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*Dolomedes sexpunctatus* Hentz (Araneae: Pisauridae) feeding on a male *Ischnura ramburii*  
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Attempts to understand the origin of Linnaeus’ name for the scorpionfly Panorpa have come to nought for a very good reason. The word does not mean anything at all. It is an interesting example of the futility of looking up names in a Latin or Greek dictionary to find their meaning when the history of the word is at all complicated. The word Panorpa is born of a series of taxonomic, philological, grammatical, and (perhaps) typographical errors which can be sorted out by a survey of the pre-Linnaean history of the word and of the insect. In order to keep the end in view throughout the argument that follows, the reader may be gratified to anticipate the conclusion that Panorpa comes ultimately from the Greek word parnops (genitive parnopos) meaning ‘locust.’

In the pre-Linnaean entomological tradition the scorpionfly was considered a kind of mosquito. Aldrovandus (1602:386-7) includes the scorpionfly in his section De Culicibus, but he is uneasy about it, and reflects that it might be classed as a Perla, by which he means the dragonflies. Many of the insects which Aldrovandus calls culices have four wings instead of two, and he naturally feels that some justification is necessary for the way he classifies them. In his comment on the illustrations which accompany the text he says (Aldrovandus, 1602:387):

“The sixth figure, along with the remaining figures that follow it on the first plate of illustrations, is four-winged. These, along with those pictured on the second plate we include among the mosquitoes [culices] despite the number of their wings, because of the shape of the abdomen, which is not nearly so similar to the flies and other like winged insects, as it is to the mosquitoes. . . . I am very doubtful about the insect in the seventh figure, whether it ought to be classified with the mosquitoes, though usually placed among them at the cost of some precision.”

The illustrations (386) and the description (387) leave no doubt that Aldrovandus is in fact talking about the scorpionfly. The description reads:

“Body about as long as your thumb including the conspicuously long antennae: head like that of a fly, snout with a prominent reddish pipe; wide thorax; abdomen marked with yellow and black; to the end of the tail is attached a sort of annulate part [segments 7-11 of the female abdomen] divided apically [the cerci], which the insect contracts and extends at will; four wings spotted with white and black. The last figure similar to the above in every respect, except the tail [now referring to the male], which is curved up like that of a scorpion. The apical segment of this tail is also thicker, and is armed with two thornlike parts [the dististyles or genital forceps].”

Having shown that the scorpionfly was considered a mosquito, we turn to a remarkable and popular book written by a Neapolitan lawyer of the 16th century, Alexander ab Alexandro, titled Genialium Dierum Libri Sex or Six Books of Pleasant Days, “stuffed with erudition varied and recondite.” It is a compendium of ancient lore and anecdote garnered from the classical authors, and arranged in chapters each of which is a short essay gathering together information on a particular question, such as: How many Vestal virgins were there? (5.12); How did the ancients burn their dead? (3.7); What are the names and the significance of each of the fingers of the hand? (4.26); What Theophrastus said about flute music as a cure for snake-bite (2.17). The format follows that of the Noctes Atticae of Aulus Gellius (2nd century A.D.), and the Pleasant Days is

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1Department of Classical Studies, University of Michigan, Ann Arbor, Michigan 48104.
2Most recently Montgomery (1973:127) in discussing Linnaean names judiciously says nothing about Panorpa.
3The translations from Latin and Greek are my own. The printing of Aldrovandus I have used (1638) has many typographical errors in the Greek, which I have corrected without comment. I have put in square brackets my own explanatory comment, or the transliteration of the original Greek word where that is important.
obviously inspired by Gellius' *Attic Nights.* I know of at least nine editions of this remarkable book between 1522 and 1673, and both Aldrovandus and Moffett used it as a source. Some observations Alexander makes about the cult of Hercules in Boeotia came to have a lasting effect on entomological nomenclature. He says (Alexandro, 1586:1.13):

"The Oetaeans worshipped Hercules Conopius [of the mosquitoes] so that he would not infest the land with mosquitoes [culicibus]. For the Oetaeans called mosquitoes *conopes.* Just as it is said Apollo Culiciarius is worshipped in Attica because he drove the mosquitoes out of the fields... The Boeotians are said to sacrifice to Apollo Pornopion so that he not infest the region with mice. For among them the mouse is called *pornopius.*"

There is a feast of errors in this passage, but it is not altogether the fault of Alexander, who took this information from his reading in the Greek geographer Strabo. The editors and translators of the Greek text of Strabo, on whom Alexander was obliged to rely, must bear the responsibility for the errors. In fact Strabo says nothing about mosquitoes, and nothing about mice.

Aldrovandus succeeded in sorting this all out. By comparing the faulty text of Strabo with a passage in Eustathius' 13th century commentary on the *Iliad,* and with a passage of Pausanias, he made the proper corrections, and showed that Strabo was really talking about *locusts,* not mosquitoes at all. It is a splendid job of textual criticism on his part, and involves both restoring the Greek text and correcting the standard Renaissance translation. It is best to let Aldrovandus speak for himself, but in order to follow the convolutions of the argument it would be well for the reader to keep in mind the following Greek glossary:

1. *kënëps* (genitive *kënëpos*): mosquito.
2. *Kornopion*: Oetaean dialect for *Parnopios* (4) meaning 'of the locusts,' mistranslated by Tifernas 'of the mosquitoes.'
3. *kornop*: (genitive *kornopos*): Oetaean dialect for *parnops* (5).
4. *Parnopios*: epithet of the god meaning 'of the locusts,' mistranslated by Tifernas 'of the mosquitoes.'
5. *parnops* (genitive *parnopos*): 'locust' but mistranslated by Tifernas as 'mosquito.'
7. *porns* (genitive *pornopos*): Boeotian dialect for *porns* (5).

Aldrovandus (1602:428) in his discussion of locusts quotes the above passage from Alexander ab Alexandro about mosquitoes and mice, and continues as follows:

"Alexander took this, it seems, from Strabo, [13.1.64] but the corrupt text of this author led Alexander astray. The text—happily for all interested parties—can be amended and restored from Eustathius [34.27]. The corrupt text now reads: "For from mosquitoes [*kënëps*] which the Oetaeans call mosquitoes [*kënëpas*], Hercules is worshipped among them as *Kornopion,* thanks to his removal of the locusts [akridin]." It should read: 'For from the locusts [*parnops*] which the Oetaeans call [*kornopas*], Hercules is worshipped among them as [Kornopion] thanks to his eliminating the locusts [akridin].'... That is what Eustathius has, only shorter. 'For the Oetaeans about Trachis are said to worship Hercules Kornopion thanks to his elimination of the locusts [akridin] or locusts [parnops] which they call [kornopas].' (Eustathius 34.27). It is to

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4The Greek text was first edited in 1516 by Tyrrenhus, and published in Venice by Aldus and Asulanus. It had been translated into Latin much earlier by Guarino da Verona (1374-1460) and Gregorio Tifernas (Gregorio da Città di Castello ca. 1415-1466) under the magnificent scheme of Pope Nicholas V to render the Greek classics into Latin. The first ten books were translated by Guarino and the remainder by Tifernas. This Latin translation was first printed in 1510, became the standard edition of Strabo, and remained so even after the much better edition and translation by Guilielmus Xylander (Wilhelm Holzmann) was printed at Basel in 1571. Xylander avoided the errors of Tifernas.

5Where Aldrovandus quotes the Greek I have put the translation or the cited Greek word in Italics. Where I have added the transliteration of the Greek word in question, when that is important for the argument, I have put it in Roman type in square brackets.
be noted that the translator [of Strabo, by which Aldrovandus means Gregorius Tifernas], renders *akridon* as culices [mosquitoes]. Likewise Strabo in the same passage [13.1.64] has: "Among the Aeolians of Asia a certain kind of mouse is called [*Pornopion*], for so the Boeotians call locusts, and sacrifice is made to Apollo Pornopios." From the above it is clear that [parnopes] are locusts, and as a synonym of [parnopes] some write [pornopes], and here I let it stand so, although in Pausanias [1.24.8] Apollo is named [Parnopios] not [pornopios]. [Aldrovandus quotes Pausanias 1.24.8 in Greek] *They call him Parnopios because when the locusts [parnopion] were destroying their land, the god promised to drive them out.* . . . As to the mouse which Strabo says the Aeolians called [parnopion]—to be frank, I have nothing to say. But I suspect they were so named either because they fought with the locusts for food, or because they wasted the fields like locusts."

This beautiful and learned argument is characteristic of Aldrovandus' clarity of mind and wide-ranging scholarship. He has demonstrated that the stories about Hercules and Apollo and the mosquitoes resulted from a confusion between *könops* 'mosquito' and *kornops* the dialectal variant for the unusual word *parnops* meaning 'locust.' He answered correctly all of the questions it was in his power to answer, but with greater knowledge of Greek dialects and comparative Indo-European grammar we can now add some information to his discussion.

The explanation of the dialectal variants can be summarized by considering the Attic form *parnops* and the Oetaean form *kornops*. They are the same word historically, that is to say, they descend from a common ancestor. Phonemes descending from the ancestral Indo-European voiceless labio-velar phoneme conventionally written *kW* will appear in Greek as *p*, *t*, or *k* depending on certain conditioning factors. For example the Indo-European root *kwel-* meaning ‘turn, move in a circle’ appears in the following three guises in Attic: *polos* ‘axle’; *telos* ‘end, result’; and in a reduplicated form *kyklos* ‘circle.’ A given dialect may favor one of these guises over another, and Oetaean has preferred *k* where Attic has preferred *p*, and the variation is no surprise.6 The variation in the vowel between the *a* of *parnops* and the *o* of *kornops* is straightforward, since it is a characteristic of Aeolic dialects in general to show or where Attica has *ar*, e.g. Lesbian *kortera*, Attica *kartera*.7

Of course the word *könops* 'mosquito' has nothing whatever to do with the complex of words meaning 'locust,' but its superficial resemblance to *kornops* led both the ancients and the savants of the Renaissance to consider them the same. To do this it was necessary to ignore blithely the quantity of the vowels, and the temporary inconvenience of a superfluous *r*, but it was done. Etymology in those days was a much more rough-and-tumble affair. The ancient dictionary of Hesychius (5th century A.D.) was for many centuries a standard reader's aid. In it he glosses *kornępides* as *könops* and this probably is the direct source for the Renaissance confusion.

But what about the mice? Although he gives a half-hearted suggestion or two, Aldrovandus throws up his hands when confronted with the mouse called locust at Strabo 13.1.64. This textual corruption, which Aldrovandus was not able to emend, has since been removed from modern editions with the help of some inscriptions discovered in the early part of this century. Aldrovandus read: "Among the Aeolians of Asia there is a mouse [mys] called [*Pornopion*], for so the Boeotians call locusts, and sacrifice is made to Apollo Pornopios." But it should read: "among the Aeolians of Asia there is a *month* [meis] called *Pornopion*." In other words the month was called the month of the locusts, and the continuation "so the Boeotians call locusts" now makes sense.8

It is conceivable, although I cannot point directly to a case, that this "mouse" also...
contributed to the misunderstanding about mosquitoes, since it is easy to confuse the Greek μῦς 'mouse' and μύια 'fly.' Indeed this was done by Geoffroy (1764:2.475) in a well-known, and annoying instance. He misnamed the soldier fly Stratiomyia instead of Stratiomys. Osten Sacken (1878:48) concluded that Geoffroy intended to translate Réeumur's mouche armée (Réeumur, 1734:4.325).

No mice, no mosquitoes, only locusts. But despite Aldrovandus' intelligent corrections, the old tradition persisted, and Thomas Moffett (1634:80) can still say in his discussion of mosquitoes:

"Of the Greek words for mosquito κόνοπα seems to be the most general, whence the Oetaeans worship Hercules Conopius, because it was believed that he drove the mosquitoes from their land. Alexander ab Alexandro says that in Attica Apollo was called Culicarius [sic]. The Bocoteans worshiped Apollo Parnopion because he drove out the mosquitoes, that is to say in their language pornopas."\(^9\)

This Greek form pornopas gives us the key to the next step, for it and its Attic counterpart parnopas, both accusatives plural of the third declension, occur very often in the texts we have been discussing. But their nominatives pornops or parnops do not occur. It happens that the first declension also has an accusative plural ending in -as, so that the accusative plural of the third declension will look like the accusative plural of the first declension. It is an easy mistake to construct from parnopas a false nominative singular of the first declension *parnopē. In fact just that was done in the margin of the 1539 translation of Strabo (1539:411). This incorrect nominative would be Latinized as *parnopa, and from that is an easy step for the faulty memory or the careless typesetter to produce the metathesized panorpa, the word as we have it today. A name with more complicated and dubious antecedents than this brummagem confection, it would be hard to imagine.

The two errors of declension and metathesis may of course have taken place in reverse order, or taken place more than once. The earliest instance of the metathesized form I can find is in Swammerdam's Historia Insectorum Generalis of 1669 (Swammerdam, 1733:95) a passage repeated with some expansion in the Bybel der Natuur (Swammerdam, 1737:277). The form of the word, a Latin nominative plural, is Panorpes, and it refers to what Swammerdam calls a pseudospheca or "false wasp" which attacks grapes.

