, we selected a branch tip in each of the four cardinal directions and marked the terminal bud of each with a plastic tie. Beginning 29 April, we examined each marked bud and recorded current-year's shoot length and length of the largest leaf on that shoot during each sticky panel collection through 22 June (see above). Also, beginning 10 May through 15 June, we recorded the number of leaves present on each of
the marked current-year’s shoots. Shoot length, leaf length, and the number of leaves present were analyzed for differences among sample dates using a mixed model ANOVA (PROC MIXED, SAS Institute 1990), with shoots within leatherwood plants assigned as a random effect of the model. Least squares means significant at the $P \leq 0.05$ level were separated using Tukey’s Studentized Range Test.

We obtained official weather records from the National Oceanic and Atmospheric Administration (NOAA, Asheville, North Carolina), for Watersmeet, Gogebic County, Michigan, which is approximately 10 km west of the study site (Fig. 1). Occasionally, weather records were not reported by the Watersmeet weather station. When that occurred, we used data from the next closest recording station, which was Stambaugh, Iron County, Michigan, located approximately 40 km east of the study site (Fig. 1). Daily heat sums were calculated for 1997, 1998 and 1999 using the averaging method, i.e. average of daily high and low temperature subtracted from base temp, and the Baskerville-Emin method (Baskerville and Emin 1969). Heat sums for each method were calculated using base 5°C and base 10°C.

**Biology.** All adult leafminers emerging from the overwintered pupae were identified as *Leucanthiza dircella* Braun (Lepidoptera: Gracillariidae) (Fig. 2) by Ronald Priest (Michigan State University, adjunct curator). This moth has been reported from Clermont County, Ohio (Braun 1914, Forbes 1920), and from Michigan (Nielsen 1998).

Most *L. dircella* moths were captured in May and early-June during all three sample years, although the number of moths captured varied greatly between years. In 1999, adults were first captured between 30 April and 10

Figure 2. *Leucanthiza dircella* adult that emerged in the lab 15 July 1999 from a larva collected 21 May 1999 in Ingham County, Michigan (total wingspan approximately 6.2 mm). Specimen provided by Ronald Priest.
Table 1. Mean number of *Leucanthiza dircella* adults collected per yellow sticky trap (2-sided; each side 15 cm by 30 cm) per sampling day and heat sums for 1997, 1998, and 1999. Heat sums (start date = March 1) were calculated using the averaging method (Averaging) and Baskerville-Emin method (B-E) for the bases 10°C and 5°C.

<table>
<thead>
<tr>
<th>Sampling period</th>
<th>Julian days</th>
<th>Adults/ trap/day</th>
<th>Heat sums base 10°C*</th>
<th>Heat sums base 5°C**</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997 (41 moths collected on 6 traps)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 June–12 June</td>
<td>157-163</td>
<td>0.97</td>
<td>66-104</td>
<td>199-266</td>
</tr>
<tr>
<td>13 June–17 June</td>
<td>164-168</td>
<td>0.07</td>
<td>112-125</td>
<td>279-313</td>
</tr>
<tr>
<td>18 June–30 June</td>
<td>169-181</td>
<td>0.03</td>
<td>131-246</td>
<td>323-498</td>
</tr>
<tr>
<td>1 July–17 July</td>
<td>182-198</td>
<td>0.01</td>
<td>257-377</td>
<td>514-713</td>
</tr>
<tr>
<td>18 July–29 July</td>
<td>199-210</td>
<td>0.00</td>
<td>387-475</td>
<td>728-871</td>
</tr>
<tr>
<td>1998 (631 moths collected on 20 traps)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 May–19 May</td>
<td>123–139</td>
<td>2.03</td>
<td>12-60</td>
<td>66-178</td>
</tr>
<tr>
<td>20 May–1 June</td>
<td>140–152</td>
<td>0.16</td>
<td>65-83</td>
<td>188-245</td>
</tr>
<tr>
<td>2 June–7 July</td>
<td>153–188</td>
<td>0.01</td>
<td>83-234</td>
<td>249-545</td>
</tr>
<tr>
<td>1999 (21 moths collected on 12 traps)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 April–14 April</td>
<td>95–102</td>
<td>0.00</td>
<td>0</td>
<td>8-9</td>
</tr>
<tr>
<td>13 April–22 April</td>
<td>103–112</td>
<td>0.00</td>
<td>0</td>
<td>9-14</td>
</tr>
<tr>
<td>23 April–29 April</td>
<td>113–119</td>
<td>0.00</td>
<td>0</td>
<td>32-44</td>
</tr>
<tr>
<td>30 April–10 May</td>
<td>120–130</td>
<td>0.02</td>
<td>1-32</td>
<td>72-142</td>
</tr>
<tr>
<td>11 May–17 May</td>
<td>131–137</td>
<td>0.02</td>
<td>32-48</td>
<td>110-149</td>
</tr>
<tr>
<td>18 May–24 May</td>
<td>138–144</td>
<td>0.04</td>
<td>50-57</td>
<td>157-184</td>
</tr>
<tr>
<td>25 May–3 June</td>
<td>145–154</td>
<td>0.03</td>
<td>57-94</td>
<td>184-253</td>
</tr>
<tr>
<td>4 June–15 June</td>
<td>155–166</td>
<td>0.05</td>
<td>99-197</td>
<td>263-411</td>
</tr>
<tr>
<td>16 June–22 June</td>
<td>167–173</td>
<td>0.01</td>
<td>197-226</td>
<td>416-473</td>
</tr>
<tr>
<td>23 June–4 August</td>
<td>174–216</td>
<td>0.002</td>
<td>237-604</td>
<td>489-1066</td>
</tr>
</tbody>
</table>

*Heat sums as of end of each day.
**Two *L. dircella* adults were captured during this sample period but the number captured per trap per day was < 0.01.

As expected, the mixed model ANOVA for *Dirca palustris* shoot length and leaf length varied significantly among sampling dates (*P* < 0.0001). The first evidence of flushing occurred 29 April 1999 when bundles of small leaves were found protruding from the buds. Shoot elongation was completed by 17 May and leaves were fully expanded between 24 May and 3 June 1999 (Fig. 3). The number of leaves per shoot averaged 5.8 on 10 May 1999, and
Figure 3. Mean (+ 1 SE) (A) number of *Dirca palustris* leaves per current-year’s shoot during the period of 10 May through 15 June 1999, (B) length of the longest leaf on a current-year’s shoots during the period of 29 April through 22 June 1999, and (C) current-year’s shoot length during the period 10 May through 22 June 1999 based on 12 shoots on 3 plants (4 shoots per plant). Means with the same letter are not significantly different at $P \leq 0.05$ (Tukey’s Studentized Range Test). *Only a tight bundle of leaves protruded from buds on 29 April; leaf length measured from tip of longest leaf to base of leaf bundle; new shoots were not visible.
Table 2. Mean (±SE) number of live Leucanthiza dircella larvae found per leaf mine and the percent of leaf mines with holes (through which L. dircella larvae could exit) that were collected from leatherwood plants in Gogebic County, Michigan, during the period 17 July to 25 August 1997.

<table>
<thead>
<tr>
<th>Sampling date</th>
<th>No. of mines</th>
<th>Live larvae per mine</th>
<th>Percent mines with holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 July</td>
<td>37</td>
<td>3.5 ± 0.4 a*</td>
<td>11 ± 5 c*</td>
</tr>
<tr>
<td>29 July</td>
<td>56</td>
<td>1.9 ± 0.2 b</td>
<td>21 ± 6 c</td>
</tr>
<tr>
<td>13 August</td>
<td>47</td>
<td>0.5 ± 0.1 c</td>
<td>68 ± 7 b</td>
</tr>
<tr>
<td>25 August</td>
<td>44</td>
<td>0.1 ± 0.1 c</td>
<td>100 ± 0 a</td>
</tr>
</tbody>
</table>

*Means followed with the same letter (within columns) are not significantly different at the P ≤ 0.05 level (Tukey’s Studentized Range Test).

then decreased slightly as the season progressed (Fig. 3). This decrease in leaf number was primarily due to the abscission of leaf-like stipules, which were first counted as leaves during the early sampling dates.

Comparing the heat sums during moth activity, i.e., number of moths collected on sticky panels (Table 1), with D. palustris phenology (Fig. 3), it appears that most moths were captured during the period of active D. palustris leaf and shoot elongation. This relationship is not surprising since L. dircella is host specific to D. palustris. Emerging early during D. palustris leaf flush would allow L. dircella adults to oviposit when leaf tissues are likely soft and most nutritious (Mattson and Scriber 1987). Early season oviposition would also allow the resulting larvae to develop during the entire growing season. This synchronization is probably most important in the northernmost range of L. dircella where development time may be limiting.

