THE LIFE HISTORY AND ECONOMIC IMPORTANCE

OF MOCHLONYX CINCTIPES (COQUILLETT)

(DIPTERA: CULICIDAE)

DISSERTATION

Presented in Partial Fulfillment of the Requirements
for the Degree Doctor of Philosophy in the
Graduate School of The Ohio State
University

By

Charles Timothy O'Conner, B. Sc., M. Sc.

The Ohio State University
1958

Approved by

[Signature]
Adviser
Department of Zoology and
Entomology
ACKNOWLEDGMENT

The author wishes to express his gratitude to Dr. Carl Venard of the Zoology and Entomology Department, The Ohio State University, for guidance in all phases of this problem. Thanks are due Dr. Alvah Peterson, also of the Zoology and Entomology Department, and Dr. Roy W. Rings of the Ohio Agricultural Experiment Station for editing this manuscript and for helpful suggestions offered during the course of the investigations.

Appreciation is extended to the experts who identified the specimens involved in this study. This group includes: Dr. Carl Venard, Dr. Charles Triplehorn of the Ohio Agricultural Experiment Station, Dr. Thomas E. Bowman of the United States National Museum, Mrs. Mildred S. Wilson of the Arctic Health Research Center, Dr. Edwin Cook of the Minnesota Agricultural Experiment Station, and Dr. Harry Yeatman of the University of the South.

Thanks are due Mr. Frank Mead of the State Plant Board of Florida for distributional data and Mr. Glenn Berkey and Mr. Clarke Robey for the photographic reproductions.

The author also wishes to express sincere appreciation to his fiancee, Miss Sandra Jeanne Bible, for her assistance in both the laboratory and field observations reported in this manuscript.
# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION AND LITERATURE REVIEW</td>
<td>1</td>
</tr>
<tr>
<td>TAXONOMIC CONSIDERATIONS</td>
<td>5</td>
</tr>
<tr>
<td>GEOGRAPHIC DISTRIBUTION</td>
<td>7</td>
</tr>
<tr>
<td>DESCRIPTIONS OF MOCHLONYX CINCTIPES (COQ.)</td>
<td>10</td>
</tr>
<tr>
<td>Adult</td>
<td>11</td>
</tr>
<tr>
<td>Egg</td>
<td>16</td>
</tr>
<tr>
<td>First Instar Larva</td>
<td>16</td>
</tr>
<tr>
<td>Second Instar Larva</td>
<td>21</td>
</tr>
<tr>
<td>Third Instar Larva</td>
<td>24</td>
</tr>
<tr>
<td>Fourth Instar Larva</td>
<td>27</td>
</tr>
<tr>
<td>Pupa</td>
<td>30</td>
</tr>
<tr>
<td>LARVAL HEAD AND SIPHON MEASUREMENTS</td>
<td>33</td>
</tr>
<tr>
<td>HABITAT</td>
<td>41</td>
</tr>
<tr>
<td>Types of Woodland Pools</td>
<td>41</td>
</tr>
<tr>
<td>Study Pools</td>
<td>42</td>
</tr>
<tr>
<td>Temperature and pH</td>
<td>44</td>
</tr>
<tr>
<td>Associations</td>
<td>47</td>
</tr>
<tr>
<td>BIOLOGY</td>
<td>51</td>
</tr>
<tr>
<td>Egg</td>
<td>51</td>
</tr>
<tr>
<td>Larva</td>
<td>51</td>
</tr>
<tr>
<td>Collection of Larvae</td>
<td>51</td>
</tr>
<tr>
<td>Larval Distribution in the Pool</td>
<td>53</td>
</tr>
<tr>
<td>Movement</td>
<td>56</td>
</tr>
<tr>
<td>Molting</td>
<td>57</td>
</tr>
<tr>
<td>CONTENTS (contd.)</td>
<td>Page</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Relative Abundance at Various Locations</td>
<td>57</td>
</tr>
<tr>
<td>Respiration</td>
<td>59</td>
</tr>
<tr>
<td>Feeding</td>
<td>62</td>
</tr>
<tr>
<td>Ingestion</td>
<td>62</td>
</tr>
<tr>
<td>Types of food consumed in nature</td>
<td>64</td>
</tr>
<tr>
<td>Types of food consumed in laboratory</td>
<td>65</td>
</tr>
<tr>
<td>Quantities of food consumed</td>
<td>66</td>
</tr>
<tr>
<td>Comparative size of prey</td>
<td>66</td>
</tr>
<tr>
<td>Duration of the Larval Stage</td>
<td>67</td>
</tr>
<tr>
<td>Predators</td>
<td>69</td>
</tr>
<tr>
<td>Protozoa</td>
<td>70</td>
</tr>
<tr>
<td>Pupation</td>
<td>71</td>
</tr>
<tr>
<td>Pupa</td>
<td>72</td>
</tr>
<tr>
<td>Adult</td>
<td>72</td>
</tr>
<tr>
<td>Emergence</td>
<td>72</td>
</tr>
<tr>
<td>Resting Places</td>
<td>73</td>
</tr>
<tr>
<td>Movement</td>
<td>74</td>
</tr>
<tr>
<td>Swarming</td>
<td>75</td>
</tr>
<tr>
<td>Mating</td>
<td>76</td>
</tr>
<tr>
<td>Oviposition</td>
<td>77</td>
</tr>
<tr>
<td>Feeding and Drinking</td>
<td>78</td>
</tr>
<tr>
<td>Longevity</td>
<td>80</td>
</tr>
<tr>
<td>ECONOMIC IMPORTANCE</td>
<td>80</td>
</tr>
</tbody>
</table>
CONTENTS (contd.)

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUMMARY</td>
<td>83</td>
</tr>
<tr>
<td>LITERATURE CITED</td>
<td>85</td>
</tr>
<tr>
<td>AUTOBIOGRAPHY</td>
<td>89</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Distribution of Mochlonyx cinctipes (Coq.) in Ohio.</td>
<td>8</td>
</tr>
<tr>
<td>2.</td>
<td>Dorsal aspect of adult male M. cinctipes.</td>
<td>13</td>
</tr>
<tr>
<td>3.</td>
<td>Lateral aspect of head and thorax of adult male M. cinctipes.</td>
<td>14</td>
</tr>
<tr>
<td>4-10.</td>
<td>Adult. 4, Last tarsal segment of female. 5, Last tarsal segment of male. 6, Tarsus. 7 and 8, Large and small scales from wing fringe. 9, Lateral aspect of penis valve. 10, Male genitalia.</td>
<td>15</td>
</tr>
<tr>
<td>11-13.</td>
<td>Egg. 11, Lateral aspect. 12, Operculum. 13, Enlarged section of chorion.</td>
<td>17</td>
</tr>
<tr>
<td>14-16.</td>
<td>First instar larva. 14, Left mandible. 15, Dorsal aspect. 16, Lateral aspect.</td>
<td>20</td>
</tr>
<tr>
<td>17-19.</td>
<td>Second instar larva. 17, Left mandible. 18, Dorsal aspect. 19, Lateral aspect.</td>
<td>22</td>
</tr>
<tr>
<td>20-22.</td>
<td>Third instar larva. 20, Left mandible. 21, Dorsal aspect. 22, Lateral aspect.</td>
<td>25</td>
</tr>
<tr>
<td>23-25.</td>
<td>Fourth instar larva. 23, Left mandible. 24, Dorsal aspect. 25, Lateral aspect.</td>
<td>28</td>
</tr>
<tr>
<td>26-27.</td>
<td>Pupa. 26, Dorsal aspect of paddle. 27, Lateral aspect.</td>
<td>31</td>
</tr>
<tr>
<td>28-29.</td>
<td>Scatter diagrams of larval head and siphon measurements.</td>
<td>36</td>
</tr>
<tr>
<td>30-31.</td>
<td>Frequency diagrams of larval head and siphon measurements.</td>
<td>37</td>
</tr>
<tr>
<td>32.</td>
<td>Semilogarithmic graph of larval head and siphon measurements.</td>
<td>40</td>
</tr>
<tr>
<td>33.</td>
<td>Woodland pool formed by melting snow and spring rains.</td>
<td>43</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>34.</td>
<td>Woodland pool formed by the overflow of a stream.</td>
<td>45</td>
</tr>
<tr>
<td>35.</td>
<td>An ice-covered woodland pool containing first instar larvae of <em>M. cinetipes</em>.</td>
<td>46</td>
</tr>
<tr>
<td>36.</td>
<td>Partly submerged logs near which <em>M. cinetipes</em> larvae congregate.</td>
<td>55</td>
</tr>
</tbody>
</table>

vii
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Measurements of head width of <em>M. cinctipes</em> larvae</td>
<td>39</td>
</tr>
<tr>
<td>2. Measurements of head length of <em>M. cinctipes</em> larvae</td>
<td>39</td>
</tr>
<tr>
<td>3. Measurements of siphon width of <em>M. cinctipes</em> larvae</td>
<td>39</td>
</tr>
<tr>
<td>4. Measurements of siphon length of <em>M. cinctipes</em> larvae</td>
<td>39</td>
</tr>
</tbody>
</table>
INTRODUCTION AND LITERATURE REVIEW

The work of Ross, Finlay, Reed, and other scientists, who demonstrated that mosquitoes are vectors of many pathogens affecting man and animals, led to intensive studies of the bloodsucking Culicidae, which form the subfamily Culicinae. The non-biting Culicidae, which form the subfamily Chaoborinae, have received little attention (Dyar and Shannon, 1924; Matheson, 1944).

The latter subfamily is composed of seven genera, and a total of 75 species have been described. Only four genera are present in the Nearctic region: Mochlonyx, Corethrella, Eucorethra, and Chaoborus. The remaining three genera, Promochlonyx, Cryophila, and Neochaoborus, consist of tropical species.