It appears that Linnaeus first used the name Panorpa in the Fauna Suecica (Linnaeus, 1746:128). Linnaeus often played fast and loose with the traditional entomological names, but in this instance he adhered to the usage of his predecessors. Needing a name for the scorpionfly, an insect customarily classified with the mosquitoes, Linnaeus chose a spurious form of a word which, in the faulty tradition available to him, meant just that.

To summarize the history of this word it is necessary to begin with the cult of Hercules in ancient Boeotia. The story that Hercules drove the locusts from the fields became muddled because of the linguistic accident that the Bocotean word for locust kornops, which is equivalent to the Attic word for locust parnops, bears a superficial resemblance to the Attic word for mosquito κόνοπα. Because of this resemblance the story gets transformed until in the Renaissance Hercules drives out mosquitoes instead of locusts, and the 16th century translator of Strabo mistranslates the word parnops, meaning 'locust' as 'mosquito.' Then from the accusative plural of parnops a false nominative *parnopē is constructed by back-formation. This is latinized to *parnopa, and then metathesized to panorpa. Linnaeus found the word in the entomological literature applied to mosquitoes, and used it to designate the scorpionfly which had been classed among the mosquitoes.

ACKNOWLEDGMENTS

I am grateful to Albert R. Thornhill of the University of Michigan Museum of Zoology, who asked me one day what Panorpa meant, and also explained features of scorpionfly morphology to me. I am indebted to the staff of the Rare Book Room of the

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\(^9\)All of this is repeated by Johnston (Jonstonus, 1653:78).
University of Michigan Library, and the staff of the UMMZ library for their courteous, learned, and skillful assistance.

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A STUDY IN THE SUMMER PHENOLOGY OF DIONYCHIOUS SPIDERS FROM NORTHERN MINNESOTA FORESTS

Bruce Cutler, Lee H. Grim and H. M. Kulman

ABSTRACT

Dionychious ground layer spiders from Larix and Populus stands were collected by pitfall traps. The typical pattern of dominant, influential and accessory species was well marked. Populus stands had greater diversity of species than Larix stands. Those species characterized by large male:female sex ratios had sharp peaks in the first month of collecting, and others had smaller early season peaks or early season and late season peaks. Traps with an apron leading to the trap caught twice as many specimens compared to traps without an apron.

INTRODUCTION

While there have been a number of papers involved with the phenology of ground layer spiders (Huhta, 1965, 1971; Russell-Smith and Swann, 1972), relatively little emphasis has been placed on the dionychious spiders, except for Merrett (1967). This is in part due to the larger absolute numbers of trionychious spiders in and on the surface layers of the soil. The commonest families collected in pitfall traps in the northern parts of the United States, Canada, and northern Europe are: the Clubionidae, Gnaphosidae and Thomisidae among the Dionychia; Agelenidae, Hahniidae, Lycosidae, Linyphiidae (sensu lato), Theridiidae among the Trionychia; and Amaurobiidae among the Cribellata. In the Minnesota collections discussed here lycosids outnumbered all other spiders by a factor of about five to one.

We have been somewhat conservative in our application of the terms Dionychia and Trionychia, fully realizing the obsolete nature of these taxa. However, it remains that in the northern parts of the Holarctic these terms clearly define certain distinguishable groups of spiders. The dionychious spiders in these parts of the Holarctic comprise a diverse group of vagrant hunting spiders. No snares are built, though retreats and eggsacs are made. The commonest families are the Clubionidae, Gnaphosidae, Salticidae, and Thomisidae.

METHODS

Two forest community types were sampled in the summer of 1972. All were in eastern Lake of the Woods and northern Koochiching Counties in north central Minnesota. The two forest types were Larix laricina (Du Roi) K. Koch stands in sphagnum bogs, and Populus tremuloides Michx. on mesic sites. Stands were sampled from the end of May until early October in Populus and from early June until mid August in Larix. All were sampled at approximately two to three week intervals (Figs. 1 to 4).

The traps were conventional pitfall traps of two designs. The basic design was a tin can, 9.5 cm in diameter by 12 cm deep, containing about 3 cm of antifreeze and water in about a 3:1 ratio. The can was sunk in the ground so that the lip lay flush with the ground surface. In the other design the same can was used but the cans were set in the center of a 0.09 m² piece of plywood which was set on the ground so that the lip of the
can was flush with the top surface of the plywood, and the rim of the board was sunk flush with the ground surface, providing an apron. In all cases (apron or not), a 0.09 m² board was propped up with nails to a height of about 4 cm over the trap to keep out rain and large debris. The aprons were used on half of the traps in aspen only. At each site within the stands 15 traps were set out in Larix, and 20 in Populus. The traps were placed 15 or more meters apart.

RESULTS

Table 1 gives the species composition and numbers collected throughout the season. Ten species were found in Populus but not in Larix, while two were collected in Larix but not in Populus. The spiders are seen to fall into dominant, influent and accessory classes as divided by Luczak (1963), exhibiting this common phenomenon even within a subgroup of an order.

Figures 1 to 4 are histograms of the numbers of dominant species (pooled species for Xysticus) as they occurred over the season. The six categories for Populus, and the four for Larix each accounted for 92% of all dionychious spiders caught within the respective stand types. The selectiveness of the catch for male thornids is apparent. It seems unlikely that the male:female sex ratios are so discrepant. A more likely explanation is...
Fig. 2. For explanation see legend for Figure 1. *G. p.* = *Gnaphosa parvula*; *D. n.* = *Drasyllus niger*.

Fig. 3. For explanation see legend for Figure 1. *A. o.* = *Agroeca ornata*; *Z. s.* = *Zelotes subterraneus*.
The wandering of the males during mating, in a hunt for the relatively sedentary females. The numbers of spiders caught from this family drops off rapidly after the period of male activity. In Agroeca and Zelotes the captures reflect the probable true nature of the activity of these spiders. It is also of interest that these spiders exhibit a bimodal activity period during the summer season in Populus stands. The absence of this bimodality in Larix may result from the absence of September collecting, or from microclimate conditions in the Larix stands. Those spiders which show a distinct male bias in the catch do not show this bimodality, even if the females alone are compared. Huhta (1965) remarked on this drop in abundance of litter layer spiders in midsummer in Finnish forests. He believes that this is a result of drying out of the surface layers, and of the spiders seeking the deeper litter layers, or cracks to avoid desiccation. The English species examined by Merrett (1967) exhibited varied phenology types. The English species within genera found in Minnesota may or may not have the same phenology patterns as the Minnesota species. This is not unexpected, since the habitat was so different. Merrett also found that within one genus the different species had different phenology patterns.

Table 2 gives the distribution of catches of the six dominants: in traps with or without aprons from Populus. The total does not correspond to the total for the season since in the first two samplings the catches were combined. As may be seen, the traps with aprons caught almost exactly double the number of dionychious spiders than the traps without aprons. Comparing pairs against each other (traps with and without aprons) over the season, the traps with aprons had larger catches 78% of the time, traps without aprons had larger catches 11% of the time, and in the remainder the same number were caught in both trap types. Thus by any criterion, the traps with aprons were more efficient in catching dionychious spiders.
Table 1. Numbers of specimens of the different species of spiders caught in *Larix* and *Populus* stands.

<table>
<thead>
<tr>
<th>CLUBIONIDAE</th>
<th>Larix</th>
<th>Populus</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Agroeca emertoni</em> Kaston</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><em>Agroeca ornata</em> Banks</td>
<td>19</td>
<td>130</td>
</tr>
<tr>
<td><em>Agroeca pratensis</em> Emerton</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><em>Castianeira cingulata</em> (C. L. Koch) bicolor form</td>
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<td>3</td>
</tr>
<tr>
<td><em>Clubiona canadensis</em> Emerton</td>
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</tr>
<tr>
<td><em>Clubiona kastoni</em> Gertsch</td>
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<td>1</td>
</tr>
<tr>
<td><em>Clubiona sp.</em></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><em>Pirurotipus borealis</em> (Emerton)</td>
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<td>11</td>
</tr>
<tr>
<td><em>Scotinella pugnatus</em> (Emerton)</td>
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<td>2</td>
</tr>
<tr>
<td><em>Scotinella sp.</em></td>
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<td>0</td>
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</table>

<table>
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<tr>
<th>GNAPHOSIDAE</th>
<th></th>
<th></th>
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<td><em>Drassylus niger</em> (Banks)</td>
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</tr>
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<td>65</td>
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<td><em>Gnaphosa sericata</em> (L. Koch)</td>
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<tr>
<td><em>Zelotes subterraneus</em> (C. L. Koch)</td>
<td>24</td>
<td>121</td>
</tr>
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<table>
<thead>
<tr>
<th>SALTICIDAE</th>
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<tr>
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<tr>
<td><em>Neon nellii</em> Peckham and Peckham</td>
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<tr>
<th>THOMISIDAE</th>
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<tr>
<td><em>Oxyptila bryantae</em> Gertsch</td>
<td>71</td>
<td>191</td>
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<tr>
<td><em>Tibellus maritimus</em> (Menge)</td>
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<td><em>Xysticus elegans</em> Keyserling</td>
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<td>88</td>
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<tr>
<td><em>Xysticus ellipticus</em> Turnbull, Dondale and Redner</td>
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<td><em>Xysticus ferox</em> (Hentz)</td>
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<tr>
<td><em>Xysticus obscurus</em> Collett</td>
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<td><em>Xysticus sp.</em></td>
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<td>131</td>
<td>770</td>
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Table 2. Comparison of number of specimens caught in traps with or without aprons. See text for discussion.

<table>
<thead>
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<td><strong>GNAPHOSIDAE</strong></td>
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<td><em>Gnaphosa parvula</em></td>
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<td><em>Oxyptila bryantae</em></td>
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<tr>
<td>All <em>Xysticus</em> spp.</td>
<td>29</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>237</td>
<td>119</td>
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</tbody>
</table>
PARASITES

Three spiders from Populus had abdominal nematode parasites. These were a female Zelotes subterraneus taken in June, a presumptive female Oxyptila bryantae taken in August, and a presumptive female lycosid taken late August-early September. It is assumed in the last two cases that the spiders were female since they were large, but no female genitalia were seen since the epigynal region was destroyed.

A male Z. subterraneus taken in mid August from Populus was approximately two-thirds the size of the other males of this species taken. Except for the smaller size there were no abnormalities, no large parasites were seen, and the palpi were of normal structure and size in proportion to the body size.

DISCUSSION

It would be tempting to try and deduce life history patterns from this study, however without having winter data this would be unduly speculative. In addition, information based on one season’s data is too subject to the vicissitudes of an abnormal data set to make broad generalizations, even with a large number of specimens. What is instructive is the bias apparent in collecting with a pitfall type trap, especially within the Trionychia. The wandering lycosids were very well represented, but the numbers of linyphiids were extremely low, and probably reflected no more than a few per cent of their true abundance. Turnbull (1973) has amply remarked on this problem. The reader is referred to his excellent and acerbic comments.

ACKNOWLEDGMENT

We wish to thank Lynne C. Thompson for providing the material from the Larix stands.

LITERATURE CITED

NEW TECHNIQUES FOR ASSOCIATING THE STAGES OF AQUATIC INSECTS

A. V. Provonsha and W. P. McCafferty

The immature forms of many benthic insect species are presently either undescribed or unidentifiable. The result is that associations with corresponding adult forms are often necessary in order to confirm specific and sometimes generic identifications. Specific determination of aquatic stages of insects is prerequisite to adequately understanding the various aspects and implications of autecological specificity and the synecological dynamics of an aquatic system. Wiggins (1966), among others, has adequately pointed out the basic necessity of being able to discriminate between immature aquatic species.

Confronted with the problem then, of inadequate immature taxonomy, workers have devised various techniques for capturing adults and for rearing aquatic insects. In conjunction with a project dealing with the aquatic insect fauna of Indiana we have, over the past two years, refined many of these techniques and developed some new ones. Although increased efficiency has been our primary criteria for equipment design and usage, the field orientation of the work has made portability and durability additional important qualities we have considered.

It is common knowledge that many crepuscular and nocturnal insects can be collected by taking advantage of their responsiveness to artificial lights. Due to the excessive damage that mechanical light traps often impose on soft bodied aquatic insects, particularly when large collections are taken, it is usually preferable to set a light source against a pale background and to simply "pick" the specimens by hand. This is especially true for the Ephemeroptera. In the past, this has usually been accomplished by picking specimens from the immediate area around the light or from the light fixture itself. Usually a reflective white cloth or sheet is draped over makeshift props or suspensions next to the water. Such techniques are crude at best.

We have designed and used a light reflector unit (Fig. 1) which is compact, highly portable, easy to set up, and can be used in most places regardless of the contours of the terrain. It is constructed by slipping two 4' X 3/4" wooden dowels through loops sewn on either end of a 42" X 33" white cloth which has a 1" wide vinyl apron sewn on the bottom to catch any insects which may fall from the screen (Fig. 2). When in use, the reflector is held rigid by two 3' X 1/8" stainless steel spring wires slipped into holes drilled part way through the two wooden dowels at approximately 1" from the ends (Fig. 3). The legs, also constructed from 4' X 3/4" wooden dowels, are attached to the reflector with four large eye screws (Fig. 4), which will allow them to rotate in any position to comply with the shape of the ground and desired angle of the reflector. The two eye screws which are attached to the frame should be bent at 45 degree angles to allow the legs to fold flat against the frame. This allows the entire reflector to be rolled up for easy transport and storage. When not in use, the reflector can be kept in a cloth or tubular carrying case, similar to those used for fishing rods.