Leaf mines were first obvious in 1997 when we visited the study site on 30 June. Each mine contained 1 to 10 legless larvae that formed upper surface blotch mines. The mean (± SE) number of live larvae per mine was 3.5 (± 0.4, N = 37 mines) on 17 July 1997 and then decreased through the remainder of the season (Table 2). Larvae began exiting mines in July, but most exited during August (Table 2). In general, larvae fed through mid-August 1997, at which time they developed thoracic legs and exited the mines to pupate. In the laboratory, after larvae exited the mines, they moved to the corners of the plastic bags where they formed a translucent, silk chamber and then pupated. In nature, larvae probably pupate in the soil or leaf litter.

Leucanthiza dircella likely overwinters in the pupal stage, given that a cold period (4°C for 120 days) was required before adults would emerge in the laboratory. Adults emerged 7-10 days after pupae were removed from cold storage and held at room temperature (ca. 20–24°C).

Leucanthiza dircella had only one generation per year in the study area in northern Michigan. Interestingly, L. dircella was reported as having two generations per year in Ohio (Braun 1914, Forbes 1920). A minimum of two generations per year likely occurs in southern Michigan, given that new L. dircella larval feeding mines were observed during both May and September on leatherwood plants in Ingham County, Michigan in 1999 (T. R. Petrice, pers. obs.). Furthermore, adults emerged in the laboratory on 14 June 1999 from larvae that were collected in Ingham County 21 May 1999 and were not subjected to a cold period.

Parasitoids. In the laboratory, seven species of hymenopteran parasitoids emerged from L. dircella larvae in 1997. They consisted of the bra-
conid Pholetesor sp. (8 specimens); and the eulophids (Chrysocharis polita Howard (5), Closterocerus trifasciatus Westwood (6), Pnigalio maculipes Crawford (4), P. minio (Walker) (2), Pnigalio sp. (3), and Sympeesis sp. (1). Only one of these species, P. maculipes, was previously reported as attacking L. dircella (Krombein et al. 1979). The genera Pnigalio and Sympeesis are ectoparasitic, which is a common method of parasitism on leafminers since the leaf mine itself serves to protect the parasitoid larvae as well as the host insect. A common behavior often associated with leafminer parasitoids is for the adult female wasps to feed on their insect hosts through the leaf tissues (Askew and Shaw 1979). This provides the adult wasp with protein, which aids in egg production. Young leafminer larvae are often the targets of this behavior, and their flattened cadavers are often found in leaf mines. Indeed, we noticed several dead larvae in mines that were in this condition in 1997.

Leaf mining damage. A total of 879 leaves was collected in late August 1997 from 110 leatherwood plants and of these, 31% contained L. dircella leaf mines. Of the 275 leaves containing mines, 259 leaves contained only 1 mine (94%), 14 leaves (5%) contained 2 mines, and 2 leaves (1%) contained 3 mines. The mean leaf size was 17.8 cm² (range = 0.9 to 66.6 cm², N = 879 leaves) and the mean mined surface area was 5.9 cm² (range = 0.2 to 24.0 cm², N = 293 mines). Although 31% of the leaves contained mines, only 11% of the total leaf surface area for all 879 leaves was mined by L. dircella in 1997.

Another interesting trend was the size of the leaves attacked by L. dircella. After dividing the leaves into six size classes, leaves that were 21 cm² in surface area or greater had the highest levels of leaf mining (F = 70.31; df = 5, 873; P < 0.0001) (Fig. 4). Leaves that were 10 cm² in size and smaller were seldom attacked (Fig. 4). The smallest mined leaf measured 7.5 cm². When considering only leaves 11 cm² and larger, more than 54% of the leaves contained mines. One explanation for this difference is that smaller leaves may not have flushed at the time when adult L. dircella were ovipositing in early summer. However this is unlikely since leatherwood has determinate growth and the number of leaves did not increase after initial leaf expansion in early spring of 1999 (Fig. 3). A more likely explanation is that female moths preferentially oviposited in larger leaves.

The L. dircella population declined in the study area in 1999. Only 8% of the leatherwood leaves contained mines in 1999 compared with 31% in 1997. The number of adult moths captured on sticky panels was also much lower in 1999 than in 1997 or 1998 (Table 1). Parasitism could have contributed to this decline, given the rich parasitoid fauna reared from L. dircella larvae in 1997. Braun (1914) noted high parasitism rates of L. dircella larvae. Freezing temperatures during 1998–1999 winter may have also contributed to the decline of L. dircella in 1999. According to NOAA weather records, in the first half of December 1998, minimum temperatures dipped well below 0°C for several days, yet there was no snow cover on the ground. When the study site was visited on 15 December 1999, snow was absent from the ground and the first several cm of soil were frozen (W. J. Mattson, pers. obs.). Leucanthiza dircella pupal mortality may have occurred as a result of freezing and cold temperatures, especially since it occurred in early winter when pupae may have not yet acclimated to their full cold hardiness. In both 1996 and 1997, NOAA weather records indicated that snow covered the ground throughout December, thus insulating the soil and leaf litter.

Other damage and insects. In addition to leaf mining damage, 8% of the 879 leaves collected on 25 August 1997 possessed rust spots of an unidentified fungus. Rust spots on leatherwood leaves were not apparent until 30 June 1997, at the same time leaf mines were first noted. A significantly
higher percentage of leaves in the 51 cm² and larger leaf size class possessed rust spots (27%), than did leaves in the smaller leaf size classes (F = 6.10; df = 5, 873, P < 0.0001).

The trunk and limbs of several leatherwood plants in the study area were infested with unidentified scale insects (Homoptera). Of the branch samples collected from the 110 plants on 25 August 1997, 3% had evidence of scale insects.

Several other insects were observed on leatherwood foliage in addition to Leucanthiza dircella adults, although actual feeding was not witnessed. These included one native beetle (Coleoptera), Glyptina brunnea Horn (Chrysomelidae); and two exotic beetles, Phyllobius oblongus (L.) (Curculionidae) and Polydrusus sericeus Schaller (Curculionidae). Phyllobius oblongus and P. sericeus were also captured frequently on sticky panels during 1997-1999. These two weevils are generalist herbivores that are native to

Figure 4. Mean percent (±1 SE) of leaves in six size classes that were collected on 25 August 1997 from 110 leatherwood plants and had evidence of leaf mining by Leucanthiza dircella. Means with the same letter are not significantly different at P ≤ 0.05 (Tukey's Studentized Range Test).
Europe (Mattson et al. 1994). All three of these beetles inhabit the soil as larvae, feeding on plant roots.

At the end of the 1999 growing season, no leatherwood mortality was evident as a result of \textit{L. dircella}. However, we did not measure possible growth loss due to several consecutive years of heavy leaf mining damage. Stem analysis of leatherwood plants in the study area revealed that annual stem elongation varied from 40–180 mm (Cynthia V. Jones, Southern Illinois University at Edwardsville, per. obs.). Some of this variation in annual stem elongation may be attributable to leaf mining damage by \textit{L. dircella}. If leatherwood becomes a popular ornamental shrub, then control of \textit{L. dircella} may need to be considered when damage becomes significant.

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LITERATURE CITED


NEW DISTRIBUTION RECORDS OF GROUND BEETLES FROM THE NORTH CENTRAL UNITED STATES (COLEOPTERA: CARABIDAE)

Foster Forbes Purrington¹, Daniel K. Young², Kirk J. Larsen³ and Jana Chin-Ting Lee⁴

ABSTRACT

We report 39 ground beetles new to five states in the upper midwestern United States. These species records include 19 new to Illinois (all but one from Lake County), 11 from Iowa, three from South Dakota, eight from Wisconsin, and two from Michigan. (Three species are new to more than one state). Enigmatically disjunct collections include the myrmecophile, Helluo­morphismoides nigripennis from western Illinois, known previously only from the Atlantic and Gulf coastal plain and piedmont, and Chlaenius amoenus, reported only from southeastern states and now from northeast Iowa.

From habitats that include agricultural zones in south central Michigan and Wisconsin, shortgrass prairie in western South Dakota, tallgrass prairies in Iowa and Wisconsin, and forested wetlands along the Lake Michigan shoreline in northern Illinois we report 39 ground beetle species (Coleoptera: Carabidae) that represent 43 new state distribution records (Bousquet and Larochelle 1993, Purrington and Larsen 1997, Purrington and Maxwell 1998).