The Chaoborinae are delicate mosquito-like flies ranging from 1.4 to 10 millimeters in length. They are a pale yellow, grey, or brown color with wing venation that is typically culicid. According to Matheson (1944) the mouthparts, with mandibles and maxillae present but lacking teeth, are short and not formed for piercing. Cook (1956) points out that although they are much less elongate, the mouthparts of the Chaoborinae are homologous with those of the Culicinae. He adds that the non-biting group has all of the structures necessary for both piercing and for feeding on liquids. The antennae are com-
posed of fifteen segments, and are more or less plumose in the male. The thorax and abdomen have no scales, although fine hairs are present. Scales are found primarily on the fringe of the wings, and in some cases, on the wing veins themselves. In one genus, scales are also found on the legs.

The larvae appear early in the spring in woodland pools and areas of standing water formed by the overflow of streams. The larvae of the Chaoborinae are predaceous upon crustaceans, mosquito larvae, and other small aquatic life in the pools. The shape and placement of the antennae vary from species to species, but they always are prehensile organs used in the capture of prey. The larvae are quite active, and move with their long axis parallel to the surface of the water.

Generally, these flies are innocuous, limiting their activities to a narrow radius surrounding the area in which they developed. Only one North American species, Chaoborus astictopus Dyar and Shannon, is considered to be a nuisance. It is commonly called the Clear Lake gnat, deriving its name from Clear Lake, California, where it develops in tremendous numbers. The abundance of this pest and the deleterious effect it has on the economy of this resort area have resulted in extensive studies of its biology (Herms, 1937; Lindquist and Deonier, 1942a, 1942b
and 1943; Deonier, 1943) and its control (Lindquist, Deonier, and Hancey, 1943; Lindquist and Roth, 1950 and 1951; Brydon, 1956).

Except for the previously mentioned species and Mochlonyx velutinus (Ruthe) (James, 1957), very few facts are known concerning the life histories of the American Chaoborinae. Until the work of Coquillett (1903), the genus Mochlonyx was assumed to be found only in Europe (Johannsen, 1903). Johannsen (1934) states that M. cinctipes "probably" overwinters in the egg or as adults. He also states that the eggs "are said" to be laid on the surface of the water. Matheson (1944) mentions the paucity of literature concerning the habits and biology of this subfamily, and suggests that students of mosquito biology should devote more attention to these beneficial insects.

The importance of these predaceous larvae in the natural control of mosquitoes has been emphasized by several authors. In regard to the Chaoborinae in general, Matheson (1944) writes that "they frequently destroy immense numbers of the larvae of aedine mosquitoes in the North." Of the larvae of M. cinctipes, he states that they "are frequently very abundant in the spring in woodland pools where they are very destructive to mosquito larvae." Cook (1956) believes that the Chaoborinae exert
considerable control on the numbers of biting species of mosquitoes. He adds that although the actual extent of this natural control has not been investigated thoroughly, his personal observations reveal that the predaceous larvae destroy large quantities of mosquito larvae.

It was the purpose of this study to investigate the life history of *Mochlonyx cinctipes* (Coq.), and its economic importance with regard to mosquito reduction.
Until relatively recent times, the taxonomic history of *Mochlonyx cinctipes* (Coquillett) has been in an unsettled state. As is apparent from the parenthesized name of the author of the species, the difficulty has been at the generic level. The following paragraphs are intended to present the proper sequence of taxonomic events and to justify the presently accepted nomenclature.

According to Coquillett (1903) the genus Corethra was established by Meigen (1803) on *Tipula culiciformis* De Geer (1776), the larva of which possesses a broad body and a subanal respiratory tube. In the same publication, De Geer also describes *Tipula crystallina*, whose larva is characterized as being slender and lacking a subanal respiratory tube. The tarsal characters of the adults of these two species cannot be determined from the descriptions. This is unfortunate, since the subsequent difficulty could have been avoided if these characters had been described.

When Loew (1844) founded the genus *Mochlonyx* on *Corethra velutina* Ruthe (1831), he based the category on the shortened first tarsal segment, which had been noted by Ruthe in his original description. The situation remained thus until 1883 when Meinert reared the larvae of the two species and discovered that *T. crystallina* adults
exhibited elongated first tarsal segments, while *T. culiciformis* adults exhibited the shortened first tarsal segments of Loew's *Mochlonyx*. These facts led Coquillett (1903) to relegate *Mochlonyx* in synonymy, since the type species of this genus was, if not the same, at least congeneric with the type species of *Corethra*. This opinion was supported by Felt (1904), Brunetti (1910), Dyar and Shannon (1924), and Matheson (1925).

Edwards (1920) took exception with Coquillett, pointing out the important fact that in his later work, Meigen indicated that he did not know *T. culiciformis*. This led Edwards to assume that Meigen had another of De Geer's species when he first described *Corethra*. Edwards concluded that the insect was the one which Meigen later described as *Corethra lateralis*, which is a synonym of *Corethra crystallinus*. The foregoing statements validate the genus *Mochlonyx* Loew, since *Corethra crystallinus* (*=T. crystallina*) possesses elongate first tarsal segments. This position was supported by Edwards (1932), Johannsen (1934), Matheson (1944), and Cook (1956).
GEOGRAPHIC DISTRIBUTION

According to Matheson (1947), *M. cinctipes* is widely distributed in Europe and North America. Cook (1956) states that it is widely but sparsely distributed across the northern section of North America. It has been reported from Alabama, Connecticut, Massachusetts, Minnesota, Montana, New Hampshire, New York, Oregon, Quebec, Virginia, Washington, and Washington, D. C.

Figure 1 is a map of Ohio showing the locations which were examined for the presence of this species. The empty circles indicate that a search was made, but neither larvae nor adults were found. The blackened circles indicate that specimens were collected.

The sparse distribution of *M. cinctipes* in Ohio is primarily a result of the inroads of man. A large proportion of the level land has been cleared and cultivated, leaving small isolated wood lots. This is especially true in southern Ohio where the bottomland of the valleys is in crops, while the hillsides are left in timber. Naturally, water does not form pools on the hillsides. When its environment is drastically altered, a species like *M. cinctipes*, which is restricted in its habitat, must migrate to a favorable area or disappear. Unfortunately, the tendency of adults of this species to remain in close proximity to the pools from which they emerged obviates the former al-
Fig. 1. Distribution of *Mochlonyx cinctipes* (Coq.) in Ohio.
ternative. The removal of more and more of the remaining woodlots in which pools are found can only serve to further limit the species.
Published descriptions of *M. cinctipes* are limited to the fourth instar larva, the pupa, and the adult. In his original description, Coquillett (1903) included the adult and the fourth instar larva. Edwards (1932) presents all three of the previously mentioned stages, while Cook (1956) describes the adult of *M. cinctipes* and refers to the fourth instar larva and pupa of *M. velutinus* (Ruthe) which, he says, cannot be distinguished from those of *M. cinctipes*.

H. G. James of the Entomology Laboratory at Belleville, Ontario kindly lent the author specimens of the various immature stages of *M. velutinus* for a comparison study. Microscopic examination revealed that these specimens and *M. cinctipes* are identical in gross morphology. Unfortunately, the specimens of *M. velutinus* were damaged in transit and the setal patterns were obliterated.

Since there is very little difference in the external morphology of the second, third, and fourth instar larvae of *M. cinctipes*, there is considerable repetition in the following descriptions of these stages. It is hoped that this situation is justified by the fact that each description is a complete entity, and it is not necessary to refer to preceding pages in order to obtain a complete mental picture of each instar.
Adult

The adult male (Figs. 2 and 3) ranges between 4.91 millimeters and 6.21 millimeters in length, with an average length of 5.32 millimeters. The female ranges between 3.92 millimeters and 5.00 millimeters in length, with an average length of 4.58 millimeters. The color is a yellowish-brown and the body is densely clothed with fine hairs. In the male, the hairs of the antennal whorls are pale yellow, while the shorter and less dense antennal hairs of the female are brown. In the female, the scape is thickly covered with long, pale hairs, while that of the male is bare. The hairs of the clypeus, maxillary palps and legs are brown, except for a yellowish band located distally on the femora and proximally on the tibiae and first four tarsal segments. The hairs of the thorax are brown, and each segment of the abdomen possesses a band of brown hairs which is joined by a yellow band posteriorly.

The antennae are pale yellow and darkened at the hair whorls. The head capsule is pale yellow, and the eyes are green in living specimens and dark brown to black in dead specimens. The thorax is greyish pruinose and marked with three dark vittae. The ground color of the abdomen is yellowish brown with the central portion of each sclerite darker, which gives the abdomen a ringed appearance.
The mottled appearance of the wings (Fig. 2) is formed by the arrangement of light and dark hairs. The wing venation is similar to that of the biting Culicidae; however, scales are present only on the fringe of the wings. These scales vary somewhat in shape and size (Figs. 7 and 8).

The legs are all about equal in length. The first segment of each tarsus is approximately one-quarter the length of the second, which is as long as the remaining three segments together. In the male, the last tarsal segment of each leg possesses a hairy basal swelling (Fig. 5). The tarsal claws are very large and equal in length, having a serrated basal tooth and a long tooth near the middle. The last segment of the female tarsus lacks the basal swelling (Fig. 4), and the smaller tarsal claws possess only the serrated basal tooth.
Fig. 2. Dorsal aspect of adult male *M. cinetipes* (12X).
Fig. 3. Lateral aspect of adult *M. cinctipes*, head and thorax of male (50X).
Figs. 4-10. Adult. 4, Last tarsal segment of female (130X). 5, Last tarsal segment of male (130X). 6, Tarsus (40X). 7 and 8, Large and small scales from wing fringe (500X). 9, Lateral aspect of penis valve (170X). 10, Male genitalia (gs-gonostyle, pv-penis valve, gc-gonocoxite) (50X).
The egg (Fig. 11) is creamy white, elongate ovoid in shape, and slightly larger toward the anterior end. The majority of the eggs remain white, but a small percentage become a light brown color after several hours. The chorion exhibits longitudinal rows of short, round pegs (Fig. 13), which are 0.01 mm. in length at each end of the egg and gradually shorten to 0.005 mm. at the widest portion of the egg. As the egg dries, the pegs shrink slightly, but they are still easily discernible. The rows are irregularly spaced as are the pegs within each row. The operculum (Fig. 12) is bell-shaped and hollow. Average length and width of the egg are 0.47 mm. and 0.15 mm. respectively.