Although aquatic insects appear to be attracted to light sources to varying degrees depending on the wave length and intensity (Hollingsworth, 1961), we have experienced good results with a portable black light such as the night collecting unit sold by BioQuip or American Biological Supplies, used in conjunction with a gas lantern. A one foot piece of heavy wire (which can be cut from a clothes hanger) is attached with a screw to the middle of the upper dowel of the light reflector unit. The black light is hung from this wire which suspends it in front of the screen, thus increasing total light reflection.

Most insects can be killed and preserved immediately upon capture. The mayflies, however, pose a special problem. Since the majority of those which come to light are

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2Department of Entomology, Purdue University, West Lafayette, Indiana 47907.
Fig. 1. Light reflector unit in operation.

Figs. 2-4. Diagram of light reflector unit assembly.
Fig. 2. Reflector unit assembly.
Fig. 3. Spring wire brace assembly.
Fig. 4. Leg assembly.
subimagos, they must be kept alive until they molt to the imago stage. This is also an explanation for the fact that light trap collecting is not efficient for mayflies. In the past, subimagos have been reared in paper bags, wire cages, and various types of small plastic and cardboard chambers which have met with only limited success.

We have found the most effective method for rearing large numbers of subimagos taken in the field is to place them in plastic crispers about the size of a shoe box (Fig. 5). By adding a small sliding door in the lid the worker can place specimens into the chamber without allowing others to escape in the process. A small section of screen may be substituted for part of the lid providing better ventilation which helps prevent over humidification in damp situations. Crumpled paper towels placed in the bottom provides good footing and when slightly dampened the problems of desiccation are greatly reduced.

We have found this procedure provides good visibility, large numbers of ‘subs’ can be collected, and most importantly since we are able to regulate the humidity the mortality rate can be kept to a minimum. However, these chambers must be kept out of the sun since plastic tends to intensify the internal temperature.

Capturing adults near the body of water from which they emerged can be helpful in making associations with their immature aquatic forms and in many cases increases substantially the probability of accurate identifications of these immatures. Obviously, such associations are only implied and are not positive proof of their relationship.

In order to obtain positive stage correlations it is necessary to rear individuals from larvae to adult. When possible, it is advantageous to maintain these larvae, which are often very sensitive to environmental changes, in their natural environment. Over the years various field rearing chambers have been developed, such as cylindrical wire cages (Needham, 1901), pillow cages (Needham, Traver and Hsu, 1931) and even modified plastic cups (Muller-Liebenau, 1969). We believe that the most important qualities to be incorporated into a field rearing chamber are good visibility, adequate footing and flight room for newly emerged winged forms, and easy access to specimens. Nevertheless, past
designers have had to sacrifice some of the above mentioned qualities in their cages to maintain others.

We have developed a field rearing chamber (Fig. 6) which incorporates all of these qualities. The top, bottom, and sides are constructed with 1/16" plexiglass while the front and back are nylon netting. The back is glued to both sides for the entire length of the chamber, while the front is glued only along the bottom 2½" and is attached along the remainder of the border with Velcro® at various points. This allows the front to be opened to varying degrees for easy access while at the same time preventing unwanted escape. These chambers may be constructed in any size desired, but the ones currently in use by us are 8" x 2" x 2". Chambers made any larger than this become bulky to transport if large numbers are needed, and they are not as practical for rearing individual specimens.

Fig. 6. Aquatic rearing chamber.
This chamber, like most others, is designed for use in the field and can be supported in a styrofoam float (Fig. 7) perpendicular to the float or at a slight angle to provide better footing for newly emerged individuals. If the float is cut in a triangle or boat shape, wire screening can be suspended from the front to detour any detritus from clogging the chambers.

LITERATURE CITED


CURRENT CLASSIFICATION OF THE FAMILIES OF COLEOPTERA

M. G. de Viedma¹ and M. L. Nelson²

Several works on the order Coleoptera have appeared in recent years, some of them creating new superfamilies, others modifying the constitution of these or creating new families, finally others are general revisions of the order. The authors believe that the current classification of this order, incorporating these changes would prove useful. The following outline is based mainly on Crowson (1960, 1964, 1966, 1967, 1971, 1972, 1973) and Crowson and Viedma (1964). For characters used on classification see Viedma (1972) and for family synonyms Abdullah (1969). Major features of this conspectus are the rejection of the two sections of Adephaga (Geadephaga and Hydradephaga), based on Bell (1966) and the new sequence of Heteromera, based mainly on Crowson (1966), with adaptations.

Order COLEOPTERA

I. Suborder ARCHOSTEMATA
   Superfamily CUPEDOIDEA
   1 Family Cupedidae
   2 Family Micromalthidae

II. Suborder ADEPHAGA
   Superfamily CARABOIDEA
   3 Family Rhysodidae
   4 Family Paussidae
   5 Family Carabidae
   6 Family Cicindelidae
   7 Family Trachypachidae
   8 Family Haliplidae
   9 Family Amphizoidae
   10 Family Hygrobiidae
   11 Family Noteridae
   12 Family Dytiscidae
   13 Family Gyrinidae

III. Suborder MYXOPHAGA
   Superfamily Sphaerioidea
   14 Family Lepiceridae
   15 Family Sphaeriidae
   16 Family Hydroscaphidae
   17 Family Torridincolidae

IV. Suborder POLYPHAGA
   Series STAPHYLINIFORMIA
   Superfamily HYDROPHILOIDEA
   18 Family Hydraenidae
   19 Family Hydrochidae
   20 Family Spercheidae
   21 Family Georyssidae
   22 Family Hydrophilidae

   Superfamily HISTEROIDEA
   23 Family Sphaeritidae
   24 Family Synteliidae
   25 Family Histeridae

¹Department of Entomology, School of Forestry, University of Madrid, Madrid (3), Spain.
²Department of Biology, Wayne State University, Detroit, Michigan 48202, U.S.A.
Superfamily STAPHYLINOIDEA

26 Family Ptiliidae 31 Family Scydmaenidae
27 Family Limulodidae 32 Family Silphidae
28 Family Dasyceridae 33 Family Staphylinidae
29 Family Leptinidae 34 Family Pselaphidae
30 Family Anisotomidae

Series SCARABAEIFORMIA

Superfamily SCARABAEIOIDEA

35 Family Lucanidae 39 Family Geotrupidae
36 Family Passalidae 40 Family Scarabaeidae
37 Family Trogidae 41 Family Glaphyridae
38 Family Acanthoceridae 42 Family Hybosoridae

Superfamily EUCINETOIDEA

43 Family Clambidae 45 Family Helodidae
44 Family Eucinetidae

Superfamily DASCILOIDEA

46 Family Dascillidae 48 Family Rhipiceridae
47 Family Karumiidae

Series ELATERIFORMIA

Superfamily BYRRHOIDEA

49 Family Byrrhidae

Superfamily DRYOPOIDAE

50 Family Psephenidae 55 Family Heteroceridae
51 Family Ptilodactylidae 56 Family Limnichidae
52 Family Eulichadidae 57 Family Dryopidae
53 Family Eurypogonidae 58 Family Elmidae
54 Family Chelonaridae

Superfamily BUPRESTOIDEA

59 Family Buprestidae

Superfamily ARTEMATOPOIDEA

60 Family Artematopidae 62 Family Brachypsectridae
61 Family Callirihipidae

Superfamily ELATEROIDEA

63 Family Cebrionidae 66 Family Cerophytilidae
64 Family Elateridae 67 Family Perothopidae
65 Family Trixagidae 68 Family Eucnemidae

Superfamily CANTHAROIDEA

69 Family Cneoglossidae 74 Family Phengodidae
70 Family Plastoceridae 75 Family Telegeusidae
71 Family Homalodidae 76 Family Lampyridae
72 Family Lycidae 77 Family Omethidae
73 Family Drilidae 78 Family Cantharidae
THE GREAT LAKES ENTOMOLOGIST

Series BOSTRYCHIFORMIA
Superfamily DERMESTOIDEA
79 Family Derodontidae
80 Family Nosodendridae
81 Family Dermestidae

Superfamily BOSTRYCHOIDEA
84 Family Anobiidae
85 Family Ptinidae
86 Family Bostrychidae
87 Family Lyctidae

Series CUCUJIFORMIA
Superfamily CLEROIDEA
88 Family Phloiophilidae
89 Family Peltidae
90 Family Trogossitidae
91 Family Chaetosomatidae
92 Family Cleridae
93 Family Phycosecidae
94 Family Melyridae
95 Family Lymexylidae

Superfamily LYMEXYLOIDEA
96 Family Mengeidae
97 Family Stylopidae

Superfamily CUCUJOIDEA
Section CLAVICORNIA
98 Family Nitidulidae
99 Family Smicripidae
100 Family Rhizophagidae
101 Family Protocucujidae
102 Family Sphindidae
103 Family Boganiidae
104 Family Hypocopriddae
105 Family Passandridae
106 Family Cucujidae
107 Family Silvanidae
108 Family Helottidae
109 Family Propalictidae
110 Family Cryptophagidae
111 Family Languriidae
112 Family Erotylidae
113 Family Phalacridae
114 Family Cerylonidae
115 Family Corylophidae
116 Family Coccinellidae
117 Family Endomychidae
118 Family Discolomidae
119 Family Merophysidae
120 Family Lathridiidae

Section HETEROMERA
121 Family Tetratomidae
122 Family Mycetophagidae
123 Family Pterogeniidae
124 Family Cisidae
125 Family Biphyllidae
126 Family Byturidae
127 Family Synchrociidae
128 Family Zopheridae
129 Family Cephaloidea
130 Family Perimylopidae
131 Family Merycidae
132 Family Monommidae
133 Family Colydiidae
134 Family Nilionidae
135 Family Tenebrionidae
136 Family Lagriidae
137 Family Alloculidae
138 Family Melandryidae
139 Family Mordellidae
140 Family Rhypophoridae
141 Family Scaptiidae
142 Family Pythidae
143 Family Trictenotomidae
144 Family Pyrochroidae
145 Family Salpingidae
146 Family Elacatidae
Section HETEROMERA (Continued)

147 Family Cononotidae
148 Family Mycteridae
149 Family Boridae
150 Family Inopeplidae

151 Family Anthicidae
152 Family Meloidae
153 Family Aderidae

154 Family Prostomidae
155 Family Oedemeridae
156 Family Petriidae

157 Family Tretothoracidae
158 Family Aculognathidae

159 Family Cerambycidae
160 Family Bruchidae

161 Family Chrysomelidae

Superfamily CURCULIONOIDEA

162 Family Nemonychidae
163 Family Anthribidae
164 Family Belidae
165 Family Oxyphagidae
166 Family Proterhinidae

167 Family Attelabidae
168 Family Brenthidae
169 Family Apionidae
170 Family Curculionidae

171 Family Phaenocephalidae

Uncertain superfamily position

LITERATURE CITED


SPATIAL AND SEASONAL DISTRIBUTION OF PINE ROOT COLLAR WEEVIL EGGS IN YOUNG RED PINE PLANTATIONS

Louis F. Wilson

The pine root collar weevil (Hylobius radicis Buchanan) is a continuous threat to young pine plantations in the northeastern United States and the adjacent Canadian Provinces. The female weevil oviposits during the daytime (Wilson, 1968a) near the root collars of red pine (Pinus resinosa Aiton), Scotch pine (P. sylvestris L.), and jack pine (P. banksiana Lambert), and occasionally other pines. During recent studies on the weevil (Wilson 1968a, 1968b) in Michigan, egg data were taken for use in population and sampling research. Presented here are distribution patterns of eggs within and between trees and throughout the oviposition period, and some implications for assessing populations.

METHODS

Seven red pine plantations were selected for study in Kalkaska, Grand Traverse, and Newaygo Counties, Michigan. In 1963, at the beginning of the study, four plantations were heavily infested (some trees were dying in each), two were moderately infested, and one was lightly infested. The trees varied from 5-12 ft tall. All plantations were sampled repeatedly at about three week intervals for four years during the summers from 1963 to 1966. Plantations were designated J, K, L, M, N, P, and R. In all, nearly 2,000 trees were sampled in the study.

Each collection consisted of egg and adult weevil counts in the root collar area from each of 20 randomly selected living trees. The procedure at each tree was to: (1) collect all adults in the vicinity of the root collar; (2) collect soil from around the root collar; and (3) dig up the root collar. The sex, location, and behavior of adult weevils were recorded (Wilson, 1968a). Specially partitioned samples of soil were taken around 100 trees in order to assess egg distribution in the soil. These were collected at the peak of oviposition in the two most heavily infested areas. The regular soil sample consisted of surface soil 1 cm deep surrounding the tree out to 9 cm, and a narrow (1-2 cm) band of subsoil 2-3 cm deep adjacent to the root collar. The partition sample was the same quality of soil as the regular sample except soil from four (or five) locations from around the tree were bagged separately. The partition samples consisted of concentric rings of soil from: (1) the first 3 cm; (2) the second 3 cm; and (3) the third 3 cm out from the root collar. The other two sample locations were: (1) the narrow band of subsoil 2-3 cm deep adjacent to and surrounding the root collar; and (2) the soil directly under branches in contact with the ground (if applicable) (Fig. 1).