Many of these records are of species that have been previously reported from one or more adjoining states and Canadian provinces. Other records are of synanthropic European introductions (Bousquet 1992) evidently expanding their ranges, or of native species possibly tracking newly favorable environments, e.g. changing climates or agricultural landscapes. A few records represent enigmatically disjunct collections of uncommon species previously known only from sites distant from the western Great Lakes region.

MATERIALS AND METHODS

All specimens were obtained with standard pitfall or blacklight trapping techniques, or were hand-collected. Vouchers are kept at The Ohio State University-Columbus (FFP), Michigan State University-East Lansing (JC-TL), Luther College-Decorah, Iowa (KJL), and the University of Wisconsin-

¹Department of Entomology, The Ohio State University, 1735 Neil Avenue, Columbus, OH 43210.
²Department of Entomology, University of Wisconsin, 237 Russell Laboratories, Madison, WI 53706.
³Department of Biology, Luther College, Decorah, IA 52101-1045.
⁴Department of Entomology, Michigan State University, East Lansing, MI 48824-1115.
Madison [Department of Entomology (DKY) and Department of Agronomy (Jon Simonsen: JS)]. The disposition of vouchers is noted by custodial initials in the following species account. Species introduced from Europe are noted.

RESULTS


State records for Illinois. *Acupalpus pumilus* Lindroth, Lake Co., Libertyville, Grainger Woods Forest Preserve and Elm Road Forest Preserve; Winthrop Harbor, Spring Bluff Forest Preserve, July 1999, numerous specimens, blacklight, [FFP].

*Agonum fidele* Casey, Lake Co., Libertyville, Grainger Woods Forest Preserve and Elm Road Forest Preserve; Winthrop Harbor, Spring Bluff Forest Preserve, June–August 1999, numerous specimens, pitfall and blacklight, [FFP].

*Agonum harrisii* LeConte, Lake Co., Libertyville, Grainger Woods Forest Preserve; Winthrop Harbor, Spring Bluff Forest Preserve, July 1999, 16 specimens, blacklight, [FFP].

*Amara apricaria* (Paykull), Lake Co., Winthrop Harbor, Spring Bluff Forest Preserve, 7/22/1999, 1 specimen, *introduced*, [FFP].

*Amara queneseli* (Schönherr), Lake Co., Winthrop Harbor, Spring Bluff Forest Preserve, 9/29/1999, 4 specimens, pitfall, [FFP].

*Badister grandiceps* Casey, Lake Co., Libertyville, Grainger Woods Forest Preserve; Winthrop Harbor, Spring Bluff Forest Preserve, July 1999, numerous specimens, blacklight, [FFP].

*Badister transversus* Casey, Lake Co., Libertyville, Grainger Woods Forest Preserve and Elm Road Forest Preserve; Winthrop Harbor, Spring Bluff Forest Preserve, June–July 1999, numerous specimens, blacklight, [FFP].

*Bembidion pseudocaustum* Lindroth, Lake Co., Winthrop Harbor, Spring Bluff Forest Preserve, 8/3/1999, 1 specimen, blacklight, [FFP].

*Bradyceillus congener* (LeConte), Lake Co., Libertyville, Grainger Woods Forest Preserve, 7/8/1999, 1 specimen; Winthrop Harbor, Spring Bluff Forest Preserve, July 1999, 2 specimens, blacklight, [FFP].

*Dyschirius integer* LeConte, Lake Co., Winthrop Harbor, Spring Bluff Forest Preserve, July 1999, 15 specimens, blacklight, [FFP].

*Elaphropus tripunctatus* (Say), Lake Co., Libertyville, Grainger Woods Forest Preserve and Elm Road Forest Preserve, July 1999, 10 specimens, blacklight, [FFP].

*Harpalus puncticeps* (Stephens), Lake Co., Libertyville, Grainger Woods Forest Preserve and Elm Road Forest Preserve; Winthrop Harbor, Spring Bluff Forest Preserve, July–August 1999, numerous specimens, *introduced*, blacklight, [FFP].

*Helluomorphoides nigripennis* (Dejean), Mason Co., Sand Prairie-Scrub Oak State Natural Area, 7/16/1997, 1 specimen, pitfall, [FFP].

*Paratachys obtitus* (Casey), Lake Co., Winthrop Harbor, Spring Bluff Forest Preserve, July 1999, 8 specimens, blacklight, [FFP].

*Platynus opaculus* LeConte, Lake Co., Libertyville, Grainger Woods Forest Preserve, 5/28/1999, 3 specimens, blacklight, [FFP].
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Plochionus timidus Haldeman, Lake Co., Libertyville, Grainger Woods Forest Preserve, 7/30/1999, 1 specimen, blacklight, [FFP].

Pterostichus melanarius (Illiger), Lake Co., Libertyville, Grainger Woods Forest Preserve; Winthrop Harbor, Spring Bluff Forest Preserve, 7/27-8/18/1999, numerous specimens *introduced*, pitfall, [FFP].

Pterostichus novus Straneo, Lake Co., Winthrop Harbor, Spring Bluff Forest Preserve, 8/30/1999 and 9/29/1999, 9 specimens, pitfall, [FFP].

Pterostichus tenuis (Casey), Lake Co., Winthrop Harbor, Spring Bluff Forest Preserve, 7/22/1999, 1 specimen, blacklight, [FFP].

**State records for Wisconsin.** Agonum fidele Casey, Sauk Co., Hemlock Draw Preserve, The Nature Conservancy, July 1998, several specimens, pitfall, [FFP].


Badister flavipes laticeps Blatchley, Green Co., 6/30/1998, 1 specimen, blacklight, [JS].


Chlaenius pusillus Say, Columbia Co., Arlington Research Station, July–August 1996, 5 specimens; Walworth Co., Lakeland Agricultural Station, 8/26/1996, 1 specimen, [DKY, JS].

Harpalus katiae Battoni, Sauk Co., Spring Green Preserve, 8/24/1995, several specimens, [DKY, FFP].

Harpalus puncticeps (Stephens), 1 specimen, Walworth Co., Lakeland Agricultural Station, *introduced*, 9/1/1995, [DKY].


**State records for Iowa.** Apenes lucidulus (Dejean), Clayton Co., Mendon Township, Effigy Mounds National Monument, South Unit Prairie, 6/27/1996, 1 specimen, [KJL].


Bembidion obscurellum (Motschulsky), Floyd Co., 6/27/1978, 1 specimen blacklight, [KJL].


Bradycellus semipubescens Lindroth, Winneshiek Co., Jackson Township, Chipira Prairie, 7/1/1996, 1 specimen, [KJL].


Harpalus affinis (Schrank), Winneshiek Co., Jackson Township, 7/22/1996, 1 specimen, *introduced*, [KJL].

Pterostichus trinarius (Casey), Allamakee Co., Fairview Township, 6/19/1995, 2 specimens, [KJL].

Scaphinotus bilobus (Say), Winneshiek Co., Decorah, Hickory Ridge Woods, 9/7/1998, 1 specimen; Canoe Township, Malanaphy Springs, 10/1/1999, 1 specimen, [KJL].

Trichotichnus autumnalis (Say), Clayton Co., Mendon Township, Effigy Mounds National Monument, South Unit, 6/27/1996, 1 specimen; Winneshiek Co., Canoe Township, Malanaphy Springs, 9/22/1999, 1 specimen, [KJL].

Trichotichnus vulpeculus (Say), Jasper Co., Walnut Creek National
Wildlife Refuge, 10/11/1997, 2 specimens; **Winnesiek Co.**, Decorah, 9/5/1995, 1 specimen. [KJL].

**State records for South Dakota.** *Bembidion mutatum* Gemminger and Harold, **Pennington Co.**, Wheaton College Science Station (Hisega), 7/10/1994, 1 specimen, [KJL].

*Carabus nemoralis* Müller, **Pennington Co.**, Wheaton College Science Station (Hisega), 6/12/1996, 1 specimen, *introduced*, [KJL].

*Carabus taedatus agassii* LeConte, **Pennington Co.**, Wheaton College Science Station (Hisega), 5/23/1995, 1 specimen, [KJL].