First Instar Larva

The first instar larva (Figs. 15 and 16) ranges between 1.39 mm. and 2.15 mm. in length, with an average length of 1.92 mm. When newly emerged from the egg, the larva is transparent and completely lacking in color. Sclerotization is limited to the head capsule and mouthparts. As development progresses, the eyes become dark brown, the head capsule and thorax assume a pale tan color, and small, pale tan sclerotized areas appear on
Figs. 11-13. Egg. 11, Lateral aspect (100X). 12, Operculum (700X). 13, Enlarged section of chorion (300X).
the dorsal and ventral regions of each abdominal segment. The siphon is lacking both in color and sclerotization.

The head averages 0.30 mm. in width. The prehensile antennae are placed wide apart. They consist of a proximal shaft and three long, movable, sharply pointed setae which are located distally. A minute apical seta is also present on the shaft. There are six pairs of short, branched setae and two pairs of stout, simple setae on the head. The simple setae are located on the posterior margin of the head; one being slightly anterior to the other. The branched setae are located as follows: one pair ventrad of the eyes, one pair dorsad of the eyes, one pair midway between the eyes and the antennae, one pair between the clypeus and the eyes, and two pairs on the lateral margins of the clypeus, one pair of which is slightly anterior to the other. A pair of widely separated simple setae is located anteriorly, where the clypeus and labrum meet. These are almost as long as the antennal setae.

The mandibles (Fig. 14) are not heavily sclerotized. A stout tooth, with five or six very small, colorless teeth on its posterior margin, is located distally and posteriorly. Four stout processes are located in a straight line on the distal margin of each mandible. Posteriorly directed pointed teeth are located on the distal two-thirds of these processes. Two long, simple setae are
situated near the center of the outer surface of the man
dible.

The head of the newly emerged larva is slightly wider
than the thorax, but the thorax increases in size until it
is half again the width of the head prior to molting to
the second instar. The thoracic segments are not distinct,
but three small sclerotized areas on the venter indicate
their presence. Six patches of long setae, both simple
and branched, are located on each lateral surface. Small,
indistinct setae are placed between the patches. Two
large, elliptical air sacs are located dorsally in the
thorax and appear as two silver colored areas.

Clusters of both simple and branched setae appear lat
erally on the first eight abdominal segments. They are
longest on the first segment and gradually decrease in
length posteriorly. The seventh segment, which contains
a pair of air sacs connected with the thoracic air sacs by
tracheae, is half again as long as those preceding it.
The siphon is located dorsally on the eighth abdominal seg-
ment. It is short, thickest proximally, and tapers to a
rounded point. A minute seta is located basally on each
side of the siphon. The last segment possesses a ventral
fan composed of 8 to 10 long setae and a small dorsopos-
terior cluster of long setae. Four anal gills, each of
which taper gradually to a rounded point, are located
terminally.
Second Instar Larva

The second instar larva (Figs. 18 and 19) varies between 2.18 mm. and 4.16 mm. in length, with an average length of 3.58 mm. When newly molted, the larva is almost transparent. Only the eyes and mandibular teeth, which are dark brown, exhibit coloration. Prior to molting to the third instar, the head becomes brown, the thorax and abdomen vary between tan and light brown, and the siphon is a yellowish-tan color.

The head averages 0.56 mm. in width. The antennae are placed wide apart and consist of a proximal shaft, four long, movable, blade-like setae, and a minute apical seta located distally on the shaft. Three of the setae are apically blunt, while the fourth, which is two-thirds the length of the others, is pointed. There is one pair of medial clypeolabral setae whose members are as long as the antennal setae and they possess short spines on the distal one-third of their length. A pair of slightly shorter simple setae are located laterally to the medial group. Three pairs of short, plumose setae are located on the anterior half of the clypeus. Another pair of plumose setae is located between the eyes and the clypeus. There are also two pairs of stout, simple setae on the posterior margin of the head; one pair of which is slightly anterior to the other. The heavily sclerotized mandible (Fig. 17) posses-
ses seven or eight stout teeth which are longest and heaviest distally. There is a fan located anteriorly which is composed of four or five movable setae. Four heavy comb-like processes are located distally on the mandible and anterior to the mandibular teeth. There are posteriorly directed teeth on the distal two-thirds of each process. The teeth on the first process are sharply pointed, and on the three remaining processes the teeth are heavy and blunt.

The thorax is only slightly wider than the head when the larva is newly emerged, but it increases in size until it is half again as wide as the head before molting to the third instar. Segmentation is indistinct, but short plumose setae roughly indicate the location of the segments. Large, elliptical air sacs are located dorsally in the thorax.

The abdominal setae are short and plumose. The seventh segment, which is half again as long as those preceding it, contains a pair of air sacs which is connected to the pair in the thorax by tracheae. The siphon is located dorsally on the eighth segment and is 2.5 times longer than wide. Segment nine is devoid of setae. There is a ventral fan composed of 28 to 30 setae on the last abdominal segment. There is a cluster of branched hairs located dorsally and posteriorly on this segment. Four fleshy anal
gills, each of which tapers to a rounded point, are terminal.

**Third Instar Larva**

The third instar larva (Figs. 21 and 22) varies between 3.69 mm. and 5.57 mm. in length, with an average length of 4.43 mm. When newly molted, the larva is somewhat transparent. The eyes and mandibular teeth are dark brown immediately after ecdysis, but several days are required for the larva to assume its complete coloration, when the head is brown, the thorax and abdomen vary between tan and light brown, and the siphon is yellowish-brown.

The head averages 0.78 mm. in width. The antennae are placed wide apart and consist of a proximal shaft, four long, movable, blade-like setae, and a minute apical seta located distally on the shaft. Three of the setae are apically blunt, while the fourth, which is two-thirds the length of the others, is pointed. There is one pair of medial clypeolabral setae. They are as long as the antennal setae and possess short spines on the distal one-third of their length. A pair of somewhat shorter simple setae is located laterally to the medial group. Six pairs of short setae are located on the head. There are two stout, simple pairs on the posterior margin of the head; one pair of which is slightly anterior to the other. A pair of
plumose setae is located between the eyes and the clypeus, and three pairs of plumose setae are located on the anterior half of the clypeus. The mandible (Fig. 20) is heavily sclerotized and possesses seven or eight stout teeth. A fan composed of five or six heavy, pointed, and movable setae is located anteriorly. Four stout comb-like processes, armed with posteriorly directed blunt teeth, are located on the distal margin of the mandible slightly anterior to the mandibular teeth.

The thorax of the newly molted third instar is slightly broader than the head, and it is about twice as broad as the abdomen. It gradually increases in width until it is almost twice as wide as the head. Segmentation is indistinct, but inconspicuous plumose setae indicate the segments. A pair of large air sacs is located dorsally.

The abdominal setae are short and plumose. The seventh segment is half again as long as those preceding it, and it contains a pair of air sacs connected to the pair in the thorax by tracheae. The siphon is located dorsally on the eighth segment and is 3.5 times longer than wide. Segment nine is devoid of setae. The last abdominal segment possesses a ventral fan composed of 28 to 30 setae. There is a cluster of branched setae located dorsally and posteriorly on this segment. There are also four fleshy anal processes, each of which tapers to a rounded point.
Fourth Instar Larva

The fourth instar larva (Figs. 24 and 25) ranges between 5.00 mm. and 8.20 mm. in length, with an average length of 6.56 mm. When newly emerged, the head is translucent, and with dark brown to black eyes; the thorax and abdomen are a light tan color. The head darkens over a period of several days until it becomes a dark brown color. The thorax and abdomen also darken, and these areas become tan to grey-brown. The mandibular teeth are also dark brown to black. The siphon is yellowish-brown.

The head is broad, averaging 1.16 mm. in width. The antennae are placed wide apart and are made up of a proximal shaft, four long, movable, blade-like setae, and a minute apical seta located distally on the shaft. Three of the setae are apically blunt, while the fourth, which is two-thirds the length of the others, is pointed. There are two pairs of medial clypeolabral setae. They are as long as the antennal setae and possess short spines on the distal one-third of their length. A pair of slightly shorter simple setae is located laterally to the medial group. There are three pairs of short, plumose setae on the anterior half of the clypeus. Another pair of plumose setae is located posteriorly between the clypeus and eyes. There are two pairs of stout, simple setae located on the posterior margin of the head; one pair being slightly
anterior to the other. The mandibles (Fig. 23) are heavily sclerotized and possess seven or eight stout teeth. A fan composed of six to seven heavy pointed setae which are movable is located anteriorly. Four stout, comb-like processes, having posteriorly directed blunt teeth, are located anteriorly to the mandibular teeth.

The thorax is half again as broad as the head and is about twice as broad as the abdomen. The width of the thorax gradually increases until just before pupation, it is almost twice as wide as the head. In the late stages of this instar, the thorax is wider posteriorly. It is indistinctly segmented but short, inconspicuous, plumose setae roughly indicate the three segments. A pair of large elliptical air sacs covered with grey pigment cells is located dorsally.