In the laboratory, the soil was carefully broken into small particles and sifted through sieves to locate and count the eggs. Soil, dried pitch nodules, and bark were carefully removed from the root collars and examined for eggs whose location was noted.

SPATIAL DISTRIBUTION AT THE TREE

Egg samples were taken from 100 red pine trees in two plantations during the main portion of the ovipositional period in order to determine egg distribution at the tree. Eggs were counted from the root collar, the soil, and the litter at the locations shown in Figure 1; cardinal direction was not considered.

The samples yielded 327 eggs—271 (83 per cent) in the soil and 56 (17 per cent) in the root collar tissues. Eggs were not found in the litter. The locations of the eggs in the soil were as follows:

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Eggs were rare (0.4 per cent) but present in location 3 (6-9 cm from the trunk, but most (88 per cent) were in zones 1 and 4 nearest the tree. Schaffner and McIntyre (1944) reported that the female oviposits some of her eggs in the soil close to the tree, and Finnegans (1962) noted that eggs are often as far as 5 cm from the tree. We found 4.4 per cent of the eggs this distance from the tree (location 2). Nineteen eggs were collected in soil beneath branches touching the ground. Only 16 trees sampled had one or more such branches and this represented 19 percent of the eggs on those trees. This suggests eggs tend to be aggregated under branches because the surface area of soil under a branch is far less than 19 percent of the surface area around the root collar. Also, eggs were occasionally found embedded in the underside of branches touching the ground.

The vertical distribution of eggs in the bark, xylem, or pitchy soil attached to the bark was as follows:

<table>
<thead>
<tr>
<th>Distance from ground surface (cm)</th>
<th>Egg nos.</th>
<th>Per cent of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above ground</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1.8</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1.8</td>
</tr>
<tr>
<td>Ground level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>29</td>
<td>51.8</td>
</tr>
<tr>
<td>Below ground</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>17.8</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>14.3</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>3.6</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1.8</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>5.3</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>1.8</td>
</tr>
<tr>
<td>Total</td>
<td>56</td>
<td>100.0</td>
</tr>
</tbody>
</table>

The majority of eggs are laid at the ground line, but some are found at least 16 cm below the ground. Millers (1960) observed eggs at depths of 18 cm. Eggs tend to be deeper around trees that have considerable injury.

Eggs are usually oviposited singly in bark cavities, but four double egg batches were collected. Some eggs were embedded in the xylem or in the pitch adhering to the bark. Schaffner and McIntyre (1944) and Finnegans (1962) reported eggs oviposited in adult feeding wounds in the inner bark of the root collar. Millers (1960, 1965) noted the egg cavities were covered with tightly packed frass.

Ninety-three per cent of all eggs, then, were found in the cylindrical zone 3 cm out from the root collar and 3 cm down from the ground line. About 2 per cent were found under a branch, and 5 per cent were in the remaining locations.

**SPATIAL DISTRIBUTION THROUGHOUT THE PLANTATION**

Dispersion of weevil eggs was estimated from 94 collections, taken from all 20 trees in all years throughout the egg laying period each year. Mean and variance were calculated for the egg counts and then the Poisson series and Taylor's power law were fitted to these data to determine dispersive patterns.

If the eggs are distributed among the trees at random, the distribution will approximate the Poisson series in which the variance ($\sigma^2$) of the population sample is equal to its mean ($m$). Most populations, however, depart from randomness in such a way that there are more zeros and high values than expected, with the result that the variance
exceeds the mean. When this occurs, the degree of overdispersion can be determined by various methods including Taylor’s power law (Taylor, 1961) by calculating the parameter $b$ of the equation

$$s^2 = am^b.$$  

The relationship between mean and variance for the egg counts, as expected, departed noticeably from Poisson expectation ($s^2 = m$) and fit Taylor’s power law reasonably well indicating overdispersion (Fig. 2). The index of aggregation ($b$) was calculated to be 1.25 and accounted for 95 per cent of the variation among the individual variances. Low egg populations, below a mean of 0.5 eggs per tree, tend not to differ from random expectation, whereas populations above this are recognizably aggregated (i.e., they fall above the Poisson line in Fig. 2).

**SEASONAL DISTRIBUTION**

Male and female weevils emerge during the period from mid-July to early September, but the females do not oviposit until the following spring. If the females survive, eggs are also laid the second spring. Finnegan (1962) reported an average of 17.5 eggs the first egg-laying season and 14.2 the second. He found that female weevils lay from one to a maximum of four per day. Schaffner and McIntyre (1944) counted 40-64 eggs per female in one season; one female laid 64 the first season and 10 the next. Millers (1965) obtained an average of 32 eggs per female with a maximum of 67.

Most investigators have recorded that eggs first appear in early to late May and disappear in September (Finnegan, 1962, Millers, 1965, Schaffner and McIntyre, 1944). In Michigan we determined the time and date of oviposition in two heavily infested plantations during two growing seasons. In all 610 eggs were studied. Eggs were first detected in mid-May, increased in numbers in early June, and reached a peak in mid-June. Numbers declined after that but rose again to a small peak in late July, then declined steadily and finally vanished in early September (Fig. 3). Finnegan (1962) reported the oviposition peak in early July in Ontario, Canada. Curiously, in our data the frequency of matching behavior paralleled the egg distribution even to a slight rise in sexual activity in late July (Fig. 3).

---

Fig. 1. Locations of partitioned-soil-samples taken for distribution of pine root collar weevil eggs.
Sex ratios of adults, despite special care in collection, differed somewhat from sex ratios in pupae. Eighty-three pupae collected in their underground cells yielded 44 females (54 per cent) and 39 males (46 per cent)—a reasonable 1:1 sex ratio. However, 908 adults collected throughout the study showed 501 (62 per cent) males. Finnegan (1962) in Ontario reported 48 per cent males in his studies. The reason for the preponderance of males in our studies was not apparent.

DISCUSSION

The female pine root collar weevil in Michigan oviposits from mid-May to early September with the peak egg laying in mid-June, mostly in the bark of the root collar or in the soil within 3 cm of the root collar. When the bottom-most branches are lying on or partially buried in the soil, the females tend to lay more eggs under these branches than the soil nearby. Adults commonly feed under such branches during the day.
1968a) so this is a likely site for oviposition. Eggs may be rarely found 18 cm underground (Millers, 1960) but only on trees that have had considerable injury from larval weevils. The lack of good oviposition sites due to heavy larval feeding may cause the insect to dig for good sites. In dry weather the insect may not have to dig to reach the root region below the root collar. The pitch-drenched soil adjacent to the tree often cracks and separates from the collar leaving an open crevice. Both sexes commonly inhabit these crevices on warm days.

Weevil eggs are aggregated or overdispersed as are most insect populations. Yet, with a dispersion index of 1.25 according to Taylor's power law (1.00 is random), the egg population is not strongly aggregated. This can be partially explained by behavior of the female. In well-stocked pine plantations, each insect disperses by walking from one tree to another almost every night (Wilson, 1968b). Its movements are nearly random, thus each tree has almost an equal opportunity of receiving a female each day. Once at a new tree a female may lay only a single egg per day or sometimes a pair (rarely more). This means that only a few trees will receive many eggs and only a few trees will have no eggs, a situation not encountered in highly overdispersed populations where many zeros and high values would be expected.

Analysis of variance and other statistical methods used in assessing sampling variation presuppose a normal distribution with variance independent of the mean. Thus it is necessary to transform overdispersed data to stabilize the variance. Because the pine root collar weevil data were aggregated, the data (x) were transformed using: log (x + 1) (Wadley, 1950); log (x + k/2) (Anscombe, 1948) using a common k of 1.782; x\(^y\) (Healy and Taylor, 1962); and log (x\(^y\) + 1) in order to find a means of stabilizing variance. Correlation coefficients between mean and variance were highly significant when original counts (Table 1) and all transformed counts were used:

![Fig. 3. Seasonal distribution of eggs and paired weevils.](image)
Original counts \((x)\), \(r = 0.86\)
Transformed log \((x + 1)\), \(r = 0.77\)
Transformed log \((x + k/2)\), \(r = 0.83\)
Transformed log \((x^{28} + 1)\), \(r = 0.63\)
Transformed \(x^{28}\), \(r = 0.71\)

Thus, none of the transformations tested were sufficiently powerful to stabilize variance for statistical purposes. Perhaps a transformation more sensitive to the limited range of \(x\)-values would be more appropriate.

Table 1. The mean and variance of original counts of eggs of the pine root collar weevil, 1963-1966.

<table>
<thead>
<tr>
<th>Location</th>
<th>(\bar{x}) ((s^2))</th>
<th>Location</th>
<th>(\bar{x}) ((s^2))</th>
<th>Location</th>
<th>(\bar{x}) ((s^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>JC1</td>
<td>3.00 (9.857)</td>
<td>RD3</td>
<td>0.27 (0.210)</td>
<td>R4</td>
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</tr>
<tr>
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<td>RS3</td>
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<td>K6</td>
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</tr>
<tr>
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<td>K7</td>
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</tr>
<tr>
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<td>JP4</td>
<td>1.20 (1.642)</td>
<td>K9</td>
<td>0.05 (0.050)</td>
</tr>
<tr>
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<td>2.40 (6.686)</td>
<td>JD4</td>
<td>1.25 (1.776)</td>
<td>K14</td>
<td>0.25 (0.303)</td>
</tr>
<tr>
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<td>1.27 (3.495)</td>
<td>JS4</td>
<td>1.00 (1.579)</td>
<td>K15</td>
<td>0.20 (0.274)</td>
</tr>
<tr>
<td>PC2</td>
<td>4.13 (16.695)</td>
<td>RC4</td>
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<td>K16</td>
<td>0.05 (0.050)</td>
</tr>
<tr>
<td>RC2</td>
<td>4.47 (30.124)</td>
<td>RP4</td>
<td>3.30 (7.274)</td>
<td>K20</td>
<td>0.15 (0.239)</td>
</tr>
<tr>
<td>JC3</td>
<td>1.21 (4.489)</td>
<td>RD4</td>
<td>2.60 (4.463)</td>
<td>K21</td>
<td>0.15 (0.239)</td>
</tr>
<tr>
<td>NC3</td>
<td>0.20 (0.171)</td>
<td>RS4</td>
<td>4.95 (19.418)</td>
<td>K22</td>
<td>0.10 (0.095)</td>
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<td>3.47 (4.267)</td>
<td>N1</td>
<td>0.75 (1.987)</td>
<td>K23</td>
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</tr>
<tr>
<td>RC3</td>
<td>1.27 (2.924)</td>
<td>N2</td>
<td>3.40 (24.568)</td>
<td>L3</td>
<td>0.03 (0.030)</td>
</tr>
<tr>
<td>JP1</td>
<td>1.87 (3.981)</td>
<td>N3</td>
<td>1.25 (1.776)</td>
<td>L4</td>
<td>0.03 (0.030)</td>
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<tr>
<td>JP1</td>
<td>1.87 (3.981)</td>
<td>N4</td>
<td>0.65 (0.776)</td>
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<td>0.08 (0.160)</td>
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<td>2.00 (2.737)</td>
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<td>0.45 (1.208)</td>
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<td>0.73 (0.781)</td>
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<td>0.20 (0.314)</td>
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<tr>
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<td>0.15 (0.239)</td>
<td>L14</td>
<td>0.19 (0.262)</td>
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<tr>
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<td>N16</td>
<td>0.10 (1.000)</td>
<td>L15</td>
<td>0.05 (0.050)</td>
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<td>JS1</td>
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<td>0.05 (0.050)</td>
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<tr>
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<td>L17</td>
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<tr>
<td>PS1</td>
<td>0.13 (0.124)</td>
<td>N19</td>
<td>0.30 (0.432)</td>
<td>L21</td>
<td>0.32 (0.339)</td>
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<tr>
<td>RS1</td>
<td>0.29 (0.220)</td>
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<td>0.40 (0.358)</td>
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<td>0.15 (0.134)</td>
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<tr>
<td>JP2</td>
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<tr>
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<tr>
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<td>K1</td>
<td>0.05 (0.050)</td>
<td>M23</td>
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</tr>
</tbody>
</table>

\(^a\)Code letters refer to plantation and plot; numbers refer to collection.
LITERATURE CITED


SPATIAL DISTRIBUTION OF EGG CLUSTERS OF THE EUROPEAN PINE SAWFLY *NEODIPRION SERTIFER* (GEOFF.), IN YOUNG PINE PLANTATIONS IN MICHIGAN

Louis F. Wilson

The European pine sawfly, *Neodiprion sertifer* (Geoffroy), is a perennial problem in young pine plantations in Eastern North America. Scotch pine, *Pinus sylvestris* L., and red pine, *P. resinosa* Ait., are its principal hosts. During recent behavioral studies of this sawfly in Michigan, spatial distribution patterns were determined in order to rapidly survey population levels in young pine plantations (Wilson and Gerrard, 1971). Earlier, Lyons (1964b) presented some distributional data on *N. sertifer* in regard to population sampling. Wright et al. (1967) and Hattemer et al. (1969) discussed *N. sertifer* distributions in Scotch pine and mixed pine species provenance plantings.