**DISCUSSION**

*Harpalus puncticeps* was inadvertently introduced from Europe into coastal New York (Long Island), probably in the mid-1900's (Dietrich 1957). Davidson (1975) reported its movement 100 km up the Hudson River to Poughkeepsie (Duchess County) and from northern Vermont (Washington County). By 1989 it had been collected in Nova Scotia, Quebec, Ontario, and Ohio (Larochelle and Lariviere 1989). Here we document its continuing westward range expansion with the first records from Michigan, Illinois and Wisconsin. This species favors ruderal and old field habitats developed on gravelly soil (Lindroth 1968).

Little is known of *Platynus opaculus* ecology although it evidently is extremely hygrophilous. Davidson and Bell (1977) reported many captures in wetland sites of several Vermont counties. They found adults under loose bark of dead trees, stumps and logs protruding from spring floodwaters. Beetles they disturbed often descended quickly below the waterline to depths of 25 cm. where they remained motionless for several minutes before surfacing. It was also found in an abandoned beaver lodge in Quebec (Lindroth 1969).

We found the recent European immigrant, *Bembidion obtusum*, in an agricultural setting in south central Michigan, the westernmost record for this recently introduced (Lindroth 1963) ground beetle.

Our records of *Harpalus katiae* are the most northern for this species, the subject of a recent taxonomic review by Will (1997), who suggested it is more stenotopic than its closely related congener, *H. caliginosus* (F.). He noted it has moved northward along major river systems, perhaps exploiting sandy alluvial habitats.

From west central Illinois we report by far the most disjunct collection of the rare putative myrmecophile, *Helluomorphoides nigripennis*, known previously from along the Atlantic coast from Massachusetts to Texas (Ball 1956). Several congeners in southwestern states accompany doryline army ants (Hymenoptera: Formicidae: Dorylinae), feeding on immatures (Wilson 1971), but apparently nothing is known of *H. nigripennis* biology (Davidson 1995). Two army ant species are recorded from Illinois: *Neivamyrmex nigrescens* (Cresson) from Adams, Pulaski and Union Counties, and *N. carolinensis* (Emory) from Pope County; a third [*N. opacithorax* (Emory)] probably occurs in the state (DuBois 1988).

Another very anomalous distribution record is that of a male *Chlaenius amoenus* from northeastern Iowa. This species, [in the *emarginatus* group of Bousquet and Larochelle (1999) with produced mandibles], has a less than certain taxonomy. According to Robert L. Davidson (pers. comm.), *amoenus* Dejean may correctly apply to another *emarginatus* group species that more closely resembles *C. pusillus* Say. This implies that the *Chlaenius* we found may be undescribed (the Dejean type needs to be examined). Until now it has
been reported only from Mississippi, Alabama and up the Atlantic coast from Florida to Virginia (Bousquet and Larochelle 1993).

We hope this report will encourage field study of ground beetle assemblages at more sites in the upper Midwest, especially in ecologically fragile areas such as small wetlands where building development pressures degrade habitats and erode biodiversity at high rates. For us to uncover 18 new state records for Illinois in two wetland enclaves close to metropolitan Chicago, thereby increasing the known state Carabidae fauna by 4%, should be a strong incentive for further such surveys. Some ground beetles found there (of 139 species) are rarely encountered anywhere, and may represent vulnerable relict populations (Purrington and Davidson 2000).

Additionally, we note that since 1997 the known ground beetle fauna of Iowa has been expanded more than 7.3% by adding 24 new records, all from counties in the northeastern corner of the state (Purrington and Larsen 1997). In Wisconsin, similar efforts have added a total 14 new records, increasing the reported fauna by 3.7% (Purrington and Maxwell 1998).

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LITERATURE CITED


LIBELLULA FLAVIDA (ODONATA: LIBELLULIDAE),
A DRAGONFLY NEW TO OHIO

Tom D. Schultz

ABSTRACT

Libellula flavida, a widespread but uncommon dragonfly of southeastern and south central North America, is now recorded from Ohio. A breeding population was discovered in an acidic fen on the site of a sandstone quarry in southern Ohio.

Libellula flavida Rambur (Odonata: Libellulidae), the Yellow-sided Skimmer, is a medium-sized libellulid dragonfly with pale yellow sclerites on the sides of the adult pterothorax. Little has been written about this species, but records indicate a range extending from the mid-Atlantic coast, across the south, to the south-central plains states (Needham et al. 2000). Although there are a few records for neighboring Kentucky (Carl Cook, pers. comm.), $L. flavida$ had never been collected in Ohio despite extensive surveys for odonates over the last decade (Glotzhober 1995, 1999, Glotzhober et al. 1995).

This paper documents the discovery of a breeding population of $L. flavida$ in Pike County, Ohio. Two adult males were first collected by the author on 24 August 1998 at a sphagnum bog located 0.5 km north of Jackson Lake along the Jackson/Pike County line (39°6.48’N, 82°47.70’W). Upon returning to the site on 24 July 1999, several adults of both sexes were collected including a few males exhibiting immature coloration.

The dragonflies were concentrated around a small sphagnum fen within a large sand mine that ceased operation in 1965 (Kritsky et al. 1999). The fen was situated on a terraced slope on the east side of the quarry. Groundwater seeped from the base of an excavated wall of Sharon Conglomerate sandstone and flowed slowly through a sphagnum mat approximately 0.5 hectare in area. In addition to Sphagnum cuspidatum Ehrh. ex Hoffm, the following plants were common throughout the fen: hardhack (Spiraea tomentosa), cattail (Typha latifolia), common arrowhead (Sagittaria latifolia), rush (Juncus effusus and J. acuminatus), bulrush (Scirpus purshianus), beakrush (Rhynchospora capitellata), Joe-Pye-Weed (Eupatorium perfoliatum), and boneset (Eupatorium maculatum).

Males of $L. flavida$ flew patrol flights over the fen and alighted frequently on stems in a manner similar to that of $L. lydia$ (Campanella and Wolf 1974). On several occasions, males were observed to seize females in flight and copulations took place while the pairs were perched. Females were observed to oviposit exophytically by hovering over open channels of water and striking the surface intermittently with their abdomens. The pH of the

1Department of Biology, Denison University, Granville, OH 43023.
water at six oviposition sites ranged from 4.4 to 7.3 with a mean of 5.8 (S.D. = 1.12). Several larvae collected from the fen were later identified as *L. flavida* (Eric Chapman, pers. comm.), confirming that the population is breeding at this site.

Several other odonates were present but uncommon around the wetland. Single adult individuals of the dragonflies *Libellula lydia* Drury, *Libellula luctuosa* Burmeister, and *Erythemis simplicollis* (Say) as well as the damselfly *Enallagma aspersum* (Hagen) were present in July 1999. During the visit to the site in August 1998, male *Somatochlora tenebrosa* (Say) were observed patrolling territories amidst the cattails of the fen. A search of the shoreline of nearby Jackson Lake yielded numerous *Libellula cyanea* Fab. and *Libellula incesta* Hagen, but no *L. flavida*.

**DISCUSSION**

Although very little has been published about the ecology of *L. flavida*, there is consistent anecdotal evidence that this species has an affinity for acid bogs and seepages. This species has been found at acidic bogs in Arkansas (Farris and Harp 1982), South Carolina, Virginia, and northwest Florida. In southern New Jersey, *L. flavida* is found exclusively at acid bogs with sphagnum, especially old cranberry bogs (Bob Barber, pers. comm.). However, *L. flavida* has also been collected at calcareous fens and sand bottomed streams.

Abandoned sandstone quarries are known to foster the development of pioneer sphagnum bog communities and serve as refugia for native bog plants in Ohio (Andreas and Host 1983). Similarly, the sandpiles of several abandoned mines in southern Ohio have been colonized over the past 50 years by tiger beetle species whose habitat is otherwise scarce in the region (Kritsky et al. 1999). It appears that these manmade habitats have provided the conditions that enabled the establishment of *L. flavida* in southern Ohio. Other sandstone quarries are common throughout southern Ohio and should be investigated for the presence of *L. flavida*. A comparison of wetland habitats where this uncommon species does and does not occur may improve our knowledge of its ecological niche.