The abdominal setae are short and plumose. The seventh segment is half again as long as those preceding it. Another pair of greyish air sacs, connected with the thoracic air sacs by tracheae, is located here. The siphon is located dorsally on the eighth segment and is 3.5 times longer than wide. Segment nine is devoid of setae. The last abdominal segment possesses a ventral fan composed of 28 to 30 setae and a cluster of branched hairs located dorsally and posteriorly. There are also four fleshy anal gills, each of which tapers to a rounded point.
Pupa

The pupal stage of *M. cinotipes* (Figs. 26 and 27) looks very much like that of the biting Culicidae. It is comma-shaped, and exhibits the cephalothoracic breathing horns and terminal abdominal swimming paddles commonly associated with the Culicinae. Immediately after molting it is a light tan color, gradually darkening to a light brown color before adult emergence. The total length ranges between 5.22 mm. and 6.50 mm., with an average length of 5.92 mm. Antennae, eyes, legs, and wing pads are easily discernible through the pupal skin.

The breathing horns are spindle-shaped and about four times longer than their greatest diameter. They are wider in the center than at either end, and the internal spiracles are located very near the tapered distal end. The surface is strongly reticulated and possesses many fine setae.

The seventh abdominal segment is quite long in proportion to the others, being about twice as long as the sixth segment and about four times as long as the eighth. The seventh segment has two blade-like setae located in each lateroposterior corner; the distal pair being much broader than the proximal. The paddles are broader than long with a distinct midrib and thickened margin. There is a short, simple seta located at the distal end of the midrib and a
plumose seta situated on the midrib, one-third the distance from the distal end.
HEAD AND SIPHON MEASUREMENTS

After a study of larval head capsule measurements in the Lepidoptera, Dyar (1890) formulated the following general statements: (1) The change in area of the sclerotized parts of an insect occur at ecdysis, there being no increase in size of these parts during a stadium. (2) The discontinuous increase in size of the sclerotized parts usually follows a geometrical progression. The first statement forms the basis for the determination of the number of larval instars in certain species of insects. In some cases, the plotting of head measurements has not formed the ideal discontinuous grouping achieved by Peterson and Haeussler (1928) and Taylor (1931). Gaines and Campbell (1935) and Metcalf (1932) were unable to successfully apply Dyar's findings to the larvae with which they worked. In spite of these deviations, measurement of sclerotized larval parts have often proved useful and are frequently utilized for instar determination.

This study was undertaken in order to discover whether or not the number of larval instars exhibited by this species can be ascertained by measurement of the head capsule and siphon, and whether or not the growth of these parts of the body follows a constant ratio.

Larvae of all instars were dipped from woodland pools and returned to the laboratory where they were killed by
immersion in boiling water. A binocular microscope which provided a magnification of 80 diameters was used to study the first and second instar larvae. The third and fourth instars were examined under a magnification of 40 diameters. A micrometer ocular, which was placed in the right barrel of the microscope, was calibrated to 0.073 and 0.145 mm. per small division of the scale for the 80 and 40 magnifications respectively. Head width was measured at the widest area of the head which occurred in the region of the eyes. Length was measured from the point of insertion of the clypeolabral setae to the posterior margin of the head. There was some difficulty involved with the measurement of the siphon, since the unsclerotized breathing apparatus of the first instar lacks the definite form of the later stadia. Although the first instar breathing tube is widest where it joins the eighth abdominal segment, this dimension was taken at the middle of the tube for the sake of uniformity, since the other three stadia were measured at the middle of the siphon where it is widest. The first instar tube length was taken between the distal tip and the point of juncture with the eighth abdominal segment. The siphon of the later stadia exhibits a narrow membranous ring at its base. This portion of the tube was ignored, and only the sclerotized length was measured. A total of 142 specimens were examined.
Figure 28 is a scatter diagram of head width and head length measurements. The clusters of points definitely show that there are four larval instars. In general, head length is not a good criterion for separating instars since there is considerable overlap of the points in the second, third and fourth instars. Head width measurements provide a positive method of both separating instars and determining the instar of an unknown specimen.

Figure 29 is a scatter diagram of siphon width and siphon length measurements. Four instars are clearly indicated by the arrangement of the groups of points. Siphon length is useful in separating first, second, and third instar larvae, but the gap between the third and fourth instar groups is small and would probably close if more points were plotted. Siphon width appears to be a better criterion for determining stadia.

Figures 30 and 31 are histograms of head width and siphon width. This frequency table has a rather well defined pattern in that the columns are higher and fewer in the early instars and shorter and more numerous in the later instars. The discontinuous grouping is more sharply defined for head width than it is for siphon width, since, in the latter case, there is a slight overlapping of extremes between the second and third instars. Since Peterson and Haeussler (1928) determined that the number
Figs. 28-29. Scatter diagrams of larval measurements. 28, Head. 29, Siphon.
Figs. 30-31. Frequency diagrams of larval measurements. 30, Head. 31, Siphon
of peaks in a histogram corresponds to the number of larval stadia, Figures 30 and 31 demonstrate that there are four larval instars in this species.

Tables 1, 2, 3, and 4 represent the ratios of the means of siphon length and width and head length and width for successive instars. A number of authors have reported that the greatest proportionate larval growth occurs between the first and second instars, while the least occurs between the penultimate and last (Gaines and Campbell, 1935; Ripley, 1930; Forbes, 1934; Abdel-Malek and Goulding, 1948). An examination of the following tables indicates that this is also true of *M. cinetipes*.

In Figure 32, the means of siphon length and width and head length and width are plotted on semilogarithmic paper in order to determine whether or not the growth progression is geometric in this species. The instars are evenly spaced along the arithmetic abscissa, while measurements are plotted along the logarithmic ordinate. The fact that the lines are not straight shows that the progression is not perfectly geometric. In all four graphs, the slopes of the lines decrease after the first instar, indicating a smaller increase in growth between the last three instars. From the data plotted in Figure 32, it is apparent that Dyar's rule does not apply to *M. cinetipes*. 
### Table 1 - Measurements of head width of *M. cinctipes* larvae

<table>
<thead>
<tr>
<th>Instar</th>
<th>Individuals</th>
<th>Mean</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34</td>
<td>0.302</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>33</td>
<td>0.555</td>
<td>1.838</td>
</tr>
<tr>
<td>3</td>
<td>37</td>
<td>0.783</td>
<td>1.411</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>1.164</td>
<td>1.487</td>
</tr>
</tbody>
</table>

### Table 2 - Measurements of head length of *M. cinctipes* larvae

<table>
<thead>
<tr>
<th>Instar</th>
<th>Individuals</th>
<th>Mean</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34</td>
<td>0.236</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>33</td>
<td>0.389</td>
<td>1.648</td>
</tr>
<tr>
<td>3</td>
<td>37</td>
<td>0.522</td>
<td>1.342</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>0.694</td>
<td>1.330</td>
</tr>
</tbody>
</table>

### Table 3 - Measurements of siphon width of *M. cinctipes* larvae

<table>
<thead>
<tr>
<th>Instar</th>
<th>Individuals</th>
<th>Mean</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32</td>
<td>0.042</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>33</td>
<td>0.082</td>
<td>1.952</td>
</tr>
<tr>
<td>3</td>
<td>37</td>
<td>0.119</td>
<td>1.451</td>
</tr>
<tr>
<td>4</td>
<td>38</td>
<td>0.185</td>
<td>1.555</td>
</tr>
</tbody>
</table>

### Table 4 - Measurements of siphon length of *M. cinctipes* larvae

<table>
<thead>
<tr>
<th>Instar</th>
<th>Individuals</th>
<th>Mean</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>33</td>
<td>0.204</td>
<td>3.400</td>
</tr>
<tr>
<td>3</td>
<td>37</td>
<td>0.402</td>
<td>1.971</td>
</tr>
<tr>
<td>4</td>
<td>38</td>
<td>0.639</td>
<td>1.590</td>
</tr>
</tbody>
</table>
Fig. 32. Semilogarithmic graph of larval measurements. A, head width. B, head length. C, Siphon length. D, Siphon width.
HABITAT

The literature contains very little information concerning the larval habitat of *Mochlonyx cinctipes*. Matheson (1944) merely mentions that the species is found in woodland pools. Edwards (1932) states that it is found chiefly in temporary pools in woods. Cook (1956) states that larvae have always been found in temporary pools. None of these authors explain precisely what a temporary pool is. The following paragraphs are intended to characterize the habitat of *M. cinctipes* in Ohio and provide information on the insect associations involved.

**Types of Woodland Pools**

Woodland pools can be roughly separated into three classes: temporary, semi-permanent, and permanent. Temporary pools are formed when the water from frequent rains collects in low-lying areas. These bodies of water are not affected by vicissitudes of the level of the water table since they have no contact with it. They generally disappear after one or two weeks of dry weather. Semi-permanent pools, however, are associated with the level of the water table. Melting snow and frequent rains in the spring cause an elevation of the ground water which is not materially affected by short periods of dry weather. As a result, these areas do not dry up until summer, and even
then, the ground remains moist. Permanent pools are those which retain enough water to support aquatic life throughout the year. They are generally spring-fed or are located in low-lying areas where the level of the water table remains above ground level, forming swamps and bogs.

**Study Pools**

Field studies were conducted at two locations which represent different types of pool situations. *M. cinctipes* was most abundant in a ten acre wood lot four miles north of Orrville, Ohio. This site contained four large pools approximately 50 to 75 feet in diameter in which there was larval activity. Figure 33 shows one of the pools. These bodies of water were of the semi-permanent type, and were interspaced with large bog areas. Their bottoms were lined with leaves. Buttonbush, *Cephalanthus occidentalis*, was present, indicating that the ground remains wet for the greater part of the year. The wood lot was made up primarily of beech and maple trees. Oak, hickory, and elm trees were also numerous. Undergrowth was spotty and consisted of poison ivy, *Rhus toxicodendron*, *L. mayapple*, *Podophyllum peltatum* L., and the marsh fern, *Dryopteris thelypteris* L.