Presented here are the spatial distribution patterns for *N. sertifer* egg clusters in several Scotch pine and red pine plantations in Michigan and some implications for survey procedures. Because *N. sertifer* is still a pest of young plantings in Michigan, the whole tree provides a useful survey unit of population. As trees age and increase in size and sawfly populations change, part of the tree or a portion of the planting may be more useful in future surveys.

METHODS AND MATERIALS

Five Scotch pine and two red pine plantations of sapling size, encompassing a wide range of infestation levels over the geographic range of the insect in Michigan, were chosen for study (Table 1). The plantations, designated A to G, were located in Ingham, Ottawa, Lapeer, and Livingston Counties. The number of trees per plot varied from 296 to 1,325; plots C and F were the entire plantations. Plantations D and G were less than 200 feet apart. The trees were originally planted 5-6 ft apart, but tree mortality from

<table>
<thead>
<tr>
<th>Plantations (plot)</th>
<th>Year at census (spring)</th>
<th>No. of trees in plot</th>
<th>Percent of original stocking</th>
<th>No. whorls of branches</th>
<th>Mean no. egg clusters per tree</th>
</tr>
</thead>
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<tr>
<td>A</td>
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<td>1,325</td>
<td>98</td>
<td>3</td>
<td>0.93</td>
</tr>
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<td>4</td>
<td>8.14</td>
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<tr>
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<td>569</td>
<td>98</td>
<td>5</td>
<td>19.53</td>
</tr>
<tr>
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<td>1962</td>
<td>581</td>
<td>50</td>
<td>6</td>
<td>1.57</td>
</tr>
<tr>
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<td>1963</td>
<td>581</td>
<td>50</td>
<td>7</td>
<td>2.90</td>
</tr>
<tr>
<td>C</td>
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<td>300⁴</td>
<td>57</td>
<td>3</td>
<td>1.76</td>
</tr>
<tr>
<td>C</td>
<td>1963</td>
<td>296⁴</td>
<td>56</td>
<td>4</td>
<td>2.42</td>
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<td>1962</td>
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<td>352</td>
<td>59</td>
<td>5</td>
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<tr>
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<tr>
<td>E</td>
<td>1963</td>
<td>314</td>
<td>71</td>
<td>5</td>
<td>0.14</td>
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<td>F</td>
<td>1962</td>
<td>352⁴</td>
<td>29</td>
<td>3</td>
<td>0.23</td>
</tr>
<tr>
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<td>1963</td>
<td>352⁴</td>
<td>29</td>
<td>4</td>
<td>0.38</td>
</tr>
<tr>
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<td>1962</td>
<td>348</td>
<td>55</td>
<td>4</td>
<td>13.89</td>
</tr>
</tbody>
</table>

*Entire plantation censused.*

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²Principal Insect Ecologist, North Central Forest Experiment Station, USDA Forest Service, East Lansing, Michigan 48824 (Office maintained in cooperation with Michigan State University).
various causes reduced the stocking levels to 29-98 per cent of the original and thus provided both sparse and dense conditions.

Sawfly egg clusters, or freshly eclosed sawfly colonies, were counted on every tree in each plot in the spring. Egg clusters were counted by tree and by whorls each year for three years in plantation A.

THE DATA

Populations varied from 0.14 to 19.53 egg clusters per tree during the study (Table 1). The layout for trees in Plantation A and typical infestation patterns for three different years at increasing population levels are illustrated in Figure 1. Black discs in Figure 1 indicate infested trees; 11 per cent were infested in 1961, 48 per cent in 1962, and 95 per cent in 1963. Frequency distributions of egg cluster populations in Plantation A at 0.93, 8.14, and 19.53 egg clusters per tree for years 1962, 1963, and 1964 are given in Figure 2. These latter represent low, medium, and high populations, respectively.

DISTRIBUTIONAL PATTERNS

DISPERSION.—Mean and variance were calculated for egg cluster counts, and then the Poisson and negative binomial series and Taylor's power law were fitted to these data to determine dispersive patterns within plots. The statistics for these have been outlined by several authors (Anscombe, 1948, 1949; Bliss and Fisher, 1953; Fisher, 1941; Taylor, 1961).

If egg clusters are distributed among the trees at random, the distribution will approximate a Poisson series in which the variance \( \sigma^2 \) of the population sample is equal to its mean \( \mu \). Most populations, however, depart from randomness in such a way that there are more zeros and higher values than expected, with the results that the variance exceeds the mean (Waters, 1959; Bliss, 1941). When this occurs, the degree of overdispersion can be determined by calculating the parameter \( k \) of the negative binomial series in the formula

\[
\sigma^2 = \mu + \mu^2/k
\]

using a common \( k \) value (Anscombe, 1949). Also, overdispersion can be determined from Taylor's power law (Taylor, 1961) by calculating the parameter \( b \) of the equation

\[
\sigma^2 = am^b
\]

which is more conveniently illustrated and fitted as the regression equation

\[
\log \sigma^2 = \log a + b \log \mu
\]

where \( b \) is the slope and \( \log a \) the intercept.

As expected, the data as a whole depart noticeably from Poisson expectation \( \sigma^2 = \mu \) and fit both the negative binomial and Taylor's power law reasonably well (Fig. 3). However, only egg cluster population means above 1.0 cluster per tree tend not to differ from random expectation. Values of \( k \) for the negative binomial varied from 0.89-4.05 with a common \( k \) of 1.37 (Wilson and Gerrard, 1971) which was used in fitting the data. The index of aggregation \( b \) of Taylor's power law was calculated to be 1.49 (Fig. 3) and accounted for 98 per cent of the variation among the individual variances.

TREE SIZE EFFECT.—Egg cluster density in plantation A is directly related to tree height, especially at medium (1963) and high (1964) population levels (Fig. 4). This also was the case for all other plantations studied which had a mean population greater than 1.0 egg cluster per tree in any year. Plantations E and F, which averaged 0.85 egg clusters or less, showed no correlation with tree size as all tree sizes (by 1-ft height classes) on the average had about the same number of clusters per class. Lyons (1964a) found a similar relationship between larval colonies and tree height for three years of attack in a red pine stand. Wright et al. (1967) and Hattemer et al. (1969) found high correlations between sawfly density and tree size in pine provenance study plantings. In the latter case several varieties of Scotch pine, pine hybrids, and pine species were involved.

Distribution of egg clusters by individual tree height classes (i.e., 6 ft, 8 ft, etc.) for all plots or plantations does not differ significantly from distribution of egg clusters for entire plots. This fact is indicated by the two aggregation indices \( k \) and Taylor's law from variance-mean relationships on 4-, 6-, and 8-ft trees from all study plantings (Fig. 5). Trees of all sizes with population means of less than 1.0 egg cluster per tree show nearly random distribution whereas those with more than 1.0 egg cluster per tree become more aggregated as population increases.
Fig. 1. Scotch pine plantation A showing distribution pattern of pines infested with sawfly egg clusters (black discs) for three years of increasing population levels. Upper edge (row 1 trees) adjoins an open grassy field; spaces between rows 10 and 11 and 20 and 21 are 10-foot wide firebreaks.
EDGE EFFECT.—Organisms tend to increase in population at community junctions or ecotones. Such a phenomenon is called an edge effect (Odum, 1959). Under certain conditions the European pine sawfly exhibits a forest edge effect where the ecotone consists of pine and grass or other low-growing vegetation. I first noticed this edge effect in plantation A which had 98 per cent of full stocking, trees spaced 5.5 ft apart, and 10 ft-wide firebreaks at 10-row intervals—thus providing "solid" blocks of trees with a major edge at the pine-grass community junction, and several minor edges at the firebreaks. The edge effect at the major edge was barely detectable in 1962 when the population was 0.93 egg clusters per tree (Fig. 6). However, it became noticeable in 1963 when the population rose to 8.14 egg clusters per tree, and this first or edge row of trees adjacent to the grassy field (row 1, Fig. 6) had significantly higher ($X^2$ test) egg clusters than any other interior row (rows 2-9 and 12-19, Fig. 6). The effect became even more pronounced and more highly significant in 1964 when the population increased to a mean of 19.5 colonies per tree. The edge row that year averaged 29.5 colonies per tree. In either year, the population on the major edge was 1½ to 2 times that of any other interior row.
Fig. 3. Relation between intertree variance ($\sigma^2$) and the mean number of sawfly egg clusters (m) per tree for all plots and years.
Fig. 4. Density of sawfly egg clusters in relation to tree height in Scotch pine plantation A for low (1962), medium (1963), and high (1964) population levels.

The firebreak edge rows (rows 10, 11, and 20, Fig. 6) tended to have slightly higher population than nonedge rows in 1963 but the differences were not significant until 1964. Unfortunately the data were not taken beyond row 10 that year so there was only one edge row along the firebreak to show the difference. Mean tree height between rows did not differ significantly so size adjustments were not deemed necessary in the analyses. Interestingly, edge effect is not as readily discernible when only the proportion of trees infested is compared between edge and interior row trees (see Fig. 1).

Edge effect was also examined in plantation B which had 50 per cent of full stocking and thus had many spaces scattered throughout the planting. Although population levels averaged only 1.6 and 2.9 egg clusters per tree for 1962, a distinct and significant edge effect was evident. The major difference, however, was that the first two rows together, instead of just the outer row, acted as an edge due to the greater number of missing trees in both rows. The data (±SE) were as follows:

<table>
<thead>
<tr>
<th></th>
<th>1962</th>
<th>1963</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean egg clusters per row 1</td>
<td>3.0 ± 0.8</td>
<td>9.4 ± 1.3</td>
</tr>
<tr>
<td>Mean egg clusters per row 2</td>
<td>3.3 ± 0.5</td>
<td>8.5 ± 1.3</td>
</tr>
<tr>
<td>Mean egg clusters per row 3-23</td>
<td>1.5 ± 0.1</td>
<td>2.5 ± 0.1</td>
</tr>
</tbody>
</table>

Besides this, the third and fourth rows of the 1963 population had about twice as many egg clusters as the remaining rows, suggesting that they, too, were a part of the "edges."
VERTICAL DISTRIBUTION.—Egg cluster distribution by whorls was recorded for all trees in Plantation A in 1963 when the population mean was 8.14 egg clusters per tree. All trees had four whorls of branches but on some the bottom whorl was stunted or dead. The order of egg-cluster density by whorls was \(2 > 3 > 1 > 4\), with over 50 per cent on the second whorl (Table 2). Adjusting the data by the number of shoot tips, however, gives the order as \(1 > 2 > 3 > 4\) with over 50 per cent on the first whorl (Table 2). Considering the amount of foliage (linear inches) on each whorl the order is \(2 > 1 > 3 > 4\) with over 45 per cent on the second whorl (Table 2).

Egg cluster location on the edge row differed somewhat from inner rows (2-9, Fig. 1) in plantation A. There were not only more egg clusters on the edge row, but they were spread out more on the crown so that whorls 3 and 4 had proportionately more of them (Table 3).
Table 2. Number of sawfly egg clusters per tree, shoot tip, and amount of foliage by whorls for Scotch pine trees in plantation A, 1963.

<table>
<thead>
<tr>
<th>Whorl</th>
<th>Egg clusters/tree</th>
<th>Number of shoot tips</th>
<th>Egg clusters/tip</th>
<th>Foliage amount (linear inches)</th>
<th>Egg clusters per 100 inches foliage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.84</td>
<td>10.8</td>
<td>0.078</td>
<td>136</td>
<td>0.628</td>
</tr>
<tr>
<td>2</td>
<td>4.95</td>
<td>80.0</td>
<td>0.662</td>
<td>645</td>
<td>.767</td>
</tr>
<tr>
<td>3</td>
<td>2.28</td>
<td>189.4</td>
<td>0.012</td>
<td>940</td>
<td>.243</td>
</tr>
<tr>
<td>4</td>
<td>.35</td>
<td>174.7</td>
<td>.002</td>
<td>626</td>
<td>.056</td>
</tr>
<tr>
<td>1-4</td>
<td>8.14</td>
<td>454.9</td>
<td>.154</td>
<td>2,350</td>
<td>1.694</td>
</tr>
</tbody>
</table>

Table 3. Distribution of sawfly egg clusters by branch whorls for edge and nonedge Scotch pine trees in Plantation A, 1963.