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**LITERATURE CITED**


DISTRIBUTION OF FIRST INSTAR GYPSY MOTHs 
(LEPIDOPTERA: LYMANTRIIDAE) AMONG SAPLINGS OF 
FOUR TREE SPECIES COMMON IN THE GREAT LAKES REGION 

J. L. Stoyenoff$^{1,2}$ and J. A. Witter$^2$

ABSTRACT

We examined the inter-tree distribution of first instar gypsy moth larvae under natural dispersal conditions in the field in Michigan in 1991. The study focused on saplings of northern red oak (Quercus rubra), white oak (Q. alba), red maple (Acer rubrum), and witch-hazel (Hamamelis virginiana), which are common understory components of forests in the Great Lakes region. Large-volume trees with foliage that is well-developed early in the spring should provide an excellent surface area for catching newly-hatched gypsy moth larvae, which are randomly dispersed by wind in the spring around the time of leaf flush or shortly thereafter. Comparing across tree species in our study, red maples had the largest crown volumes and well-flushed leaf material, but very few larvae were found on these trees at both sampling times in mid-May. Despite the lack of larvae on red maple, these trees were liberally covered with gypsy moth silk, indicating that many larvae landed on these plants but left rapidly when they apparently found the trees to be an unacceptable food source. Among the other three tree species, patterns of larval distribution reflected levels of host phenological development during both sampling periods, with more insects occurring on tree species that had more advanced leaf development. The highest numbers of larvae were found on northern red oak and witch-hazel. Intermediate numbers of insects were present on white oak. Trends in insect distribution also paralleled patterns seen in tree phenology across slope gradients. Defoliation ratings corresponded well to measures of first instar presence for each tree species. Northern red oak and witch-hazel trees experienced more early defoliation on average than did red maple and white oak. For those tree species that are acceptable hosts of the gypsy moth, average level of phenological development for a given tree, species, or forest stand at the time of larval dispersal can be an important predictor of plant or stand susceptibility to gypsy moth establishment and subsequent defoliation.

Gypsy moth (Lymantria dispar (L.)) larvae are broadly polyphagous, feeding on 300 different host species (Leonard 1981). In many lepidopterans, choice of the larval food plant is made by the ovipositing adult female. Gypsy moth females, however, are relatively unselective about where they lay their egg masses, readily depositing them even on inedible objects such as rocks,
stumps, and recreational vehicles (Lance 1983). When larvae hatch in spring, they must find their own food. By spinning silk threads, larvae are able to balloon on the wind in an attempt to find an acceptable host plant. Studies of larval behavior have reported that all healthy larvae will undergo at least one such ballooning dispersal, and larvae will generally balloon again if they land on an unsuitable substrate (Lance and Barbosa 1981, Capinera and Barbosa 1976, van der Linde 1971). Typically at the time of gypsy moth first instar larval dispersal in Michigan, tree phenology varies among tree species and individual trees on a given site from tight buds to flattened, expanding leaves (Chilcote 1990, Chilcote et al. 1992).

Several factors affect whether dispersing larvae will encounter a given plant. These include characteristics of the plant community, plant location relative to wind patterns and obstacles, plant size and branchiness, and the level of phenological development of foliage (Stanton 1983, Feeny 1976). Tendency to remain on a particular plant once it is encountered may be affected by factors such as plant species, phenological stage of the foliage, density of larvae on the plant, and the level of food reserves available for re-dispersal attempts remaining in the larva's body.

Some aspects of dispersal by first instar gypsy moth larvae have been more thoroughly investigated, such as the effects of velocity and turbulence of air currents on larval movement, dispersal distances, and settling (Zlotina et al. 1999, Fosberg and Peterson 1987, Taylor and Reling 1986, Mason and McManus 1981, McManus 1973). The effects of differing plant characteristics on dispersal activity and distribution of young larvae within a stand is another important aspect which encompasses many factors (Naidoo and Lechowicz 1998, Weseloh 1998, Ticehurst and Yendol 1989, Lance and Barbosa 1981, Barbosa 1978a, van der Linde 1971). In particular, understanding has been incomplete relative to ways in which the stage of foliar phenological development may affect gypsy moth larval distribution among trees during the ballooning first instar dispersal phase. We undertook this study to examine how first instar gypsy moth larvae are distributed among saplings of various common tree species in the field and how this distribution may be related to patterns of host phenological development.

**MATERIALS AND METHODS**

**Study site and trees.** This study was performed in 1991 at a moderately mesic site dominated by 15 to 20 year old trees of northern red oak (*Quercus rubra*), white oak (*Q. alba*), bigtooth aspen (*Populus grandidentata*), trembling aspen (*P. tremuloides*), red maple (*Acer rubrum*), and witch-hazel (*Hamamelis virginiana*) in Kalkaska County, Michigan (T25N, R6W, S26). The vegetation in this area tended to be somewhat open. The site was situated on a slope, so that study trees fell into one of three locations: lower slope (elevation of 353 m), midslope, or hilltop (elevation of 385 m) areas. Natural gypsy moth egg masses were moderately abundant throughout the site. Five minute walks through the site (Eggen and Abrahamson 1983) in each of the three slope locations yielded egg mass counts of 100, 134, and 143 in upper, mid, and lower slope areas, respectively.

The plant material selected for study consisted of 19 saplings of northern red oak and 20 saplings each of white oak, red maple, and witch-hazel. All study species were represented in each of the three slope locations, except in the midslope area where northern red oak trees of the appropriate size and exposure (see below) were not available. Neither aspen species present at the
site was used in this study due to lack of trees of the appropriate size and exposure in the necessary locations.

We chose these particular tree species for study because they are common throughout the Great Lakes region and represent a range of foliage conditions at the time of gypsy moth dispersal from tight buds to flattened, expanding leaves, as well as a range of suitability for gypsy moth larvae from low to high (Chilcote 1990, Chilcote et al. 1992). We used understory-sized trees both to increase ease of sampling and because research by Ticehurst and Yendol (1989) has demonstrated that more than 80% of all early instar gypsy moth larvae may be found in the lower canopy, understory, and forest floor during both day and night.

Because tree volume is an important component of how apparent any given plant is to food-seeking herbivores, we attempted to choose experimental trees that were naturally of similar sizes (Lance 1983). Some pruning was done during April 1991 on almost all study trees from the ground or from ladders to remove portions of branches that extended beyond the height that could easily be viewed from a 2.5 m ladder (average total tree height after pruning: 2.35 ± 0.26 m for witch-hazel, 2.82 ± 0.29 m for northern red oak, 2.88 ± 0.30 m for white oak, and 3.19 ± 0.34 m for red maple). No sample trees were pruned heavily, however. After all pruning was completed, the diameter of each tree crown was measured in two directions and averaged, and the crown height and total tree height were each estimated to the nearest 0.3 m. The crown height and average crown diameter were used in the equation of volume for a cone to estimate the volume for each tree crown.

Trees selected for use in the study were in relatively exposed locations so that larvae could readily blow onto them but could not crawl or drop onto the experimental trees from other overhanging trees. In a few cases, portions of nearby large trees were pruned away to avoid blockage of study trees and to help equalize amounts of exposure. Before eggs began hatching in May in the area of the study site, the study trees were inspected for gypsy moth egg masses, which were scraped off when encountered. Also, circles of forest floor at least 2 m in diameter around each sample tree were cleared of all woody debris and leaf litter prior to egg hatch. This helped isolate study trees from sources of potential colonizers in the forest floor litter, since egg masses may be found there as well. These measures were taken so that caterpillars encountered on the trees during the course of the experiment could reasonably be expected to have reached the trees through aerial dispersal activity, rather than being present simply because a given tree was in direct contact with or in close proximity to a large number of egg masses.

**Sampling procedures.** Daily monitoring revealed that peak egg hatch occurred at the study site on 12 May 1991. The weather was very warm and dry (12 May maximum: 27°C, minimum: 16°C), and larvae began to disperse soon after hatch. By the following day, a large portion of the larvae were moving about among potential host plants at all levels of the slope.

We began the first sample of the study trees during mid-morning of 13 May. Each tree was given an overall rating of leaf development according to the phenological scoring system employed by Chilcote (1990) (Table 1), and a complete count was made of all larvae located anywhere on the tree from the groundline to the tips of the branches. To be counted, larvae had to be in direct contact with the bark or leaves of the tree; larvae suspended from branches by silk strands were not included in the counts. Upper portions of the trees were inspected with the help of 2.5 m ladders, which allowed us to easily view all branches. As larvae were counted, they were removed from the tree and killed. The first sample of all 79 trees was completed on 14 May.

A second sample was planned to take place near the end of major gypsy...
Table 1. Phenological scoring system for budbreak and leaf expansion of hardwood trees based on Chilcote (1990).

