MOSQUITO STUDIES IN NORTHERN WISCONSIN
I. LARVAL STUDIES[1]

R. E. SIVERLY[2] AND GENE R. DEFOLIART[3]

INTRODUCTION. *Objectives of the studies.* Mosquito studies were made in northern Wisconsin during the spring-summer of 1966–1967 in order to determine: (1) sites of production, and characteristics of larval populations, (2) relative abundance of species of mosquitoes occurring in the study area, and (3) the seasonal succession of adult mosquito populations.

This paper deals with data obtained in implementing the first objective. Data concerning adult mosquito populations will be reported in the second paper in this series.

METHODS. *Study area.* Larvae were collected from various sites in Lincoln County and in Forest County, Wisconsin. These counties lie within the region of Wisconsin described as conifer-hardwood forest (Curtis, 1959). All of the Forest County sites are within the Nicolet National Forest.

Two basic soil types are recognized throughout the five-county area—light soils and heavy soils. The light soils characteristically are sandy, drain well, occur at higher elevations than heavy soils, and support deciduous trees, such as sugar maple and ash. The heavy soils contain clay, drain poorly, and support trees and shrubs such as black spruce, tamarack, and tag alder.

Heavy soils occur in bogs, which are very numerous. Many of the bogs are spring-fed, and sub-surface water is present under a spongy, superficial layer of turf during most of the year. Many of these bogs are of the muskeg type, with stunted conifers—tamarack and black spruce—the dominant trees. Sphagnum and leatherleaf constitute much of the understory.

Transitions between light and heavy soils may be abrupt. Steep sidehills bordering bogs show this effect. On these sidehills, the tree species include sugar maple, hemlock, yellow birch and white cedar. Some of these trees are established; others have fallen, creating pockets in which spring water, rain water or water from snow melt accumulates. Pockets also occur on low, relatively level ground. Sometimes these small pools are bordered with rock outcroppings. Sphagnum moss usually is present (Figure 1). Regardless of location, these sphagnum pockets tend to be utilized very intensively by early spring *Aedes* species.

Frequency of collecting. Of the 53 collections made in Lincoln County, 42 were made from eight sites which were sampled one or more times. Of the 31 collections made in Forest County, 16 were made at three sites which were sampled from four to six times each. There were 84 collections in all.

Most of the collections were made during the months of April and May. After June 1, efforts were mainly directed toward adult sampling.

Sampling procedures. Samples were taken in the conventional way, with a white enamel dipper. Larvae were transported to the laboratory for species determinations. Samples were reared to adulthood, when necessary, to confirm larval identifications. The senior author collected larvae in the study area during the first week of April, 1966, and during the last week of April, 1967.

A procedure for live-shipping larvae from northern Wisconsin to Muncie, Indiana was followed, both in 1966 and 1967. Local people in Lincoln and Forest Counties collected and packaged the lar-

[1] This investigation was supported in part by Public Health Service grants AI-0071 and AI-07453 from the National Institute of Allergy and Infectious Diseases.

[2] Visiting Professor in Entomology, University of Wisconsin. Address during academic year: Ball State University, Muncie, Indiana.

[3] Professor of Entomology, University of Wisconsin.

FIG. 1.—Sphagnum pocket, northern Wisconsin bog.

vae. Shipments were made at weekly intervals during May, thus establishing a continuity in surveillance each year during the interval between initial larval collecting and full-time summer study.

RESULTS. *Table 1.* With the exception of *Aedes canadensis, A. cinereus, A. vexans, Culiseta morsitans,* and possibly *A. punctor,* all species listed in Table I were univoltine. One brood appeared in late May or early June, with no evidence of a second brood or delayed hatch. Note the later time periods when larvae were collected in Forest County as compared with Lincoln County collections. In one instance (occurrence of mature *A. diantaeus* larvae) the observed time difference was 6 weeks.

Table 1 does not include two species of *Anopheles,* three species of *Culex,* four species of *Culiseta, Mansonia perturbans* and *Wyeomyia smithii,* all of which occur in the study area. Emphasis in this study was directed to preimaginal *Aedes* which contribute to the sharp peak of emergent mosquito populations in late May and early June.

Accounts of species—established state records. A brief habitat description is given for the species listed in Table 1, as follows: *A. abserratus* was found in leatherleaf-sphagnum associations, often in exposed situations, in small pools on footpaths in open bogs. *A. aurifer* larvae came from a cattail pond, in an open area close by permanent water. In Indiana, *A. aurifer* more likely is found in shaded, temporary pools.

A. canadensis utilized a variety of habitats, was found as early as April, and as late as August. Larvae found in temporary ground pools following early fall rains may represent a partial second generation or delayed hatch. These same observations apply to *A. cinereus,* although *A. cinereus* occurred more frequently in roadside ditches bordering acid bogs in water with high organic content. *A. cinereus* larvae were collected in Lincoln County as late as October 23.