<table>
<thead>
<tr>
<th>Whorl</th>
<th>Mean no. egg clusters (+ SE)a</th>
<th>Percentage</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Row 1 (edge)</td>
<td>Rows 2-9</td>
<td>Row 1 (edge)</td>
</tr>
<tr>
<td>1</td>
<td>1.09 ± .16</td>
<td>0.80 ± .05</td>
<td>7.0</td>
</tr>
<tr>
<td>2</td>
<td>7.77 ± .64</td>
<td>5.17 ± .20</td>
<td>49.5</td>
</tr>
<tr>
<td>3</td>
<td>5.34 ± .60</td>
<td>2.45 ± .12</td>
<td>34.1</td>
</tr>
<tr>
<td>4</td>
<td>1.48 ± .49</td>
<td>0.25 ± .06</td>
<td>9.4</td>
</tr>
<tr>
<td>1-4</td>
<td>14.96 ± 1.18</td>
<td>8.51 ± .31</td>
<td>100.0</td>
</tr>
</tbody>
</table>

aStandard error.
Table 4. The mean, variance, and \( k \) values of counts of egg clusters of the European pine sawfly, 1962-1964.

<table>
<thead>
<tr>
<th>Plot/yr</th>
<th>Original counts (x)</th>
<th>Transformed, log (x + 1)</th>
<th>Transformed, log (x + k/2)</th>
<th>Transformed ( x^{26} )</th>
<th>Transformed log (( x^{26} + 1 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Variance</td>
<td>( k )</td>
<td>Mean</td>
<td>Variance</td>
</tr>
<tr>
<td>A-62</td>
<td>0.925</td>
<td>1.805</td>
<td>0.973</td>
<td>0.207</td>
<td>0.060</td>
</tr>
<tr>
<td>A-63</td>
<td>8.140</td>
<td>40.309</td>
<td>2.060</td>
<td>.843</td>
<td>.121</td>
</tr>
<tr>
<td>A-64</td>
<td>19.480</td>
<td>157.880</td>
<td>2.742</td>
<td>1.208</td>
<td>0.115</td>
</tr>
<tr>
<td>B-62</td>
<td>1.583</td>
<td>4.200</td>
<td>.957</td>
<td>.299</td>
<td>.092</td>
</tr>
<tr>
<td>B-63</td>
<td>2.895</td>
<td>12.156</td>
<td>.905</td>
<td>.443</td>
<td>.126</td>
</tr>
<tr>
<td>C-62</td>
<td>1.760</td>
<td>5.233</td>
<td>.892</td>
<td>.320</td>
<td>.099</td>
</tr>
<tr>
<td>C-63</td>
<td>2.339</td>
<td>6.051</td>
<td>1.575</td>
<td>.429</td>
<td>.090</td>
</tr>
<tr>
<td>D-62</td>
<td>14.363</td>
<td>202.726</td>
<td>1.095</td>
<td>1.001</td>
<td>.186</td>
</tr>
<tr>
<td>D-63</td>
<td>2.446</td>
<td>9.085</td>
<td>.901</td>
<td>.397</td>
<td>.120</td>
</tr>
<tr>
<td>E-62</td>
<td>.847</td>
<td>1.024</td>
<td>4.047</td>
<td>.208</td>
<td>.048</td>
</tr>
<tr>
<td>E-63</td>
<td>.147</td>
<td>.165</td>
<td>1.193</td>
<td>.042</td>
<td>.013</td>
</tr>
<tr>
<td>F-62</td>
<td>.228</td>
<td>.262</td>
<td>1.516</td>
<td>.064</td>
<td>.019</td>
</tr>
<tr>
<td>F-63</td>
<td>.378</td>
<td>.447</td>
<td>2.077</td>
<td>.102</td>
<td>.028</td>
</tr>
<tr>
<td>G-62</td>
<td>13.786</td>
<td>82.667</td>
<td>2.759</td>
<td>1.071</td>
<td>.106</td>
</tr>
</tbody>
</table>

\( r = 0.92 \) \((P < 0.01)\)  \( r = 0.76 \) \((P < 0.01)\)  \( r = 0.18 \) \((P > 0.05)\)  \( r = 0.06 \) \((P > 0.05)\)  \( r = -0.40 \) \((P > 0.05)\)
Fig. 6. Density of sawfly egg clusters by row in plantation A for low (1962), medium (1963), and high (1964) population levels. Row 1 adjoins an open grassy field; rows 10, 11, and 20 adjoin narrow firebreaks. Number of trees per row varies from 52-62. Rows 11-20 were not censused in 1964.

DISCUSSION

Spatial distribution of European pine sawfly egg clusters is influenced by many factors including the behavior of the sawflies, the interactions among themselves and other organisms, and especially the distribution of the essential elements of their habitat. Although pine plantations (if monocultures) are relatively uniform, there is still some variability in gene pool, spacing, height, and physiology which influences insect attraction. Appropriately then, the European pine sawfly—as with most other organisms—tends to be overdispersed in particular parts of the habitat rather than in a random or regular pattern.

The negative binomial series and Taylor's power law both provide useful indices of overdispersion which are constants, but by either index, the spatial pattern between trees is not detectably different from random at population levels below approximately 1.0 egg cluster per tree. Above this level overdispersion is clearly apparent.

Tree size, density, and location modify spatial distribution. There is a direct relationship between tree size and egg population. Overdispersion of egg clusters occurs within all height classes indicating that trees are not equally attractive to ovipositing female sawflies once the egg-cluster density reaches a certain level in a stand; or at least an overdispersed pattern is not discernible until this occurs. Using variance-mean ratios, Lyons (1964b) noted that distribution of *N. sertifer* larval colonies per tree (for 2- to 20-ft tall trees) was nearly random for some height classes. Intermediate level classes,
however, showed the colonies to be moderately aggregated. Thus he surmised that trees of the same height were not equally exposed to attack in some cases. Larval colonies and egg clusters of this insect should have approximately the same pattern of distribution between trees—unless heavy predation occurs or starvation forces larval migration. Why Lyon's larval colony data appeared random and my egg colony data were not is not certain. His plantation trees ranged from 2-21 ft in height whereas most of mine varied from 2-8 or 2-10 ft; this may or may not be important.

Several authors state that *N. sertifer* prefers isolated or border trees and that the degree of exposure within a stand is also directly related to aggregation (Hein, 1956; Kangas, 1941; Nicklas and Franz, 1957; Breny, 1957; Lyons, 1964a; Hattemer et al., 1969). Lyons (1964a) reports this is due to the tendency of adult females to oviposit on well-illuminated zones of their habitat, and exposed trees, wherever they are, may be expected to have more acceptable sites than shaded or crowded ones. My studies indicate the females do oviposit more heavily on border trees especially along an ecotone and especially as the population increases. In well-stocked plantings the border or edge consists generally of one row of trees, whereas in poorly stocked plantings more than one row may constitute the border because of the gaps between trees. At all densities the sawflies prefer the upper crown, but on exposed trees they tend to lay more eggs lower on the tree. As the female oviposits on the shoot tip, she probably chooses the location by the tip rather than by the amount of foliage. Borodin (1973) recently determined that the distribution of eggs in the trees by height is cubic parabolic. He provides a method for making quantitative estimates of the egg population.

The distribution pattern of *N. sertifer* should be considered in sampling for the eggs or larval colonies, especially if surveys are performed systematically rather than at random. Care should then be taken to sample all tree sizes and edge trees in proportion to their numbers in the stand. This seems to be unnecessary, however, if the rapid sampling technique devised by Wilson and Gerrard (1971) is used randomly or systematically. This technique involves sampling the proportion of trees infested. There appears to be no difference by tree size or location (edges) when proportion of trees infested is considered. Edge rows, for instance, had no more infested trees than interior rows even though the population may have been twice as large on the edge rows.

Analysis of variance and other statistical methods used in assessing sampling variation presuppose a normal distribution with variance independent of the mean. Thus it is necessary to transform overdispersed-type data to stabilize the variance. Because the sawfly egg cluster data were highly aggregated, they were transformed using: 

\[(x + 1)\] (Wadley, 1950); 
\[\log(x + K/2)\] (Anscombe, 1948); 
\[x^Y\] (Healy and Taylor, 1962); and 
\[\log(x^y + 1)\], in order to find a means of stabilizing variance. The correlation coefficient between mean and variance was highly significant when original counts and counts transformed to 
\[\log(x + 1)\] were used, and not significant with the other transformations (Table 4). Taylor's power law transformation \([xy]\) was the most powerful of those tested and the most satisfactory for statistical purposes.

**LITERATURE CITED**


REARING OF SCOLYTUS MULTISTRIATUS (MARSHAM) (SCOLYTIIDAE: COLEOPTERA) FOR TOXICOLOGICAL EXPERIMENTS

H. Riedl and J. W. Butcher

In a study of the oral and contact toxicity of methoxychlor residues to the smaller European elm bark beetle, *S. multistriatus*, it is essential to have beetle material available which is of uniform physiological condition and age (Riedl, 1973). Several rearing containers for bark beetles have been described in the literature (Clark and Osgood, 1964; Fox, 1958; Germain and Wygant, 1967; Schmitz, 1972). A common problem in such containers appears to be fungus growth on the logs due to insufficient ventilation and high humidity. Although these environmental conditions might not cause high mortality, they can render emerging beetles unsuitable for bioassays. In order to guarantee fresh beetle material of uniform age newly emerged beetles must be extracted immediately. This paper describes emergence drums with a ventilation system that prevents fungus growth. Also described is an efficient extraction device which prevented the insect from moving back into the rearing container once it reached the collecting apparatus.

The rearing unit consisted of a 35-gallon steel drum to which an extraction container was attached (Fig. 1: A, B). The drum was covered in front with a circular black plastic sheeting which was conveniently tied down with rubber cord. A circular air screen was inserted in the lower half of the plastic cover to aid air circulation. This screen was covered loosely by a piece of black plastic sheeting which prevented light from penetrating to the inside of the drum. The extraction device proper consisted of a 2" long piece of polyvinyl chloride (PVC) pipe glued into a circular hole close to the lower rim of the drum. A transparent plastic bottle from which the bottom had been cut was fitted snugly over the PVC pipe. One end of a short piece of tygon tubing was inserted into the mouth of the bottle and the other end led straight down into a 1-gallon carton. Paper towels were placed in the carton to increase the surface upon which extracted beetles could move about. A 20-watt cool white neon bulb provided the necessary light stimulus to attract emerging beetles into the collection containers.

The ventilation system (Fig. 1: C, D, E) consisted of the blower (the speed of which could be varied with a 3-way switch) an 8 ft long PVC pipe with several air outlets, and an adjustable valve to regulate the airflow. Tygon tubing guided air into each emergence drum. One end of the 8 ft PVC pipe was supported by the blower housing and the other end rested on a wooden support which consisted of ¼" Masonite board sandwiched between two pieces of plywood. A sliding piece of Masonite board allowed continuous regulation of airflow into the drums. If desired the ventilation of each individual drum could be regulated by means of adjustable clamps on the tygon tubing.

For comparison purposes, relative humidity and temperature data were recorded for the rearing room, and for an unvented and a vented rearing unit over a two-week period. The same number of fresh beetle-infested logs were placed in each of the two units. Temperature in the two rearing units did not, as might be expected, differ from the temperature in the rearing room. However, relative humidity for the rearing room averaged 55%. It was higher by 13% in the vented drum, but was constantly 100% in the unvented rearing unit. The logs in the vented drum were free of fungus and yielded high beetle emergence and low mortality. The 100% relative humidity in the unvented drum caused extensive fungus growth and an overall unsatisfactory environment for beetle development which resulted in poor emergence.

For optimum rearing air flow for all units was adjusted to maintain between 70% and 80% R.H. when filled with elm logs. Desiccation of logs due to constant air exchange in the drum was not excessive. The temperature in the rearing room was maintained at

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1Michigan Agricultural Experiment Station Journal Article Number 6910.
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Fig. 1. Design of emergence drum plus extraction device (A: front view, B: side view) and ventilation system (C: front view: blower housing and air pipe plus support, D: view from above; blower housing, E: side view; support of air pipe with valve half closed). 1. 35 gal. steel drum; 2. Black plastic sheeting; 3. Tie-down rubber cord (3/16"); 4. Air-screen; 5. PVC pipe (3"); 6. 500 ml transparent plastic bottle; 7. Tygon tubing (¼"); 8. 1 gal. ice-cream carton; 9. 20 WATT cool white neon light; 10. Blower housing; 11. Wooden support with adjustable valve; 12. Dayton blower (model 2C781); 13. 3-way switch; 14. Copper tubing (5/8").
26° C ± 1.5. For a continuous supply of S. multistriatus, fresh elm logs were infested in completely closed cardboard boxes at intervals of two weeks. After 10 days they were transferred to emergence drums where the first adults emerged after roughly five weeks. The adult beetles obtained under these standardized conditions displayed great vigor and were very uniform in size.

LITERATURE CITED
ASPECTS OF THE FEEDING BEHAVIOR OF *SCOLYTUS MULTISTRIATUS* (MARSHAM) (SCOLYTIDAE: COLEOPTERA) AND IMPLICATIONS FOR CONTROL

H. Riedl and J. W. Butcher

Successful protection of elm trees can only be accomplished by means of thorough understanding of the feeding behavior of the smaller European elm bark beetle, *Scolytus multistriatus* (Marsham). Wolfenbarger and Buchanan (1939) and Whitten (1958) noted that most feeding occurred in the outer portion of the upper crown region, but offered no quantitative data. Therefore, this study was initiated to investigate the regional distribution of feeding injuries along a vertical and horizontal gradient in native American elm, *Ulmus americana* L.