<table>
<thead>
<tr>
<th>Score</th>
<th>Foliar Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Winter condition; buds tight.</td>
</tr>
<tr>
<td>2</td>
<td>Buds swelled but no expansion of scales.</td>
</tr>
<tr>
<td>3</td>
<td>Buds and scales expanding.</td>
</tr>
<tr>
<td>4</td>
<td>Scale expansion greater than 2 mm.</td>
</tr>
<tr>
<td>5</td>
<td>Leaf material showing at tip of bud.</td>
</tr>
<tr>
<td>6</td>
<td>Leaves exposed beyond scales but blades not flat.</td>
</tr>
<tr>
<td>7</td>
<td>Leaves exposed and blades flattened.</td>
</tr>
<tr>
<td>8</td>
<td>Leaves expanding and soft.</td>
</tr>
<tr>
<td>9</td>
<td>Leaves expanding and tough.</td>
</tr>
<tr>
<td>10</td>
<td>Leaves fully expanded and tough; dark and leathery.</td>
</tr>
</tbody>
</table>

moth egg hatch and dispersal at the field site in order to confirm patterns seen at the first sample. Warm temperatures and steadily increasing degree day accumulations during mid-May (Fig. 1) facilitated a rapid hatch. Observations of egg masses in the area indicated that most eggs were hatched by 16 May. Therefore, trees were sampled a second time on 16–17 May, using the same procedures and following the same pattern through the site. On 18 May, percent defoliation of each study tree was scored as one of five classes based on visual estimation of all foliage on each tree (1 = defoliation < 10%, 2 = 11–25% defoliation, 3 = 26–50% defoliation, 4 = 51–75% defoliation, and 5 = 76–100% defoliation).

**Statistical procedures.** Statistical analyses were performed with the General Linear Models procedure in SAS (SAS 1996). A two-factor analysis of variance (ANOVA) design was used, which included factors of tree species, slope location, and the interaction of these factors. The sampling unit was individual trees (20 for each species, except 19 for northern red oak).

Assumptions were tested using plots of residuals versus predicted values, normal probability plots, stem-and-leaf plots, and skewness and kurtosis coefficients. Where necessary, log transformations were performed on the data before analysis to more closely meet assumptions of normality and homogeneity.

Scheffe's multiple comparison procedure was used in the evaluation of the data. This procedure was employed for tests of all pair-wise comparisons because its relatively low power reduces the risk of Type I errors occurring in the inferences made. An experiment-wise α of 0.05 was used.

**RESULTS**

Average tree volume differed significantly among tree species (F = 4.13; df = 3, 68; p = 0.01). Red maple trees had the greatest average volume, although their volume was significantly different only from northern red oak trees with Scheffe's multiple comparison procedure (Table 2). Volume was not significantly affected by slope location (F = 0.60; df = 2.68; p = 0.55) or the interaction of species and slope location (F = 0.79; df = 5.68; p = 0.56).

Average tree phenology on the first sampling date (13–14 May) was significantly affected by species (F = 25.07; df = 3, 68; p = 0.0001) and slope location (F = 12.26; df = 2.68; p = 0.0001). Leaf flush of white oak trees was delayed compared to the other tree species (Table 2). White oaks had an
Figure 1. Weather data recorded at the National Oceanic and Atmospheric Administration weather station in Kalkaska, Michigan, USA.
Table 2. Plant characteristics and presence of first instar gypsy moth larvae on four tree species at two sampling times during May 1991.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Red maple</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>20</td>
</tr>
<tr>
<td>Mean crown volume (m$^3$)</td>
<td>1.31 ± 0.14 a</td>
</tr>
<tr>
<td><strong>Sample 1 (13–14 May 1991):</strong></td>
<td></td>
</tr>
<tr>
<td>Mean phenological rating$^a$</td>
<td>6.8 ± 0.1 ab</td>
</tr>
<tr>
<td>Mean larvae/tree</td>
<td>51.5 ± 7.7 b</td>
</tr>
<tr>
<td>Mean larvae/m$^3$ of crown</td>
<td>44.6 ± 7.1 c</td>
</tr>
<tr>
<td><strong>Sample 2 (16–17 May 1991):</strong></td>
<td></td>
</tr>
<tr>
<td>Mean phenological rating$^a$</td>
<td>7.4 ± 0.1 b</td>
</tr>
<tr>
<td>Mean larvae/tree</td>
<td>14.5 ± 2.2 c</td>
</tr>
<tr>
<td>Mean larvae/m$^3$ of crown</td>
<td>13.2 ± 2.6 c</td>
</tr>
<tr>
<td>Mean defoliation rating$^b$</td>
<td>1.0 ± 0.0 c</td>
</tr>
</tbody>
</table>

Means within each row followed by the same letter do not differ significantly with Scheffe's multiple comparison procedure.

$^a$1 = Winter condition buds; 2 = Buds swelled, no scale expansion; 3 = Buds and scales expanding; 4 = Scale expansion > 2 mm; 5 = Leaf material at tip of bud; 6 = Leaves exposed beyond scales, blades not flat; 7 = Leaves exposed, blades flat; 8 = Leaves expanding and soft; 9 = Leaves expanding and tough; 10 = Leaves fully mature. (Modified from Chilcote (1990).)

$^b$1 = defoliation < 10%, 2 = 11–25% defoliation, 3 = 26–50% defoliation, 4 = 51–75% defoliation, and 5 = 76–100% defoliation.
Average phenology of stage 5 (leaf material just showing at the tip of the bud) as compared to averages of stage 6 (leaves exposed but not flattened) to stage 7 (leaves exposed and flattened) for the other species. In terms of slope location, leaf flush of lower slope trees was significantly delayed compared with mid-slope and upper slope trees (lower slope = 5.7 ± 0.2 a; mid-slope = 6.3 ± 0.2 b; upper slope = 6.7 ± 0.1 b, different letters indicate mean values significantly different with Scheffe's multiple comparison procedure). The interaction of tree species and slope location was also significant in relation to tree phenology (F = 3.45; df = 5.68; p = 0.01).

Average number of larvae per tree at the first sampling period also was significantly affected by tree species (F = 61.58; df = 3, 68; p = 0.0001). At that time, northern red oak and witch-hazel trees had significantly more larvae present on them on average than did trees of either white oak or red maple (Table 2). Slope location significantly affected number of larvae present on trees as well (F = 10.94; df = 2.68; p = 0.0001), with an increase in number of larvae per tree as one progressed up the slope (lower slope = 127.6 ± 31.5 larvae/tree a; mid-slope = 256.0 ± 54.9 larvae/tree b; upper slope = 467.5 ± 59.0 larvae/tree c). The interaction of species and slope location was also significant (F = 2.97; df = 5.68; p = 0.02).

Examining insect presence on the basis of number of larvae per unit volume of tree crown revealed results that were very similar to the results for absolute number of larvae per tree. Average number of larvae per unit volume of tree crown at the first sampling period was significantly affected by tree species (F = 67.20; df = 3, 68; p = 0.0001). Northern red oak had the greatest average number of larvae per unit volume followed by witch-hazel, and the figures were significantly larger on each of these species than on either white oak or red maple, which were not significantly different from one another (Table 2). Slope location also significantly affected average number of larvae per unit volume of tree crown (F = 6.11; df = 2.68; p = 0.004), with increasing values as one progressed up the slope (lower slope = 207.3 ± 71.6 larvae/unit volume a; mid-slope = 328.4 ± 70.5 larvae/unit volume b; upper slope = 640.6 ± 97.7 larvae/unit volume c). The interaction of species and slope location was significant as well (F = 3.47; df = 5.68; p = 0.01).

At the second sampling period (16–17 May), average tree phenology was once again significantly affected by tree species (F = 21.73; df = 3, 68; p = 0.0001), with white oak trees still significantly behind the others in terms of average phenological stage (Table 2). Biologically, however, the average phenological condition of the white oak trees indicated that they were beginning to be more suitable as food for the caterpillars at this point. White oak trees now had an average phenology of stage 6 to 7 (leaves fully exposed beyond bud scales with leaf blades not yet flat to blades exposed and flattening), as compared to the average white oak phenology at the first sampling period of a stage 5 (leaf material just showing at the tip of the bud). Slope location also significantly affected average phenology at the second sample date (F = 12.75; df = 2, 68; p = 0.0001). Mean phenological stage, averaged across all trees in the study, increased as one progressed up the slope (lower slope = 7.0 ± 0.1 a; mid-slope = 7.4 ± 0.1 b; upper slope = 7.8 ± 0.1 c). The interaction of species and slope location was also significant (F = 2.34; df = 5, 68; p = 0.05).