The second site was located four miles west of Wooster, Ohio, and consisted of several small pools approx-
Fig. 33. Woodland pool formed by melting snow and spring rains.
Approximately 20 feet in diameter formed by the overflow of Killbuck Creek (Fig. 34). These bodies of water are also of the semi-permanent type, whose bottoms are lined with leaves. During a dry spring, these pools disappear at the end of May, resulting in the death of many late larvae and pupae. This no doubt accounts for the relatively small population of *M. cinctipes* in this area. The trees are primarily maples with a scattering of oak and shagbark hickory. The undergrowth is almost exclusively poison ivy.

Experience indicates that relatively large and dense wood lots with open, semi-permanent pools are ideal for this species. Specimens have never been collected from pools filled with aquatic plants, nor from pools in the small grazed-over patches of trees which are so often found in pastures.

**Temperature and pH**

During the larval development of *M. cinctipes*, the water temperature of the pools varies considerably. First instar larvae were collected in early March when the water temperature was $33^\circ$ F. At this time, it was necessary to cut holes through a layer of ice one inch thick which covered the surface of the pool (Fig. 35). Since these pools are relatively small and shallow, water temperature is
Fig. 34. Woodland pool formed by the overflow of a stream.
Fig. 35. An ice-covered woodland pool containing first instar larvae of *M. cinctipes*.
closely associated with that of the air. In shallow, sun-
lit pools, the disparity between water and air temperatures
may be only two or three degrees. In shaded pools, the
temperature differential sometimes was 10°F. As the
spring season progresses and the air temperature rises, the
water temperature rises with it. The maximum temperature
observed in a pool containing predaceous larvae was 84°F.
Temperatures were taken two inches below the surface and,
where pools were of sufficient depth, six inches below the
surface. These figures seldom differed by more than three
degrees Fahrenheit.

Oxyphen indicator paper possessing a scale of colors
was used for the rapid determination of the pH of the pools
in which larvae were found. Water samples were periodical-
ly taken to the laboratory and tested with a Beckman pH
meter. These analyses served to check the color change
method used in the field. It was found that the pH of the
pools which contained larvae ranged between 5.5 and 6.8,
with an average of 6.2.

Associations

The average semi-permanent woodland pool supports a
varied fauna. Since these bodies of water disappear in
the summer, animals, such as fish, which require a perma-
nent aquatic habitat and are incapable of migrating when
water is lacking, are absent. Frogs and salamanders, which aestivate in wet soil are usually present. Habitats of this type are especially suited to animals that have either a short life cycle or only need standing water for a portion of the life cycle.

Most woodland pools abound with small crustaceans. Branchiopods, copepods, ostracods, and amphipods are important in the diet of the predaceous larvae. It has been found that *M. cinctipes* is absent or at least poorly represented in pools where the concentration of crustaceans is low. Predaceous larvae have never been collected from pools containing no crustaceans.

While dipping *M. cinctipes* larvae for laboratory studies, many immature and adult insects were collected. These specimens represented incidental collections. No attempt was made to completely survey the insect fauna of the pools. The following list contains all of the species collected:

**Diptera**

*Chironomidae*

*Chironomus plumosus* Linn.

*Syrphidae*

*Eristalis* sp.

*Culicidae*

*Aedes stimulans* (Walker)
Aedes canadensis (Theobald)
Anopheles punctipennis (Say)
Aedes vexans (Meigen)
Culiseta
Chaoborus flavidus (Meigen)
Culex territans (Walker)

Hemiptera
Salidae
Salida interstitialis (Say)

Trichoptera
Limnephilidae
Limnephilus submonilifer (Walker)
Frenesia missa (Milne)

Coleoptera
Helodidae
Cyphon sp.
Dytiscidae
Laccophilus maculosis (Say)
Thermonectes sp.

Hydrophilidae
Tropisternus sp.
Enochrus cinctus (Say)
Enochrus perplexus (Lec.)
Paracymus subcupreus (Say)

Odonata
Aeschnidae

Aeschna eremita (Scudder)

Libellulidae

Libellula semifasciata (Burmeister)

Lestidae

Lestes dryas (Kirby)

Both adult and immature frogs were numerous at several locations. The eastern wood-frog, Rana sylvatica LeConte, was encountered most frequently, while the striped chorus-frog, Pseudacris nigrita triseriata Wied., and the spring peeper, Hyla crucifer Wied., were found at only a few locations.
BIOLOGY

Other than a few general statements concerning overwintering, site of oviposition, and larval and adult feeding habits, there is very little mention of M. cinctipes in the literature (Edwards, 1932; Johannsen, 1934; Matheson, 1944). It is the purpose of the following paragraphs to present data on the biology of this species, which was observed under both laboratory and field conditions.

Egg

M. cinctipes has one generation per year and overwinters in the egg stage. The eggs are deposited along the moist periphery of the pool between the middle of May and the middle of June. They remain on the ground during the summer, fall, and winter, hatching in early March when the pools form again. It was found that the eggs undergo partial development during the summer months and then enter diapause until the following spring. This type of development has also been found in the case of Mochlonyx velutinus (Ruthe), a closely related species (James, 1957).

Larva

Collection of Larvae

It was found that a one-pint, white enamel dipper is
the most efficient means of collecting larvae. During the spring of 1957, the larvae were transferred from the dipper to holding jars by means of a wide-mouthed eye dropper. In 1958, this method was changed in order to expedite the collection of Mochlonyx and to obtain crustaceans and early instar Aedes larvae to be used in the maintenance of a laboratory colony. A piece of cheesecloth was placed in an embroidery hoop to form a fine-mesh sieve. When placed in shallow water, the central portion of the sieve remained beneath the surface, while the periphery remained above the surface. Water dipped from the pools was slowly poured through the cheesecloth, which retained even very small crustaceans. After sufficient material was collected, it was washed to the center of the sieve. Transfer to holding jars was accomplished by inverting the hoop over the jar and pouring clear water through the cloth.

At collection sites where the water was of sufficient depth, a rectangular net made of cheesecloth was utilized. In this way, large volumes of water could be sieved in a very short time. The material was concentrated in the center of the net and transferred to holding jars in the manner described in the previous paragraph. At times, large amounts of debris were picked up in the net, making it difficult to determine the presence of the desired aquatic fauna. When this occurred, the net was inverted over a
large enamel pan, and the contents were washed into it. After the debris was removed by hand, the presence or absence of *Mochlonyx* and its prey could be established.

Second, third, and fourth instar *Mochlonyx* are easily discernible in the dipper, but this is not the case with first instar larvae. Their minute size and lack of coloration make them virtually invisible. It has been found that the shadow of the larva, which appears on the bottom of the dipper when it is exposed to sunlight, is of great assistance in determining the presence of the first instar. On cloudy days, a flashlight was used to produce shadows.

**Larval Distribution in The Pools**

Larval distribution patterns are greatly influenced by the area and depth of the pool. The presence of partly submerged objects is also important. In small, shallow pools that contain no growing trees or partly submerged logs, the larvae are rather evenly dispersed throughout the water. In small pools with deep centers, the great majority of immature *Mochlonyx* are located around the edge where the water does not exceed six to eight inches in depth.

Experience has shown that the presence of larvae in large, deep pools can be rapidly ascertained by dipping in a few carefully selected locations. The proximity of hid-
ing places and food largely determine the distribution of the immature stages in these pools. Water surrounding partly submerged logs and growing trees harbors the greatest concentrations of larvae (Fig. 36). The moss and algae growing on these surfaces and the crustaceans and mosquitoes that congregate around them provide both hiding places and food. When submerged logs and growing trees are found at the edge of the pool, *Mochlonyx* will generally be found, even though the water be 12 or more inches in depth. Larvae can be found in the shallow water at the periphery of large pools as well as the small ones, but they are more widely dispersed than they are when located near submerged objects.

This difference in larval concentration was demonstrated by taking 25 water samples with a dipper along the shallow periphery of a pool and 25 water samples around objects partially submerged in the pool. The number of third and fourth instar *Mochlonyx* collected near the submerged objects ranged between zero and seven, with an average of 2.8 per dip. In the shallow water near the edge of the pond the number of larvae ranged between zero and three with an average of 0.8 larvae per dip.

Newly hatched first instar larvae exhibit a tendency to congregate around objects in the water. At these locations, it is a common occurrence to collect as many as 15
Fig. 36. Partly submerged logs at the periphery of a pool near which *M. cinctipes* larvae congregate.
larvae per dip, while none are found in the intervening areas. After molting to the second instar, the larvae begin to disperse. This gradual movement ultimately results in the types of distribution previously described.

Movement

*M. cinctipes* larvae exhibit two types of movement.

One type involves vertical displacement. When larvae at or near the surface are disturbed, they slowly sink to the lower levels of the pool, while maintaining their horizontal position. When the disturbing element is removed, they simply rise to the surface, again in the horizontal position which is typical of the species. This rising and sinking motion is utilized by the larva when obtaining air becomes pressing. The other type of movement is lateral motion and is considerably more rapid. With a switching motion in which the extremities almost meet, the larva is quickly propelled through the water. In some cases, when a larva is disturbed while at the surface, it reaches the bottom of the pool by means of the switching motion and a slight inclination of the body from the horizontal plane. These movements coupled with protective coloration and a tendency to go under bottom debris in the pools, are of value to the larvae as protection from predators.
Molting

As the time of molting approaches, there is a period of relative inactivity. The larva ceases the vertical movements associated with breathing, and remains near the surface. It will sink into deeper water when disturbed, but returns to the surface almost immediately. This period of quiescence continues for several hours. Normally, the act of shedding the skin of the previous instar requires only a few minutes. The head appears first, then the thorax and abdomen are freed by rapid wriggling motions. Not all larvae molt so readily. A fourth instar larva was observed that had considerable difficulty in shedding the third instar skin. This partially emerged specimen remained on the surface of the water for more than one-half hour before it succeeded in extricating itself.