TABLE 1.—Numbers of Mosquito Larvae Collected in Lincoln County (A) in 1966 and 1967, and in Forest County (B), 1967

	April 1–10		April 11–20		April 21–30		May 1–10		May 11–20		May 21–30		June 1–10		June 11–20		June 21–30		Total		
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	Total
Aedes abserratus	9	..	5	..	3	2	3	5	3	1	1	1	..	..	..	1	1	..	25	10	35
Aedes aurifer	..	..	..	..	1	..	11	..	1	..	..	..	..	..	..	..	1	..	14	0	14
Aedes canadensis	..	..	1	..	21	1	26	..	7	1	..	8	5	42	..	25	16	..	76	76	152
Aedes cinereus	1	..	4	..	37	..	..	..	1	..	5	..	3	1	..	2	19	..	70	3	73
Aedes communis	6	..	1	..	18	34	23	10	..	25	..	68	..	23	..	..	..	..	48	160	208
Aedes diantaeus	..	..	..	..	12	..	4	..	7	..	4	..	..	20	..	35	..	..	27	55	82
Aedes excrucians	13	..	12	..	50	..	38	..	42	..	63	3	..	..	..	7	5	..	223	10	233
Aedes fitchii	1	..	..	..	14	..	5	..	..	..	8	3	..	..	..	..	..	..	28	3	31
Aedes implicatus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	0	1	1
Aedes intrudens	..	..	..	..	15	..	1	..	2	..	..	..	..	..	..	..	..	..	18	0	18
Aedes punctor	18	..	17	..	41	8	48	15	21	0	2	11	1	29	..	1	19	..	167	73	240
Aedes stimulans	..	..	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	0	3
Aedes trichurus	14	..	8	..	41	..	5	..	1	..	4	..	..	..	..	..	..	..	73	0	73
Aedes vexans	..	..	..	..	..	..	..	..	1	..	3	3	..	..	..	..	1	..	5	3	8
Culiseta morsitans	..	..	..	..	..	..	..	..	..	..	..	..	13	..	..	..	5	..	18	0	18
Total	62	0	51	0	253	45	164	30	86	35	90	97	22	115	0	72	67	0	795	394	1189

A. communis was found in small partially shaded ground pools, in snow melt pools in a balsam fir stand, and in unshaded hillside pools formed from snow melt on a former logging road bordering a glacial kettle. The site called *Tsuga,* in the Nicolet National Forest, evidently produced only *A. communis* in the spring of 1967. It has a tremendous production potential and can be described briefly as follows:

> It is an oval pocket, approximately 50 by 30 feet. In late April and May, the pocket contained water in maximum depth to three or four feet. The pocket is usually dry by July 1 and remains dry until snow melt the following spring. *Tsuga* is located in dense shade, with hemlock the predominant component of the overstory. There is a scattering of yellow birch and sugar maple in the area. Ground cover is sparse, consisting of small sugar maple, woods fern, woods sorrel, and two species of partridge berry. The soil is a somewhat poorly drained monico silt loam, a member of the Iron River series. Water table in late August stood at about 18 inches below the surface.
>
> On April 27, *Aedes communis* were taken here at the rate of approximately 50 per dip. *Tsuga* again was sampled on May 11, May 16, and May 23, and yielded nothing but *A. communis* on each collection. Not allowing for mortality, this pond has an estimated production potential of 4,500,000 mosquitoes (30 x 50 x 1 (mean depth) x 60 (pints/cu. ft.) x 50/dip).

A. excrucians was the most abundant band-legged *Aedes* in the study area. Larvae were found in unshaded grassy pools and roadside ditches, in water which was high in organic matter. *A. fitchii* tended to utilize more extensive areas, such as flooded ditches, cattail ponds and temporary grassy pools with emergent vegetation and shrubs.

A. intrudens larvae were recovered from grassy, seepage, snow melt pools on the fringe of a mixed hardwood and deciduous forest. Larvae were associated with *A. diantaeus* and other cold-hardy *Aedes.*

A. punctor was found in leatherleaf-sphagnum associations. It was sometimes present with *A. excrucians* in roadside ditches but occurred most abundantly in sphagnum pockets (Figure 1). *A. punctor* larvae were found in abundance in water containing chunks of ice, and this species evidently can complete development when water temperature does not exceed 55° F. *A. punctor* is very well adapted to northern Wisconsin. Of the species reported in this study, larvae of *A. punctor* were collected in greatest number (Table 1).

Early in the spring, *A. punctor* was found either as a single species, or coexistent with others of the cold-hardy *A. communis* group. Later in the spring, it was associated with *A. canadensis.* When water remained cool (below 60° F.) *Culiseta morsitans* sometimes followed *A. punctor,* especially when part of the habitat was dark, as around subterranean, exposed roots of trees in the more remote reaches of water pockets.

During 1966, *A. punctor* were taken as late as August 10 in the Nicolet National Forest. The presence of larvae in August, and presence of unrubbed adult specimens in light traps and from biting collections suggest a partial second brood or delayed hatch for *A. punctor* in the study area.