Average absolute number of larvae present on the study trees at the second sampling period was significantly affected by tree species (F = 128.60; df = 3, 68; p = 0.0001). Northern red oak and witch-hazel trees had the greatest numbers of larvae per tree on average, and the numbers on these species were significantly greater than the numbers on white oak (Table 2). Numbers of larvae on red maple were significantly lower than numbers of larvae on any other tree species. At this second sampling period, average numbers
of larvae per tree were not significantly affected by slope location \( (F = 2.25; \text{df} = 2, 68; p = 0.11) \) or an interaction of species and slope location \( (F = 1.87; \text{df} = 5, 68; p = 0.11) \).

Results based on number of larvae per unit volume of tree crown at the second sampling period were once again very similar to the results for absolute numbers of larvae per tree. Average number of larvae per unit volume of tree crown was significantly affected by tree species \( (F = 156.92; \text{df} = 3, 68; p = 0.0001) \), with values being greatest on northern red oak and witch-hazel, which were not significantly different from each other (Table 2). These were followed by the significantly lower figure on white oak and finally the average number of larvae per unit volume of tree crown on red maple, which was significantly lowest of all species. Average number of larvae per unit volume of tree crown was not significantly affected by slope location \( (F = 0.75; \text{df} = 2, 68; p = 0.48) \) but was affected by the interaction of species and slope location \( (F = 2.80; \text{df} = 5, 68; p = 0.02) \).

Average defoliation levels were significantly affected by tree species \( (F = 124.67; \text{df} = 3, 68; p = 0.0001) \) and ranged from <10% to >50% (Table 2). High defoliation levels were due to the large number of gypsy moth caterpillars per tree on certain species and the small size of leaves early in the season. Slope location also significantly affected defoliation levels \( (F = 10.27; \text{df} = 2, 68; p = 0.0001) \). Effects of slope location on defoliation followed the general pattern seen for tree phenological development and numbers of larvae present, with lower defoliation occurring on the lower slope and increasing defoliation as one moved up the slope (lower slope=1.5 ± 0.1 a; midslope=2.0 ± 0.3 b; upper slope = 2.9 ± 0.2 c; where class 1 = defoliation < 10%, class 2 = 11–25% defoliation, class 3 = 26–50% defoliation, as described above). Tree species and slope location significantly interacted to affect defoliation as well \( (F = 3.18; \text{df} = 5, 68; p = 0.01) \).

**DISCUSSION**

Work by others has shown that oaks are highly favored host plants of the gypsy moth, but maples are not very acceptable or suitable hosts, which is perhaps due to the presence of toxic/deterrent chemicals in maple foliage (Barbosa et al. 1990, Martinat and Barbosa 1987, Lance 1983, Barbosa and Greenblatt 1979, Barbosa et al. 1979, Barbosa 1978a, 1978b). However, red maples often tend to be among the earlier flushing tree species in the Great Lakes region and in our study ranked highest in terms of average volume. Large-volume trees that flush early and have relatively large leaves should provide an excellent surface area for catching insects that are randomly dispersed by the wind, and one might expect to find high numbers of larvae on such trees. Despite this, the number of larvae present on red maple trees in our study was very low at both sampling times, both in terms of absolute numbers and on the basis of mean larvae per m³ of crown. A qualitative examination revealed that red maple buds and branch tips were often covered with more insect silk than was true for trees of other species except for white oaks with very delayed phenology, on which the amount of silk appeared similar to that seen on red maple. The large amount of silk observed on red maple trees indicates that they were probably encountered by many larvae. However, since we found very few larvae remaining on the trees it is likely that larvae may have re-dispersed in search of different host material. Because few larvae were located on this species, it suffered very little defoliation on average during the study period. Research by others has demonstrated that young gypsy moth larvae do disperse rapidly and with high

While there are other factors that also come into play when insects choose among relatively favored host species, match of optimal host phenology to insect activity is one important factor. An appropriate level of phenological development means that adequate leaf material in suitable condition for feeding is available (Stoyenoff et al. 1994a, Raupp et al. 1988). Level of phenological development is also related to other important characteristics of the foliage, such as nutrient and water content, toughness, and levels of defensive compounds (Hunter and Lechowicz 1992, Hough and Pimentel 1978, Feeny 1976). Many workers have found that plant phenology is a major factor affecting insect host use (Parry et al. 1998, Kolb and Teulon 1992, Crawley and Akhteruzzaman 1988, Larsson and Ohmart 1988, Raupp and Denno 1983, Mitter et al. 1979, Schweitzer 1979, Witter and Waisanen 1978, Hollday 1977, Feeny 1970, Greenbank 1956).

For those species that are acceptable hosts of the gypsy moth, average level of phenological development seen on a given tree, species, or forest stand at the time of larval dispersal may be one important predictor of plant or stand susceptibility to insect establishment and subsequent defoliation. We found that numbers of insects present on acceptable host species tended to strongly follow patterns seen in plant phenology, with more insects occurring on tree species that had advanced leaf development. For instance, at the first sampling period, northern red oaks had on average leaf material free of the bud scales and flattening out, witch-hazels had leaf material free of the bud scales but on average more folded, and white oaks had much leaf material still surrounded by bud scales with only some tightly folded leaf material showing at the tips of the buds. Northern red oaks at this sample had a high number of larvae present on them on average, witch-hazels had a slightly lower number, and white oaks had a much lower number. This was true both in terms of absolute numbers of larvae per tree and number of larvae per unit of crown volume.

In the case of the significant increase in insect numbers on white oak between the first and second sampling times, the phenological changes that took place over this time period greatly altered the usefulness of these plants to young gypsy moth caterpillars. However, while this phenological change may be very important, it is inadequate to elevate numbers of insects found on white oak to the level found on the other acceptable host species. At stage 6, white oak leaves are still covered by many dense trichomes, and the presence of trichomes has been shown to inhibit feeding in some cases of plant-insect interactions (Agrawal 1999, Zvereva et al. 1998, Dix et al. 1996, Kanno 1996, Oghiakhe 1995, Wright and Giliomee 1992, Gross and Price 1988, Khan et al. 1986, Hardin 1979, Johnson 1975, Levin 1973). This factor may be coming into play here. By contrast, northern red oak trees at the second sample date were about 1.5 stages more advanced than white oak on average and had expanding, soft, young leaves that had shed any trichome covering. While it is possible that insect numbers were higher on northern red oak because the more phenologically advanced northern red oak leaves had larger flattened leaf surfaces available for catching larvae than did white oak, we repeatedly observed that the lower-phenology white oak trees were covered with more caterpillar silk than were the northern red oak trees, indicating that large numbers of larvae were also encountering the white oak trees but some were leaving in search of more highly acceptable food sources.

Average defoliation levels observed for the various tree species in this study indicate that northern red oak and witch-hazel were very acceptable food sources to the larvae, and they ate large fractions of the leaf material on
these species. Since white oak leaves were on average less developed and smaller than leaves of northern red oak and witch-hazel by the date defoliation was evaluated, it would have been possible for the white oaks to score higher in terms of defoliation rating even if they were fed on less, due to the fact that white oak trees had less expanded foliage available to begin with (Valentine 1983). Such was not the case, however. Despite larger amounts of foliage present, northern red oaks and witch-hazels scored significantly higher in terms of average defoliation rating than did white oaks in this study. Both white oaks and red maples escaped significant defoliation early on in the season due to various characteristics that led to these plants being less acceptable to young gypsy moth larvae.

Foliage of preferred host species has been shown by others to generally retain higher numbers of gypsy moth larvae than foliage of less preferred species (Lance 1983, Lance and Barbosa 1981, Barbosa 1978a). Based on average number of insects present and average defoliation levels seen in the field in this study, witch-hazel appears to be a very acceptable host species for young gypsy moth larvae, almost as much so as northern red oak. Larvae may use species such as witch-hazel and northern red oak at a time when other species such as white oak or aspens are phenologically behind and are not as acceptable to the insects. The insects can later move on to aspens and white oak as their leaves flush and their acceptability increases (Stoyenoff et al. 1994b, 1994c). Presence of acceptable hosts that are phenologically well timed with caterpillar hatch and early dispersal can therefore increase overall defoliation potential of a stand throughout the season and heighten performance of the gypsy moth in an area.