While the larval exuviae of the Culicinae generally float for some time after molting, those of M. cinctipes do not. Immediately upon emergence, the cast skin of the previous instar sinks to the bottom. Newly emerged larvae quickly move around.

Relative Abundance at Various Locations

The concentration of larvae varies considerably from one pool to the next. When superficially examined, many
pools which appeared to be ideally suited for *M. cinctipes* habitats had no larvae. At a location in Summit County, a shaded pool 30 feet in diameter yielded only one larva and one pupa in 47 dips. On the other hand, a similar pool in Wayne county yielded an average of three larvae per dip. Gradations between these extremes have been found on several occasions.

There are at least two factors involved in these differences in larval concentrations. One factor is the size of the crustacean population. It has been found that when crustaceans are absent, *M. cinctipes* is also absent. The converse of the foregoing statement is not necessarily true, since crustaceans have been abundant in pools where immature *M. cinctipes* were absent. In general, when predaceous larvae are found in pools, their numbers appear to be closely associated with the size of the crustacean population. A second factor involved in *Mochlonyx* population differences is the relative permanence of the pools. Some of the smaller pools dry up at the beginning of June, resulting in the death of many predaceous larvae. With a small number of adults to oviposit, the number of immature *M. cinctipes* is small. There are no doubt other elements which affect larval density, such as abundance of other predaceous aquatic life, but the two previously discussed factors seem most important.
Respiration

The four Nearctic genera of the Chaoborinae exhibit considerable diversification in the means employed in obtaining oxygen. All genera possess anal gills, but only Mochlonyx and Corethrella possess an elongate dorsal siphon. Eucorethra has a short spiracular disc, while Chaoborus exhibits no trace of an external respiratory apparatus on the eighth abdominal segment. Chaoborus astictopus D. and S. spends the winter at the bottom of deep lakes, using only the anal gills for breathing (Herms, 1953). Edwards (1932) states that the larvae of M. cinctipes seldom come to the surface. Observations were made in order to determine how long the larvae of M. cinctipes remain beneath the surface between breathing periods, and whether or not the anal gills are important in breathing.

The tracheal system of living specimens was examined with the aid of a binocular microscope. Fourth instar larvae were placed in a Syracuse watch glass that contained just enough water to cover them. When filled with air, the ramifications of the tracheae can be traced with ease, since they appear as silver-colored lines.

Two thick trunks connect the spiracles at the apex of the breathing tube with the ventroposterior margin of the abdominal air sacs. A posteriorly directed tube from each of the spiracular trunks branches to supply the ninth and
anal segments. The tracheal system of the anal gills is easily discernible. There are two dorsal longitudinal trunks which connect the abdominal and thoracic air sacs. Although these parallel tubes lie close together, they are not connected laterally. In each of the abdominal segments, these trunks give rise to a dorsal branch and a lateral branch. The dorsal branch extends to the body wall where many smaller tracheae appear. The lateral tube from the longitudinal trunk splits in two; one tube reaching the ganglion of the ventral nerve chord and the ventral body wall. A branch arising at the posterior end of each thoracic air sac supplies the crop and body wall. Two branches arise from the anterior end of each thoracic air sac and extend to the brain, the muscles of the mouth-parts, and the wall of the head capsule.

In order to determine the importance of the anal gills in respiration, pond water was placed in the lower half of a large dessication jar, and four larvae were added. A narrow ring of cotton was placed around the lip that separates the section which normally contains the dessicating chemical from the section which contains the material to be dried. A round piece of 50 mesh screen was placed on the cotton ring, and enough water was added to completely cover the screen. This arrangement made it impossible for the larvae to obtain atmospheric oxygen. The tests for each of the four instars were conducted separate-
ly at a temperature of 45°F.

The results of these experiments indicate that, in general, the earlier instars live longer than the later instars when denied access to atmospheric oxygen. This is to be expected, since the proportionately smaller larvae need less oxygen to maintain themselves. First and second instar larvae remained alive and active for 32 hours. Third instar larvae lived as long as the first and second stadia, but their activity was curtailed after ten hours. Two inactive though living larvae in the third stadium were permitted access to the atmosphere after the 30 hour period, and, although they revived somewhat, both ultimately died. Fourth instar larvae died after ten hours in the dessication jar. First instar woodland pool Aedes larvae were subjected to these conditions, but they became inactive after four hours and died after six hours.

Incidental observations conducted on third and fourth instar larvae which were placed in three inch shell vials for feeding tests revealed the average normal submergence period to be ten minutes with a range between six and 14 minutes. The fact that there was only a small volume of water and very little water surface for oxygen exchange accounts for the relatively short submergence period. Larvae maintained in a shallow stainless steel pan measuring 24 inches long and 12 inches wide remained beneath the
surface approximately twice as long as those kept in shell vials. A greater amount of dissolved oxygen provided by aquatic plants in the pan and the large water surface which permitted oxygen transfer no doubt accounts for this difference.

It appears that all larval instars are dependent upon atmospheric oxygen in order to complete their development, and, if necessary, the anal gills are utilized to remove dissolved oxygen from the water as breathing organs.

Feeding

Edwards (1932) states that *M. cinetipes* is often associated with mosquito larvae on which they feed, although they also feed on small crustaceans. According to Johannsen (1934), the predaceous larvae feed on crustaceans and aquatic insects. The following paragraphs report the results of a comprehensive study of the mechanics of feeding and the type and quantity of food ingested.

Ingestion—Monchadskii (1945) carefully studied the mechanics of feeding the genus *Chaoborus*. His results exhibit many points of similarity with the observations which were conducted on *M. cinetipes*. Generally, the capture and ingestion of food by *M. cinetipes* is too rapid to be determined with any degree of certainty, but repeated observations have revealed many interesting facts. Small prey such as immature crustaceans and first instar mosquito
larae are drawn into the oral opening by water currents initiated by rapid movement of the prehensile antennae. Larger prey are actually grasped by the antennae and forced into the oral opening. Food particles pass through the oral opening, the pharynx, and the esophagus, which leads into the crop where digestion occurs. The wall of the crop has two layers of fibers lying perpendicular to each other. These fibers are elastic and play an important role in the contraction and expansion of the crop. The following movements of the wall of the crop were observed in a first instar larva when it ingested a small crustacean. There appeared to be a crushing effect, since the crustacean, though alive when swallowed, died in approximately 30 seconds. A constricted area at the posterior end of the crop stops undigested chitinous material from passing into the midgut where absorption occurs. Under the microscope, wave-like movements of the midgut, which resemble peristalsis, result in the exchange of material between the crop and midgut. Since this exchange occurs repeatedly, it results in the posterior movement of digested materials to the midgut and the anterior movement of enzymes to the crop. After digestion is completed, the chitinous remains in the crop are expelled by regurgitation. Monchadskii (1945) states that the pharynx, esophagus, and anterior part of the crop are everted during this
process in larvae of Chaoborus. James (1957) reports that skeletal remains are ejected by the eversible crop in M. velutinus. Although regurgitation was observed on three occasions by the author, there was no indication of eversion of part of the alimentary tract. Deonier (1943) did not observe eversion of the crop in Chaoborus astictopus except in injured specimens.

Types of food consumed in nature—As a result of their small size, first instar larvae are restricted in their diet. The examination of stomach contents revealed the presence of single celled algae and the remains of very small crustaceans. One larva was observed to feed on a small copepod. As the immature M. cinctipes progress beyond the first instar, their food becomes more varied. Ostracods, copepods, cladocerans, and mosquito larvae have been found in the crops of the latter three instars. Of the larvae which were critically examined as to food contents, copepods were definitely most numerous. The following list contains the species of copepods found in the stomach contents of 30 third and fourth instar M. cinctipes:

- *Cyclops vernalis*
- *C. navus*
- *Bryocamptus hutchinsoni*
- *B. minutus*
- *B. sp. (prob. hiemalis)*
Canthocamptus sp. (prob. staphyllnoides)

Some identifiable ostracod fragments were also found in the stomach contents. These larvae do not restrict their feeding to actively moving food. On two occasions, fourth instar larvae were observed feeding on colorless fungi growing on the surface of a submerged leaf. One specimen was found with its crop full of filaments whose ends were dangling from the oral opening, giving the larva a bearded appearance. This mass of material was regurgitated several hours later. Another specimen was discovered with its crop full of filaments which were still attached to the leaf. After trying unsuccessfully for four hours to pull the filaments from the leaf with periods of wriggling and twisting punctuated by frequent rests, the larva regurgitated the ball of filaments.

Types of food consumed in the laboratory—It was found that the larvae of M. cinctipes fed on all of the small crustaceans obtained from woodland pools. There also appears to be no preference as to mosquito larvae. Immature Mochlonyx fed readily on the larvae of Aedes aegypti, Culex territans, Aedes stimulans, and Culex pipiens. Larvae of Anopheles punctipennis were not consumed as rapidly as the others, but this is a result of their habit of remaining at the surface for long periods. When other food was scarce, cannibalism was common. On a few occasions, fourth
instar larvae were observed eating smaller members of the same species even though other food species were present. Attempts at rearing M. cinctipes on dog food pellets proved unsuccessful.

**Quantities of food consumed**—The fact that the crop is capable of expanding until it almost fills the thoracic region, permits the consumption of large amounts of food. Twinn (1931) found that four M. cinctipes larvae ate 46 Aedes vexans larvae in nine days. He does not mention the stage of development of the M. cinctipes or the A. vexans larvae. In the author's experiments conducted with second instar Aedes aegypti larvae, it was a common occurrence for third and fourth instar M. cinctipes to consume three larvae per day. Several immature Mochlonyx averaged four A. aegypti larvae per day. One particularly ravenous fourth instar specimen consumed five second instar Aedes in six minutes. The Aedes larvae were seized almost as soon as they were placed in the water. The majority of the immature Aedes were swallowed head first, although some specimens were swallowed tail first. As an extreme example of crop expansion, microscopic examination of the crop contents of a fourth instar M. cinctipes revealed the head of a third instar larva of the same species.