Another objective of this study concerned a detailed analysis of feeding scars in order to correlate specific physical characteristics of twig crotches with feeding injuries. Chemical aspects of feeding stimulation have received considerable attention (Baker and Norris, 1967), but the importance of physical characteristics of the twig crotch of the feeding process was not fully researched. Information of this kind could be valuable in the selection of elms with twig crotch characteristics which would not induce feeding attack. However, as Heybroek (1969) pointed out, an elm resistant to feeding by *multistriatus* could still be attacked by other vectors.

MATERIALS AND METHODS

Six elm trees henceforth designated A to F were sampled at three height levels: 5, 10 and 15 meters. The elms were park trees and had not been sprayed at any time during the previous five years. In this respect the natural feeding pattern was not disturbed. Tree height ranged from 15 to 18 meters. Random samples of 50-70 twig crotches were taken from five points in each height level (from four compass points and the interior of the crown). A light-weight aluminum pole pruner, extendable to 16 m was used to sample elm twigs. The total number of twig crotches and the number of feeding injuries were recorded from each sample. The number of scars in places other than twig crotches (mainly in leaf axils) was not included in the figure for total attack. The average feeding attack for each height level was computed from the percentage feeding at the five sample points (Table 1). Also, the position of the sample branches at the three height levels was recorded as: (a) pointing upwards, (b) projecting horizontally, and (c) pointing downwards.

For a study of feeding preference for vertical quarters, each sample tree was subdivided into five sections: N (north), S (south), E (east), W (west), and C (center). In order to demonstrate the consistency of the horizontal feeding pattern over the three height levels, the twig-crotch injury data for each tree was subjected to Friedman’s ANOVA according to rank (Siegel, 1956, p. 166). Tree A was deleted from this analysis because of the low attack rate at all levels.

In order to study the association of certain morphological features of twig crotches to feeding, 300 samples from tree B and 400 samples from tree D were analyzed. The following characteristics were recorded:

1. Angle between the two lateral members of crotch. This was measured by placing the twig crotch on polar coordinate graph paper (accurate to 5°).
2. Crotch base: either rounded or acute (Fig. 1).
3. Injuries by vector feeding.
4. Position of feeding scar; either lateral or central (Fig. 1).

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Table 1. Feeding attack in three height levels of six mature elm trees.

<table>
<thead>
<tr>
<th>Tree</th>
<th>Height level (m)</th>
<th>5</th>
<th>10</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>a)</td>
<td>0</td>
<td>2.9 ± 1.3</td>
<td>4.5 ± 1.5</td>
</tr>
<tr>
<td></td>
<td>b)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>a)</td>
<td>9.3 ± 1.4</td>
<td>34.8 ± 4.8</td>
<td>62.1 ± 5.7</td>
</tr>
<tr>
<td></td>
<td>b)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>a)</td>
<td>24.0 ± 7.8</td>
<td>84.2 ± 1.8</td>
<td>92.6 ± 2.3</td>
</tr>
<tr>
<td></td>
<td>b)</td>
<td>0</td>
<td>11</td>
<td>32</td>
</tr>
<tr>
<td>D</td>
<td>a)</td>
<td>17.8 ± 4.2</td>
<td>81.7 ± 9.2</td>
<td>83.0 ± 9.6</td>
</tr>
<tr>
<td></td>
<td>b)</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>E</td>
<td>a)</td>
<td>27.2 ± 8.9</td>
<td>65.2 ± 14.0</td>
<td>81.7 ± 5.1</td>
</tr>
<tr>
<td></td>
<td>b)</td>
<td>0</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>F</td>
<td>a)</td>
<td>0.4 ± 0.4</td>
<td>27.8 ± 6.6</td>
<td>63.0 ± 9.0</td>
</tr>
<tr>
<td></td>
<td>b)</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

a) Average per cent attack, ± SE.
b) Total no. attacked leaf axils.

Several t-tests were performed on the angle data of attacked and unattacked twig crotches to test if *multistriatus* had a preference for twig crotches with certain angles. No t-value was calculated for tree B at the lowest height level because the numbers of attacked crotches was too small.

Combinations of type of twig crotch base and type of feeding were tested for their independence in a 2 x 2 contingency table. The combinations were round-lateral, round-central, acute-lateral and acute-central.

Fig. 1. Type of twig crotch base: (a) rounded, (b) acute and type of feeding: (c) lateral, (d) central.
RESULTS AND DISCUSSION

REGIONAL DISTRIBUTION OF FEEDING INJURIES ALONG A VERTICAL GRADIENT.—The relationship between height level and amount of feeding (Table 1) appeared to be linear for low and high vector pressure (Fig. 2). It appears that as most available twig crotches in the top level become attacked, newly arriving vectors have difficulty finding suitable feeding sites and move down into the middle level of the crown region. This explains the departure from the linear relationship between elevation and feeding in trees C and D.

In trees where the attack rate exceeded 80%, the beetle vectors occasionally resorted to feeding in leaf axils. This was especially noticeable on trees C, D, and E, but feeding wounds of this kind were also present on tree F where the average attack at height level 2 was lower (27.8%). The importance of feeding in leaf axils with regard to effective disease transmission is not known. Twig crotches were sometimes attacked more than once, particularly in samples with a great number of feeding injuries.

The amount of feeding was not correlated with branch position. Location of the feeding wound, in respect to upper or bottom side of the twig showed no pattern regardless of the position of the branch. Morphological variation of twig characteristics among the six sampled elms was considerable. Some elms had long slender twigs which were very flexible. These also had few crotches (tree E and F) while others had many crotches and were more sturdy in appearance.

REGIONAL DISTRIBUTION OF FEEDING INJURIES ALONG A HORIZONTAL GRADIENT.—Using Friedman’s ANOVA by rank only trees B and E had greater differences in feeding attack between the five sample points consistently over all three height levels (Table 2). In tree B the percentage of feeding injuries was lowest in the S sector, but considerably higher in the N and E sectors. Tree E had the least feeding in the W sector and the highest number of injuries in the E sector.

Initially it was suspected that the central sector at the lower height levels 2 and 3 would be the region with the fewest number of feeding scars, because of a reported
Table 2. Comparison of feeding attack in four cardinal quarters and center section of elm trees using Friedman's ANOVA.

<table>
<thead>
<tr>
<th>Tree</th>
<th>$X^2_f$</th>
<th>Significance</th>
<th>Highest feeding in quarter of tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>7.47</td>
<td>0.20</td>
<td>N, E</td>
</tr>
<tr>
<td>C</td>
<td>3.67</td>
<td>n.s.</td>
<td>—</td>
</tr>
<tr>
<td>D</td>
<td>3.00</td>
<td>n.s.</td>
<td>—</td>
</tr>
<tr>
<td>E</td>
<td>7.47</td>
<td>0.20</td>
<td>E</td>
</tr>
<tr>
<td>F</td>
<td>6.50</td>
<td>0.20</td>
<td>—</td>
</tr>
</tbody>
</table>

$X^2_f = 7.78 (a = 0.10, df = 4)$

$X^2_f = 5.99 (a = 0.20, df = 4)$

vector preference for the periphery of the crown (Wolfenbarger and Buchanan, 1939). However, this was not the case in this study.

Uneven distribution of feeding wounds in the 5 vertical sections of the tree (N, S, E, W, C) was probably not the result of preferential feeding in any one of the five regions. Rather, the proximity of a beetle-producing elm tree to a particular quarter of the above sample trees might have caused this difference in attack.

The question of a possible difference in the overall feeding pattern on elm trees in a closed stand and on road-side elms was also raised. Sample trees A, B, C and D were in closed stands, together with other tree species, while trees E and F were part of a road-side planting. The vertical and horizontal distribution of feeding injuries in these two groups of trees did not seem to be different. However, both road-side elms showed differences in the number of feeding injuries in the five sectors of the tree. Whether this is a general trend among road-side trees can only be speculated upon since the sample was too small. These findings suggest that the whole upper tree region requires particular attention during spraying operations. Differential hazard regions for fungus infection must be considered as well. Fungal infections originating from feeding wounds in the lower part of an elm tree are more likely to cause quicker mortality because of the shorter distance the fungus has to travel to the main trunk (Zentmeyer et al., 1946). As a consequence, spray application methods should be judged in respect to their performance on the whole tree.

ASSOCIATION OF PHYSICAL TWIG CROTCH CHARACTERISTICS WITH FEEDING.—No relation was observed between crotch angle and feeding (Table 3). Of interest is the fact that the angle means of the height level samples for tree B, with 87.3°, 83.0° and 84.5°, were considerably higher than the means for tree D, with 64.6°, 66.8° and 69.1°. The great difference in angle means between these two trees is an example of the morphological variability one can find among elm trees.

Ouellette (1962) noted that lateral feeding resulted in a higher infection rate than did central feeding. Presumably during lateral feeding the beetle vector with the spores attached to its body exterior establishes better contact with the conductive tissue.

The contingency table (Table 4) suggested that twig crotches with a rounded base are more likely to induce lateral rather than central feeding responses. Therefore, the probability of fungal infection is higher on trees with a greater proportion of twig crotches with a rounded base because of the preferred lateral type of feeding.

SUMMARY

Extensive sampling of untreated elm trees revealed that Scolytus multistriatus feed preferentially in the whole upper tree region. Feeding attack rate increased linearly from the bottom to the top. This behavior must be considered for the proper choice and evaluation of a spray application method in order to achieve maximum protection. Differences in attack in vertical sections of a tree were observed but were believed to be more directly related to the close proximity of a beetle-producing tree than to a particular
Table 3. T-comparisons of angle means of attacked and unattacked twig crotches.

<table>
<thead>
<tr>
<th>Tree</th>
<th>Height level (m)</th>
<th>Type</th>
<th>n</th>
<th>Mean angle</th>
<th>s_x</th>
<th>t calc</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>5</td>
<td>Att.</td>
<td>5</td>
<td>85.0</td>
<td>3.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unatt.</td>
<td>95</td>
<td>87.3</td>
<td>0.85</td>
<td>not calc</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Att.</td>
<td>32</td>
<td>84.1</td>
<td>2.63</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unatt.</td>
<td>68</td>
<td>82.4</td>
<td>1.50</td>
<td>.575</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Att.</td>
<td>32</td>
<td>81.7</td>
<td>3.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unatt.</td>
<td>68</td>
<td>85.7</td>
<td>2.01</td>
<td>1.11</td>
</tr>
</tbody>
</table>

- \( t = 1.980 \) (\( \alpha = .05 \), \( \text{df} = 98 \))
- \( t = 1.960 \) (\( \alpha = .05 \), \( \text{df} = 148 \))

Table 4. Association between type of feeding and type of twig crotch base.

<table>
<thead>
<tr>
<th>Type of feeding</th>
<th>Twig crotch base</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Round</td>
<td>Acute</td>
</tr>
<tr>
<td>Lateral</td>
<td>124</td>
<td>60</td>
</tr>
<tr>
<td>Central</td>
<td>83</td>
<td>72</td>
</tr>
<tr>
<td>Total</td>
<td>207</td>
<td>132</td>
</tr>
</tbody>
</table>

- \( X^2 \) calc = 6.78
- \( X^2 \) tab = 3.84
- \( (\alpha = 0.05, \text{df} = 1) \)

quarter of a sample tree. Several physical twig crotch characteristics were investigated with respect to their association with vector feeding. The size of the angle between the main and lateral member of a twig crotch had no influence on feeding. However, there was a significant relation between a more rounded twig crotch base and lateral feeding. Lateral feeding reportedly results in more successful inoculations than does central feeding. These findings pointed out a possible resistance mechanism against feeding by *multistriatus*.

LITERATURE CITED


NOTES ON THE BIOLOGY AND PARASITOIDS OF THE SWEET FERN UNDERWING (LEPIDOPTERA: NOCTUIDAE) IN MICHIGAN

Louis F. Wilson

INTRODUCTION

The sweet fern underwing, *Catocala antinympha* (Hübner), sometimes called "the wayward nymph" (Holland, 1968), is one of several lepidopterous defoliators of sweet fern, *Comptonia peregrina* (L.) Coult. Investigators have dealt only briefly with this insect because it is difficult to collect and rear in quantity and consequently, its biology is poorly known. The early works are basically taxonomic treatises. Barnes and McDunnough (1918b) updated the synonymy which remains intact to date. They placed *antinympha* as belonging to their Group IV (*Catabapta* Hulst), a group comprising *Myrica* (=*Comptonia*) feeders. Their treatise presents excellent color reproductions of the adult and mature larva. Previously, Beutenmüller (1902) described the six larval instars.

The present paper adds a little more to the distribution, biology, and habits of the sweet fern underwing, with emphasis on Michigan, and includes the known parasitoids and the effect of some of them on the size of the larval head capsule.