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COMPARISON OF TWO POPULATION SAMPLING METHODS USED IN FIELD LIFE HISTORY STUDIES OF *MESOVELIA MULSANTI* [HETEROPTERA: GERROMORPHA: MESOVELIIDAE] IN SOUTHERN ILLINOIS

Steven J. Taylor and J. E. McPherson

ABSTRACT

A field life history study of *Mesovelia mulsanti* was conducted in southern Illinois, the results of which are compared with those from an earlier study also conducted in southern Illinois. The two studies differed in the collecting techniques used (quadrat sampler versus aquatic net). Results of the present study give a clearer picture of the life history of this insect because the quadrat sampler collected representative samples of nymphs and adults more effectively than the aquatic net and, thus, the quadrat samples more accurately represented the actual chronology of the annual generations.

The water treader *Mesovelia mulsanti* White occurs from Newfoundland, Nova Scotia, New Brunswick (Scudder 1987), New York, and Massachusetts south to Florida, and west to British Columbia and California; it also has been reported from Mexico to Argentina, the West Indies, and the Hawaiian Islands (Smith 1988). It occurs throughout much of Illinois (Taylor 1996).

*Mesovelia mulsanti* is epipleustonic, inhabiting shaded and unshaded areas, especially standing water with duckweed and algae (McPherson 1988, Taylor 1996). It is predaceous, feeding primarily on insects on the water surface and, possibly, on small organisms that come to the surface from below (McPherson 1988).

This insect’s life history has been studied in southern Illinois (Galbreath 1973, 1975, 1976a, 1976b; McPherson 1988) and elsewhere (e.g., Hoffmann 1932; Hungerford 1917, 1920; Lanciani 1987). However, there is some question about the number of generations per year. In southern Illinois, for example, Galbreath (1973, 1975) stated that this species has five and possibly more generations per year, whereas McPherson (1988) found only three generations and a partial fourth, with eggs apparently overwintering.

McPherson’s (1988) field study was conducted in the La Rue-Pine Hills Ecological Area (now La Rue-Pine Hills Research Natural Area) in Union Center for Biodiversity, Illinois Natural History Survey, 607 East Peabody Drive, Champaign, Illinois 61820-6970.

2Department of Zoology, Southern Illinois University at Carbondale, Carbondale, Illinois 62901-6501.
County from 1983 to 1986. Specimens were collected with a 0.33 m-wide aquatic net at approximately weekly intervals during the active season (April to November). Data from the four years were combined to gain a better understanding of the annual life cycle. However, there is some question about the reliability of his data because of problems inherent in the use of an aquatic net (i.e., smaller specimens are more likely to be overlooked) and because the study was part of a larger qualitative study of both the semi-aquatic and aquatic Heteroptera. For this larger study, sweeps collected material below and on the surface of the water simultaneously and included aquatic vegetation, detritus, and insects. There was no attempt to limit sweeps to the surface of the water and, therefore, detecting the earlier instars of *M. mulsanti* (1st instars averaged less than 1.00 mm in length [unpublished data]) in samples containing much organic debris was difficult. As would be expected, the number of adults collected represented an artificially high percentage of the total number of individuals collected during the study (2,239/5,092; 44%).

This paper results from a larger study of the biology of the Gerromorpha in Illinois (Taylor 1996). As a part of that project, we studied the life histories and microhabitat distributions of several species (including *M. mulsanti*) during 1989 and 1990 at President's Pond on the campus of Southern Illinois University at Carbondale, Jackson County, Illinois. President's Pond is roughly triangular, with a surface area of approximately 0.29 hectare (0.72 acre) (see Taylor [1996] and Taylor and McPherson [1998a, 1998b, 1999] for detailed description of pond).

The collecting technique for President's Pond was designed specifically to sample all gerromorphan instars, regardless of size. Because McPherson's (1988) study was conducted only 25 km southwest of President's Pond, we were able to compare our results and collecting techniques with his. Therefore, the purposes of this paper are to present the results of our study of the annual life cycle of *M. mulsanti* at President's Pond, compare the efficacy of the collecting technique with that of McPherson (1988) for sampling nymphal and adult stages, and examine the influence of these techniques on our ability to distinguish between generations.

### MATERIALS AND METHODS

Samples were collected weekly from 18 March to 25 November 1989 and, because of overcollecting in 1989, biweekly from 11 February to 2 December 1990. Sampling was limited to an area along the eastern shore because (1) the cattails along the western shoreline prevented use of the quadrat sampler (see below); (2) the riprap shoreline of the southern border was unnatural and, often, disturbed by fishermen; and (3) the water surface along the eastern shore, which was a mosaic of open water, duckweeds, and emergent stems, supported a diverse gerromorphan fauna.

Four 60 m transects were made parallel to a relatively uniform section of the eastern margin at 0, 0.5, 1.0, and 1.5 m from the shoreline. Each sample was collected with a floating quadrat sampler (0.25 x 0.25 x 0.05 m) (see Taylor 1996), with four replicates placed randomly along each transect; the resulting 16 quadrat samples were pooled, providing a broad sampling of the habitat. Prior to each sample, the collector (SJT) stood for approximately 3 minutes to allow the insects to acclimate to the disturbance; then, the sampler was placed on the surface of the water. Epiphiestonic arthropods were removed with a fine mesh nylon net (0.42 mm diam. mesh openings), preserved in alcohol, and sorted in the laboratory by instar, and, ad-
RESULTS AND DISCUSSION

*Mesovelia mulsanti* apparently overwinters as eggs. Combining data from 1989 and 1990, first instars were found from late April through mid-September, second instars from mid-April through late September, third instars from late April through late September, fourth instars from late April...
Table: Percent in each sample of total individuals of same stage of *Mesovelia mulsanti* collected at President's Pond, Southern Illinois University at Carbondale campus, Jackson County, during 1989. Beginning and end points of each shaded area represent sample dates preceding and following collection of specimens, respectively.

Figure 2. Percent in each sample of total individuals of same stage of *Mesovelia mulsanti* collected at President's Pond, Southern Illinois University at Carbondale campus, Jackson County, during 1989. Beginning and end points of each shaded area represent sample dates preceding and following collection of specimens, respectively.

through late September, fifth instars from late April through late September, and adults from early May through early November (Figs. 1-4).

The number of generations per year was difficult to determine although apparently there were four or five. Hoffmann (1932), under uncontrolled laboratory conditions, reported nymphal development averaged 20.02 days; whereas Lanciani (1987), under controlled conditions (28°C, 12L:12D photoperiod), reported it averaged 13.38 days. Because these insects are active from April to November in Illinois (McPherson 1988, Taylor 1996), and developmental time varies with changes in temperature (Galbreath 1975), the short generation time reported by Lanciani (1987) suggests that the active season is of sufficient length to allow four or five generations per year in southern Illinois.

McPherson (1988) reported three generations and a partial fourth. Al-
Figure 3. Percent of individuals in each stage per sample of *Mesovelia mulsanti* collected at President's Pond, Southern Illinois University at Carbondale campus, Jackson County, during 1990. Beginning and end points of each shaded area represent sample dates preceding and following collection of specimens, respectively.

though it might seem that his study would have been more thorough because it was conducted over four years rather than two, voltinism was determined by combining the data across all years into a single year because the numbers of early instars were low. In addition, sample dates varied slightly from year to year, and, therefore, samples from the four years were lumped into weekly samples (JEM, unpublished data). Therefore, it is likely that the peaks corresponding to generations were obscured.

As discussed earlier, McPherson (1988) collected aquatic and semiaquatic Heteroptera with an aquatic net, whereas the present study used a quadrat sampler. Because sampling was limited to the epipleuston in the present study, samples were relatively free of organic debris compared to those collected in McPherson's (1988) study. Comparisons of the numbers of nymphal instars and the adults showed that the quadrat sampler collected representa-
Figure 4. Percent in each sample of total individuals of same stage of *Mesovelia mulsanti* collected at President's Pond, Southern Illinois University at Carbondale campus, Jackson County, during 1990. Beginning and end points of each shaded area represent sample dates preceding and following collection of specimens, respectively.

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Figure 5. Life stage distribution (percent of individuals) for *Mesovelia mulsanti*. A—specimens collected with quadrate sampler in 1989 at President's Pond, Southern Illinois University at Carbondale campus, Jackson County. B—specimens collected with aquatic net from 1983 to 1986 at La Rue-Pine Hills Research Natural Area, Union County (McPherson 1988).

LITERATURE CITED


Taylor, S. J. 1996. Habitat preferences, species assemblages, and resource partitioning by Gerromorpha (Insecta: Heteroptera) in southern Illinois, with a faunal list and
keys to species of the state. Ph.D. Dissertation, Department of Zoology, Southern Illinois University at Carbondale.


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