**Comparative size of prey**—The relative size of Mochlonyx larvae and their prey plays an important part in develop-
ment. This is most critical in the case of the first instar. When small crustaceans and algae are not present, the larvae die. Larvae of later instars are less restricted in their feeding habits, and their greater size permits them to consume food that the first instar could not ingest. At times, the larvae attempt to consume prey which is too large. On one occasion, a fourth instar larva attempted to swallow an immature tipulid longer than itself. Approximately one-third of the tipulid’s length could not be forced into the crop. Although the Mochlonyx larva continued its efforts for almost ten minutes, complete ingestion did not take place. Finally, the tipulid was regurgitated. Another instance of this type occurred when a fourth instar Mochlonyx seized a fourth instar Aedes larva near the base of the siphon. The predator maintained its grip for only a short time after the Aedes began to wriggle and twist. After freeing itself, the Aedes larva sank to the bottom of the beaker and died. Sailer and Lienk (1954) found that Chaoborus flavicans sometimes killed Aedes larvae and did not eat them.

Duration of the Larval Stage

Hatching of the eggs begins during the first week in March and sometimes continues for several weeks. The duration of the hatching period is partially dependent upon the rate at which the pools fill with water. Eggs deposited at
the periphery of the pools when they are filled with water will not hatch until the water reaches the same level during the following spring. This phenomenon can be characterized by an example. At one location, which is relatively well-drained, the pools did not reach normal size until late March in 1958, as a result of unusually light rainfall during late winter and early spring. At another location where the water table is higher, the pools reached normal size at the end of February. At the former site, first instar larvae were found as late as April 15, while at the later site, third instar larvae predominated and first instar larvae were no longer present at this date.

The earliest dates at which the various immature stages were first collected in 1958 at Orrville, Ohio are as follows: first instar--March 3, second instar--March 26, third instar--April 3, fourth instar--April 13, and pupa--April 30. These data provide developmental periods of 23, 8, 10, and 17 days for the first, second, third, and fourth instars respectively. These figures indicate that a total of 58 days were spent in the larval state. The total larval developmental period was three months in duration, since the last fourth instar larva was collected on June 4. In 1957, when rainfall during March, April, and May exceeded that of the same period in 1958 by 4.74 inches and monthly temperatures averaged 2.3° F. higher, the last
fourth instar larva was collected on May 27.

**Predators**

Attacks on the larvae of *M. cinctipes* by predators in the pools was observed on only three occasions. A dytiscid larva of the genus *Thermonectes* was seen with a third instar larva impaled on its mandibles. The immature *Mochlonyx* wriggled convulsively, but could not escape. When an attempt was made to collect the pair, the beetle released its prey and swam away. The *Mochlonyx* died after a short time. On another occasion, a large, red water mite was discovered swimming about with a third instar larva which it had seized at the lateroposterior edge of the thorax. The mite swam aimlessly about with the feebly struggling larva for three or four minutes before it disappeared into a clump of aquatic vegetation. The only other case of this type that was observed involved a nymphal damselfly, *Lestes dryas* Kirby. The nymph rested on the bottom of a collecting jar while masticating a fourth instar larva.

In certain cases, predators probably have a noticeable effect on the immature *Mochlonyx* population, although there is no evidence to support this contention. The Hydracarina are very common in most woodland pools. Damselfly nymphs, dragonfly nymphs, and both larval and adult predaceous beetles are also frequently found. At some locations, these predators were so numerous that specimens were col-
lected in every dipper of water. This is especially true of the water mites and Thermonectes larvae.

Protozoa

Protozoa were frequently found attached to *M. cinctipes* larvae, although these colonies of single celled animals did not reach the proportions sometimes observed on *Aedes* larvae. Twinn (1931) states that protozoa are often found attached to mosquito larvae, sometimes so abundantly as to completely cover the insect. The author has observed larvae of *Aedes stimulans* which exhibit a fuzzy appearance as a result of a thick coat of stalked Infusoria.

The scattered colonies of Protozoa on the larvae of *M. cinctipes* are not restricted to any particular body site. They are as numerous on the heavily sclerotized body regions as on the lightly sclerotized body regions. Identification of the colonies was not attempted, but Kudo (1945) points out that species of the genera *Vorticella*, *Rhabdostyla*, and *Epistylis* are commonly found attached to animal and plant life in fresh water. Twinn (1931) states that the presence of these organisms is not believed to be harmful to mosquito larvae. This also appears to be the case with *M. cinctipes*, since fourth instar larvae which possessed relatively heavy infestations of stalked Protozoa reached the pupal stage with no evidence of difficulty.
**Pupation**

As is the case with ecdysis between instars, the fourth instar larva ceased feeding for a period of almost 24 hours prior to pupation. Pupal breathing horns are discernible through the body wall 10 to 12 hours before this stage appears. The larva exhibits a period of quiescence at the surface of the water which continues for four to five hours. During this time, short, jerking movements are seen which gradually lessen until the larva moves only when touched by a foreign object. All vertical movement ceases approximately three hours before pupal emergence.

Once the longitudinal split appears in the thorax, the appearance of the pupa follows rapidly. After the head and thorax emerge from the larval skin, the abdomen swings forward to form a right angle with the plane of the water surface. Then the portion of the exuvium which covers this region slips off, and the entire skin sinks to the bottom. The pupal abdomen continues to swing toward the thoracic region until the comma-shape, which is associated with this stage, is reached. While emerging from the larval skin, the pupa exhibits only slight wriggling motions. Immediately upon assuming its typical form, the pupa swims actively.
Pupa

Pupae were first collected in the pools on April 30. Although almost transparent immediately after the transition from the fourth instar, they gradually become darker, until, at the end of this stage, three to four days later, they are dark brown in color. Superficially, this stage is quite similar to a mosquito pupa. It is comma-shaped and swims actively by means of a rapid paddling motion of the abdomen. Like the larva, the pupa of M. cinctipes hides under debris on the bottom of the pools when disturbed. Unlike the larva, the pupa does not remain beneath the surface for extended periods.

Adult

Emergence

As the time of emergence nears, the pupa becomes less active. It rests at the surface and moves only when disturbed. This quiescent period is from four to six hours in duration. Approximately 15 minutes before the actual appearance of the adult, the abdomen begins to straighten posteriorly, and the pupa loses its comma-shape. In a single convulsive movement, the abdomen straightens completely and the adult begins to emerge through the dorsal longitudinal split in the thorax. The head and thorax appear
first, followed by the abdomen. The legs, which lie ventrally to the abdomen, are not freed until emergence is almost completed. Only four to five minutes are required for the adult to appear, after which it stands on the surface of the water for five to ten minutes before flying to a surface where it rests while drying. The scutum and eyes are dark when the adult first appears, but approximately 20 minutes are required to completely assume normal coloration.

Resting Places

Although adults can be swept from vegetation, the vast majority utilize trees as resting places. They are primarily found on the bark of standing trees, but they have been taken on the lower surfaces of those lying on the ground and inside hollow stumps. With the aid of an aspirator, as many as 25 specimens have been collected in 10 minutes from these locations. The most productive collecting sites are rough-barked trees such as elm and oak. Maple trees also provide many specimens. No adults were observed on the smooth areas of beech bark, although a few have been collected near the roots of older trees where there are furrows. There seems to be no particular area of the tree which is preferred. Adults rest as high as 20 feet and as low as three inches from the ground. They can be found on both the sunlit and shaded sides of the tree,
although the shaded side usually has more specimens.

Most of the adult life is passed on the trees. At the start of one observation period, the location of a female specimen on a tree was marked by stabbing a pen knife into the trunk below it. This location was periodically examined, and at the end of observation period three hours later, the adult had not moved from its original position.

Adults rest in a vertical position with the head higher than the abdomen. When a bottle containing a specimen is inverted, the adult quickly reverses its position and rests again with the head above the abdomen.

During the evening studies, it was found that adults on the trees exhibit no particular reaction to light. The adult moves neither away from nor toward the source when a beam of light is placed on it. On several occasions, adults walked through a circle of light on the trunk of a tree without displaying any reaction.

**Movement**

If disturbed while resting on the bark of a tree, the adults will fly to another tree nearby. They fly slowly and only for short distances. Adults have never been found on trees more than 70 feet from the pool. Temperature more so than relative humidity, seems to effect activity. The adults are sluggish and will fly only when
disturbed at temperatures below 50° F. They have been ob­served in flight at relative humidities ranging between 40 and 90%. Adults walk rapidly with the body raised well a­bove the surface on which they are moving.

Swarming

Although many insect swarms were observed at the sur­face of the pools, *M. cinctipes* adults were never taken. *M. cinctipes* was found to swarm in clear spaces among the trees surrounding the pools. The adults gather in the evening when the light intensity falls to 3.5 foot-candles as measured by a Weston Master II light meter. Individu­als fly rapidly in a weaving pattern, while the main body of the swarm which ranges between 8 and 20 feet above the ground, moves very little from its original position. Ex­amination of the swarms was made by passing a collecting net through them. It was found that males outnumber females by almost eight to one. When a net is used in this way, the adults scatter, only to regroup almost im­mediately. This type of behavior was also observed when a flashlight beam was placed on the swarm. During the swarming period, no males could be found at rest on the tree trunks, although females were present. Dissection of females collected from the trees during this period revealed that they were carrying eggs. At this hour in the evening, it is difficult to see the adults unless they
are outlined against the sky. The best method of locating the swarms is by ear, since the shrill, humming sound which they produce is audible for 20 feet. The swarming period continues for approximately 45 minutes, after which both males and females can again be found resting on tree trunks.