METHODS AND MATERIALS

Underwing moth larvae in various stages of development were collected by sweep-netting from sweet fern in Alcona, Wexford, Lake, and Grand Traverse counties, Michigan, during the summers of 1971 and 1972. Specimens not injured or preserved in alcohol were reared in petri dishes in a small unheated laboratory trailer near Fife Lake, Wexford County. Fresh foliage was supplied daily, and head capsule widths were measured after each ecdysis. A total of 175 larvae were collected, and of these, 139 were reared. These yielded 52 adult moths, 67 hymenopterous parasitoids, 6 dipterous parasitoids, and 14 mortalities due to injuries and unknown causes. Braconid and ichneumonid parasitoids that matured were sent to W. R. M. Mason at the Canadian Biosystematic Research Institute and H. K. Townes at the American Entomological Institute for identification.

Fourteen of the reared larvae, during their last instar, were placed outdoors on a sweet fern plant enclosed by a cage so we could observe pupation. Other specimens that pupated in their rearing dishes were allowed to emerge into a small cage. They were then captured, transferred to a larger cage in the field and placed over a cluster of sweet fern plants. Protective hiding places (short pine bolts) and food (a mixture of beer, molasses, and bananas) were provided. All sweet fern plants were removed in mid-October each year and examined carefully for eggs. Those found were placed in vials and stored overwinter in a garage.

DISTRIBUTION

*C. antinympha* occurs in southern Canada from Ontario eastward through Quebec to Nova Scotia, and in the northern United States from New England west to the Mississippi River. Specifically, it has been recorded in the literature from Maine, New Hampshire, Massachusetts, New York, Maryland, Pennsylvania, and Wisconsin (Forbes, 1948; Barnes and McDunnough, 1918a; Cary, 1928; Darlington, 1949; Holland, 1968; Schaffner and Griswold, 1934). In Michigan it is common in the northern part of the lower peninsula (Fig. 1), but it has been collected in Allegan, St. Clair, Livingston, and Wayne Counties which are southern and not particularly abundant in sweet fern which appears to be its only host.

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Fig. 1. Michigan counties where the sweet fern underwing has been collected.
BIOLOGY

*Catocala antinympha* is univoltine and overwinters in the egg stage—typical traits of the genus. Insufficient numbers were collected to accurately define all the life stages. However, it is possible to outline a generalized life cycle from the insects observed and from the scattered records in the literature.

The light brown eggs are deposited on the host in early August several days after adult emergence. This delay is probably owing to a shortage of mature ova as dissections of freshly emerged adults show. Most eggs are found singly on the flower stem within two inches of the litter. They are somewhat hemispherical in shape with an oval base; the sides have 20-25 vertical ribs about half of which reach the micropylar area at the top. Some ribs are branched. Numerous faint transverse ribs occur in the matrix between the vertical ribs. Seven eggs averaged 0.99 mm long, 0.71 mm wide, and 0.71 mm high.

After the eggs overwinter, larval eclosion begins about mid- to late May. The larvae migrate up the stems of the host and feed on the edges of the young sweet fern leaves. The larvae are day feeders in contrast to many *Catocala* that rest or hide until evening. Even so, they are difficult to detect because of their mottled markings and their habit of stretching out parallel to the foliage and twigs while feeding and resting. They are not easily captured because they twist violently and drop to the ground when either they or their host plant are touched. Only once did I see one rear up and sway from side to side instead of dropping off the host. The larvae are generally solitary (Fig. 2); three or more larvae per plant is uncommon.

There are six larval instars—all were described fully by Beutenmüller (1902), but he did not give head capsule measurements. He segregated *antinympha* larvae into a group designated as those "without processes or elevation on the eighth abdominal segment." Head capsule width measurements of non-parasitized larvae from Michigan for the various instars were:

<table>
<thead>
<tr>
<th>Instar</th>
<th>No. measured</th>
<th>Mean width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0</td>
<td>0.40 (est)</td>
</tr>
<tr>
<td>II</td>
<td>4</td>
<td>0.58</td>
</tr>
<tr>
<td>III</td>
<td>17</td>
<td>0.82</td>
</tr>
<tr>
<td>IV</td>
<td>15</td>
<td>1.25</td>
</tr>
<tr>
<td>V</td>
<td>36</td>
<td>1.77</td>
</tr>
<tr>
<td>VI</td>
<td>21</td>
<td>2.53</td>
</tr>
</tbody>
</table>

The first two instars passed quickly, probably averaging about three or four days and probably not exceeding seven to eight each. Instars III-VI increased progressively, reaching an average of 14 days for the 6th (last) instar. Beutenmüller (1902) observed ecdysis at only two-day intervals for instars I to IV, but this likely occurred under warm laboratory conditions.

When ready to pupate, mature larvae migrate to the soil and spin a thinly webbed cocoon (Fig. 3) in the leaf litter adjacent to the soil. Darlington (1949) recorded the pupa as occurring in the soil and "trash" (i.e. litter). Pupae are nearly an inch long, brown, and dusted with a pale blue coating. I found the pupal stage to vary from 15 to 23 days, beginning in early July and ending in late August, about an eight-week period. Brower (1994) gave the pupal period as 20-30 days and Schaffner and Griswold (1934) stated the pupal period occurred from July to early August. Darlington (1949), however, found larvae alive as late as October 20 in southern New Jersey, but did not say whether the larvae were healthy or capable of pupation. Adults (Fig. 4) are gone by this time as attested by most collectors.

Adult capture dates outside of Michigan include: July and August (Schaffner and Griswold, 1934), August (Holland, 1968), and August-September (Cary, 1928). Capture dates in Michigan varied from July 12 to September 18.\(^2\) My rearing records show adults

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\(^2\)Data from collections at Michigan State University, The University of Michigan, J. H. Newman (entomologist) (MSU), and M. C. Nielsen (lepidopterist), Lansing, Michigan.
emerging from July 29 to August 29 and several were still alive in cages in the field on September 13, 1972, when the tests were terminated.

LARVAL PARASITIZATION

PARASITOIDs.—In Michigan, five species of parasitoids were reared from Catocala antinympha larvae: an ichneumonid, Zele melloa Cresson, an unidentified dipteran, and several braconids including Hyposoter annulipes Cresson. The other braconids of the
Fig. 3. Pupa of sweet fern underwing in cocoon in leaf litter.

Fig. 4. Adult of sweet fern underwing.
genus Microplitis were at first thought to be three distinct species from their kinds of cocoons. They were, however, identified as two species, *M. bradleyi* Muesebeck and *Microplitis* n.sp.—the latter having sexually dimorphic cocoons. Easily separable, the cocoon of the male of the latter is elongated, somewhat irregular in contour, and tan with the black band around the middle; that of the female is more smoothly contoured with a faint, almost imperceptible band. The cocoon of *M. bradleyi*, in contrast, is strongly prolate and dark brown with raised gray ridges.

Schaffner and Griswold (1934) also reared *Hyposoter annulipes*, a new species of *Microplitis*, and two dipterans, *Chaetopilaeus* sp. and *Winthemia* sp., from *C. antinympha* larvae from the New England States.

PARASITISM AND HEAD CAPSULE SIZE.—Each kind of parasitoid emerged as fully developed larvae from two different instars of the underwing. *M. bradleyi* and *Microplitis* n.sp. female emerged from 4th and 5th instars, and *Microplitis* n.sp. male emerged from 5th and 6th instars. All *microplitis* parasitoids reduced the head capsule size of the host in the instar of emergence (Table 1), not in any of the instars prior to the one in which the parasitoid emerged. For example, head capsules for normal and parasitized larvae averaged 1.24 and 1.25 mm, respectively, for 4th instars, and 1.75 and 1.77 mm, respectively, for 5th instars—the measurements for the parasitized ones being in the instar prior to parasitoid emergence.

The reason that *Microplitis* spp. emerge in more than one instar is not fully clear, but it probably has to do with the instar in which the host is parasitized. Several of the parasitized larvae that were reared in the laboratory passed through two "normal looking" instars prior to the instar with the reduced head capsule (*i.e.*, instars II and III, and III and IV for those parasitoids emerging in instars IV and V respectively), so the larvae must have been parasitized in the 1st and 2nd instar before they were collected. Older larvae collected later in the season, however, may have been parasitized in the 3rd and 4th instars and thus the parasitoid emerged in the last instar.

Head capsule reduction was greatest when the parasitoid emerged from a later instar (Fig. 5). For example, *M. bradleyi* emerging from the 4th instar *Catocala* larva reduced the 4th instar head capsule an average of 35%, whereas when emerging from the 5th instar, it reduced that head capsule an average of 88%. This reduction can be readily seen by comparing growth ratios or "progression factors"—the ratios of mean head capsule widths between two successive instars. Growth ratios for normal larvae for the last three instars were 1.44, 1.42, and 1.42, indicating a nearly constant progression of development. Head capsules of parasitized larvae, however, showed a declining progression of

Table 1. Head capsule widths and growth ratios of normal and parasitized larvae of *Catocala antinympha*. Parasitoids emerged from stage indicated.

<table>
<thead>
<tr>
<th>Larval instar of <em>Catocala</em></th>
<th>Normal larvae</th>
<th>Larvae parasitized by <em>Microplitis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><em>bradleyi</em></td>
</tr>
<tr>
<td>Head capsule widths (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>1.25 ± 0.02a</td>
<td>1.10 ± 0.01</td>
</tr>
<tr>
<td>V</td>
<td>1.77 ± 0.01</td>
<td>1.31 ± 0.04</td>
</tr>
<tr>
<td>VI</td>
<td>2.53 ± 0.03</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Growth ratiosb</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>1.44</td>
</tr>
<tr>
<td>V</td>
<td>1.42</td>
</tr>
<tr>
<td>VI</td>
<td>1.42</td>
</tr>
</tbody>
</table>

aStandard error. Means calculated from 3 to 36 measurements.
bRatios of mean widths between IV/III, V/IV, VI/V instars.
Comment on How Parasitism Can Interfere with Determination of Instars Head Capsule Size.

Insect development and the number of instars are determined for many insects by either rearing immatures through all their instars and counting molts, or by collecting many immatures throughout the developmental period and plotting their head capsule measurements as a frequency histogram. The latter method also provides reliable estimates of means and standard errors if sufficient measurements are used and if there is a gap between measurements of adjacent size classes.

When parasitism affects head capsule size, errors will be introduced in these measurements as in the following example. Larval head capsule measurements of *antinymphal*, when plotted as a frequency histogram, showed distinct size classes that normally should provide reliable means and standard errors. However, head capsules from larvae parasitized by *Microplitis*, when plotted with normal ones, causes some classes to become shifted to the left (Fig. 6) so that there was an underestimate of these class means. Also, highly reduced head capsules either produced false classes in between the true classes, or they were among those of the prior instar class (Fig. 6). Such errors were greatest for *C. antinymphal* larvae parasitized by *M. bradleyi*, which reduced head capsule size in the 5th instar. Head capsules were reduced sufficiently to cause an underestimate of the class means of the last three instars, and, of course, the more larvae parasitized, the greater will be the expected underestimate.

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Fig. 5. Head capsule width development for normal sweet fern underwing larvae and for *Microplitis* spp. parasitized larvae. (Dashed line indicates estimate of first instar larval size.)
Different kinds of parasitoids can affect the head capsules of their hosts in several ways. First, the parasitoid may affect the head capsule only during the instar in which it emerges, as occurs with antinympha parasitized by Microplitis spp. In this case, one cannot determine by head capsule width which larva is parasitized in the instar in which the parasitoid emerges. Conversely, one can recognize a parasitized larva and tell at what instar the parasitoid will emerge by the less-than-normal head capsule size.

Second, the parasitoid can affect head capsule size in several instars and then emerge either in a late larval or the pupal stage, as occurs with the larch sawfly, Pristophora erichsonii Hartig, when parasitized by Olesicampe benefactor Hinz (Muldrew, 1967). In this particular case, the head capsule size of the sawfly progressively decreases through the last four instars of larval development. Thus, this type of parasitism strongly affects means and histograms of head capsule data, but easily permits one to identify parasitized larvae during several instars before parasitoid emergence.

Third, there may be no appreciable size reduction in any instar, as for example, when the yellow-headed spruce sawfly, Pikonema alaskensis (Rohwer), is parasitized (Van Derwerker and Kulman, 1974). This type of parasitism, of course, does not affect frequency histograms or means of head capsule measurements, but does prevent one from identifying parasitized larvae by head capsule size alone, if that is desirable.

LITERATURE CITED


Very soon after my paper, "Gynandromorphism in the Odonata" was published in The Michigan Entomologist (1971, Vol. 4, No. 3), Russell Rahn called my attention to his report of an aberrant "Agrion maculatum Beauvais" which I had overlooked. He described the specimen as "basically a male, with the genital organs on both the second and the last abdominal segments." The specimen was taken in the Nine Mile Swamp Conservation Area of Marathon County, Wisconsin on June 18, 1969. According to a typewritten note by Mr. Rahn on the copy of his paper sent to me, the specimen is in the Dartmouth Museum.

Recently, among the odonatological notes Mary Davis Ries gave me shortly before her death, I found her notation concerning another example mentioned in a paper by Dr. Calvert (1919) in which he described Enallagma vesperum, n.sp. In his list of specimens examined (p. 383-384) is "Wisconsin, Washington County, July 29, 1907, 1(gynandromorphic)♂"."( . . . in the Brooklyn Institute of Arts and Science.)" No further comments were made about it.

The following should be added to the references listed in my paper:


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