Mating

Adults were not observed in the act of copulating. James (1957), in his study of *M. velutinus*, found that mating occurred during swarming. In cages, males seized females in flight, and the pairs fell at once to the sides or the bottom of the cage. Specimens of *M. cinctipes* which were placed in cages measuring 18 x 12 x 12 inches lived only a few days and neither swarmed nor mated.

Observations were conducted on adults in the field during the swarming period. On one occasion, while sweeping through these sustained flights with a collecting net, six males and one female were obtained. The terminal segment of one of the males was rotated 90° from its normal position and the claspers were opened in a manner suggestive of copulation. On a number of occasions, adults in sustained flight were seen to meet in mid-air, but the course of their flight was impossible to follow in the reduced light. Examination of the ground under the swarms and the trees and foliage surrounding the swarms with aid
of a flashlight revealed no copulating adults.

Oviposition

Oviposition occurs during the evening at the periphery of the pools. The eggs are generally scattered singly on and under surface debris, although in a few instances as many as five eggs were found in small, irregular groups. Specimens which were collected in the woods were placed in cages containing one petri dish with water only and another with moist leaves. Eggs were deposited under folds in the leaves and between the leaves and the glass in the second petri dish, but none were deposited on the surface of the water in the first petri dish.

Before oviposition begins, the abdomen of the female fills with eggs. There is no evidence of other internal organs at this time. Dissection of gravid females revealed an average of 98 eggs per specimen. Externally, all of the eggs appear to be in the same stage of maturation, but they are not deposited all at once. Specimens caged alone or in pairs laid 8 to 13 eggs during an oviposition period. In the field, females collected while flying from the edges of the pools to the trees surrounding the pools contained varying numbers of eggs. One specimen contained only six eggs which were located posteriorly, the remainder of the abdomen being empty. This phenomenon was observed a number of times. In each case
where a portion of the matured eggs had been deposited, the remaining eggs appeared to have been displaced posteriorly with the vacated anterior region remaining empty. Unfortunately, no gravid females remained alive for more than three days, so the duration of the oviposition period was not determined.

During the late summer and fall of 1957, leaf litter was collected from the locations where the pools had been. At this time of year, standing water was no longer present. This material was returned to the laboratory where it was placed in a cold room at 32° F. Beginning in February, portions of the leaf litter were removed from cold storage and held at room temperature for two weeks. They were then placed in water in hopes of obtaining first instar larvae. No larvae were obtained. There are two possible explanations for this failure: (1) The dry atmosphere of the cold room caused some of the eggs to desiccate and collapse. (2) Prolonged exposure to freezing temperatures may have killed the embryos. Leaf litter which was stored for the winter at room temperature and at 45° F. also failed to produce larvae.

Feeding and Drinking

No evidence of feeding was observed either in the field or in the laboratory. Caged specimens were provided with prunes, raisins, honey water, and wild flowers, and
although observations were conducted during the day and night, no adults were seen to visit the food sources. Careful examinations of possible food sources in the field also proved fruitless.

As was stated previously, Matheson (1944) writes that the mouthparts of the Chaoborinae, with mandibles and maxillae present but lacking teeth, are short and not formed for piercing. Cook (1956) states that the members of this subfamily "have all of the structures necessary both for piercing and for feeding on fluids." Dissection of the mouthparts of *M. cinctipes* revealed that the mandibles, maxillae, and hypopharynx are present. The mandibles are 0.25 mm. in length and have no teeth. The maxillae are also short, but they possess minute spines on the distal end. The hypopharynx is spatula-shaped and lacks teeth.

The literature contains no records of attacks on man by *M. cinctipes*, and adults in the field never attempted to bite the author. The author inserted his hand and forearm into a cage containing male and female *M. cinctipes* for fifteen minute periods during the morning, evening, and night, and no adults attempted to bite during these observation periods.

Newly emerged and several day old males and females were dissected in order to examine the alimentary tract. *Aedes stimulans* adults were also dissected for the purpose
of comparison. The various parts of the digestive system of the mosquito were easily discernible, but the adult *Mochlonyx* exhibited no more than a rudimentary straight tube. In the case of gravid females, the entire abdomen was filled with eggs, and no trace of the alimentary tract was observed.

On two occasions, adults were seen to apparently imbibe water. The adult lands on the surface of the pool and lowers its body until it almost touches the surface of the water. This places the mouthparts in contact with the water. The process takes approximately 45 seconds, after which the adult raises its body to the normal resting position, and then flies away.

**Longevity**

The adults appear at the end of April or the beginning of May. The majority of the early emerging *Mochlonyx* are males, although collections made throughout the adult season indicate no preponderance of either sex. Both the males and females live 12 to 14 days. The adults disappear at the middle of June and none are seen again until the following spring.

**ECONOMIC IMPORTANCE**

The larvae of *Mochlonyx cinctipes* are predaceous on the larvae of biting mosquitoes as well as other forms of
aquatic life in semi-permanent woodland pools, and the adults do not bite man. In these respects, it may be classed as a beneficial insect. The following paragraphs are intended to present the degree of beneficial activity and to determine whether or not attempts to use M. cinctipes as a biological control agent would be justified.

Statements which mention the predatory nature of the Chaoborinae with regard to the larvae of biting mosquitoes are found in most of the publications concerning this subfamily (Matheson, 1944; Hinman, 1934; Edwards, 1932; and Cook, 1956). These statements appear to be mainly based on the general knowledge that these are predatory and that they will consume large number of mosquito larvae in the laboratory (Twinn, 1931). In these cases, mosquito larvae were fed to Mochlonyx which had access to no other source of food. This type of experiment only reveals the biological control potential under the experimental conditions. Under natural conditions, the diverse sources of available food would no doubt reduce such spectacular results.

Hintz (1951) lists ecological situations in order of mosquito production as: (1) floodwater remnants, (2) artificial containers, (3) woodland pools, (4) swamp-ponds, and (5) streams and ditches. He adds that this is in roughly reverse order to the abundance of predators. Mead (1949) states that the worst pests in central Ohio are
temporary pool breeders. In semi-permanent pools where

*M. cinctipes* is found there are two factors other than

predators which limit the size of mosquito populations.

(1) Many members of the pool fauna compete with mosquito
larvae for available food. Weed (1924), in his study of

a pond, felt that cladocerans completely prevented mos­
quito breeding by utilizing all of the food. (2) Larg­
er animals by their movements create an unfavorable en­
vironment for mosquito larvae. Hintz (1951) states that

constant escape reactions by larvae and pupae can slow
down their development and expose them to predation.

During the study of the immature stages of *M. cinc­
tipes*, it was found that although large quantities of

first and second instar *Aedes aegypti* larvae were consumed

in the laboratory, several factors served to mitigate pred­
atation in the field. The relative size of the prey is very

important. The eggs of *M. cinctipes* hatch at about the

same time as those of the pest species in the woodland

pools. First instar larvae of biting mosquitoes were dip­
ped from the pools when *M. cinctipes* first emerged. The

larvae of *Aedes stimulans*, the most numerous biting mos­
quito found in the pools, exhibits a greater mean length

in each instar than those of the predaceous species. This

intrinsic difference in length and the fact that the im­
mature biting mosquitoes develop more rapidly than those
of *M. cinctipes* tend to inhibit predatory action. A low degree of predation may result in the case of large *Mochlonyx* larvae and small pest larvae, since the range of larval lengths is extensive.

The feeding habits of the larvae are another factor which mitigates their value as biological control agents. The crop contents of 80 third and fourth instar *Mochlonyx* larvae which were killed immediately after collection were placed on slides for examination. Remains of biting mosquito larvae were found in the crop contents of only two larvae. Both mature and immature copepods and ostracods predominated.

The sparse distribution of *M. cinctipes* is another factor which limits its value in the control of biting mosquitoes. There are relatively few situations in this state which provide the semi-permanent pools necessary for the completion of the long life cycle of this species. On the other hand, the most important pest mosquitoes in this state breed in temporary pools.

For the reasons discussed in the previous paragraphs, *Mochlonyx cinctipes* is not considered a significant predator of biting mosquitoes in Ohio.

**SUMMARY**

*Mochlonyx cinctipes* (Coquillett) breeds in semi-per-
manent woodland pools formed by melting snow and spring rains. There is one generation per year and the winter is passed in the egg stage. The larvae appear at the beginning of March, and the adults appear at the end of April or the beginning of May. The adults are no longer present after the middle of June.

The larvae are omnivorous, feeding on crustaceans, mosquito larvae, algae, and fungi. They are capable of remaining beneath the surface of the water for extended periods. Under crowded conditions, cannibalism is a common practise.

Adults were not observed to feed, although they do imbibe water. They swarm in the evening, and the females oviposit under leaves and other debris at the periphery of the pools. The adults remain in close proximity to the pools, and pass most of their lives resting on tree trunks.

The larvae of this species are not considered important in the control of biting mosquitoes because of their omnivorous habit, sparse distribution, and long life cycle.
LITERATURE CITED


Dyar, H.G. 1890. The number of moults of lepidopterous larvae. Psyche 5: 420-422.


I, Charles Timothy O'Connor, was born in Atlantic City, New Jersey, August 1, 1930. I received my secondary education in the public schools of Atlantic City, New Jersey, and my undergraduate training at Rutgers University, which granted me the Bachelor of Science degree in 1953. I also obtained my Master of Science degree at Rutgers University in 1955. While in attendance there, I was research assistant to Dr. Philip Granett of the New Jersey Agricultural Experiment Station staff. In July, 1955, I was appointed research assistant at the Ohio Agricultural Experiment Station. I held this position for three years while completing the requirements for the degree of Doctor of Philosophy.