The virtual absence of *A. stimulans* in the study area is not clearly understood, since the range of this species extends into Canada. It occurs in sizable numbers in southern Wisconsin.

A. trichurus was found in grassy pools formed by snow melt and exposed to direct sunlight. Large numbers of eggs hatch very early, but survival during the immature stages appears to be reduced because of parasitism by protozoa (probably *Vorticella* spp.). According to Barr (1958) the spring emergence is after that of *A. implicatus* and the other early members of the *A. communis* group. Observations in the present study indicate that *A. trichurus* emergence may be as early, if not earlier, than that of *A. punctor* and *A. communis.*

Ecologically, *A. vexans* is associated with *A. canadensis* and *A. cinereus.* Typically,

A. vexans is a summer and fall mosquito, occurring in temporary pools after rains. On August 10, 1966, a larval collecting trip was made which included parts of the Nicolet Forest, other parts of Forest County, and parts of Vilas and Oneida Counties. Approximately 10 percent of specimens collected were identified. Numbers identified of different species were as follows: *Aedes canadensis,* 7; *A. cinereus,* 26; *A. punctor,* 2; *A. vexans,* 28; *Culex territans,* 7; *Culiseta morsitans,* 3.

For the most part, these collections were made in flooded ditches and gullies bordering streams where overflow water had accumulated following early fall rains. *A. punctor* was collected on this trip in a sphagnum pocket in the Nicolet National Forest. Late larval collecting of *A. cinereus* and *A. vexans* already has been mentioned.

Account of species—infrequent species and new state records. Smith (1952) reported *A. diantaeus* from Wisconsin, but did not include a habitat description for the single male specimen which constitutes the only previous Wisconsin record. Dickinson (1944) did not report *A. diantaeus* as occurring in Wisconsin. In this study, numbers of *A. diantaeus* were collected from a site called *Cedar,* in the Nicolet National Forest. *A. implicatus* also was collected at *Cedar.* Our reporting of this species is believed to be a new state record for Wisconsin. A description of the habitat follows:

> The collecting area consists of a series of pockets containing trapped water under partial shade. A slough, predominantly sedges, adjoins the collecting area on the south.
>
> The overstory is dense, and predominantly hemlock, although fir, yellow birch, white birch and an occasional cedar also are present. The understory vegetation is typical for moist, partially shaded situations in wet areas: Canada may-flower, bunch-berry, woods fern, gold thread, dwarf cornel, *Lycopodium* spp. and *Clintonia borealis.* There is some maple and hemlock propagation in the understory.
>
> The soil is a poorly drained, outwash, sandy loam. The pockets, or depressions where water stands for long periods were formed by cedar and hemlock windthrow. A heavy layer of deciduous leaves and grasses covers the bottoms of the pools. The slough evidently was formed at the juncture of moraine and outwash. The pools receive side light as a result of the open, exposed slough area immediately adjacent to the south.

Jenkins and Knight (1952) described the habitat of *A. diantaeus* in the region of Southern James Bay, Ontario, mentioning dead leaves and other organic matter on the bottoms of pools where the species was found.

One larva of *A. implicatus* was taken at *Cedar* on June 12, 1967. It appeared to have a fungus infection and did not complete development. However, one adult female *A. implicatus* subsequently was recovered from a CDC trap a short distance away.

Four larvae of *Culiseta silvestris minnesotae* Barr were collected close by Shelp Lake on August 1, 1967. Larval collecting followed recovery of two specimens from a CDC trap at the same site on July 22, 1967. The three larvae were successfully reared. Two males emerged on August 6, and one female emerged on August 8. Appearance of the larval skins and emerged adults fitted well the description given by Barr (1958) for this species. *C. s. minnesotae* is believed to be a new state record for Wisconsin.

The shelf, or mat bordering Shelp Lake (from which *C. s. minnesotae* larvae were collected) is composed of moss (sphagnum) peat and is approximately 3 feet thick. It is quite porous. The mat is well invaded by leatherleaf, and on the lake edge by cattail, sedge and grass. The *C. s. minnesotae* larvae were collected in the vicinity of alder, where the mat is not as wide, and probably less than 3 feet in thickness. The soil in the vicinity of the alder likely contains some mineral as well as organic elements.

Culiseta melanura larvae were collected at Shelp Mat, and also at a bog site bordering Highway 32 in the Nicolet National Forest. This bog is typical muskeg, with black spruce and tamarack the dominant

conifer trees. The soil is a well-decomposed fibrous peat.

DISCUSSION. Based on observations in the field, collections from both Wisconsin and Indiana, and laboratory rearings, the temperature threshold for egg hatching in ten species of *Aedes* mosquitoes approximates the following order: *A. trichurus*< *A. punctor*<*A. communis*<*A. diantaeus* <*A. intrudens*<*A. abserratus*=*A. excrucians*<*A. fitchii*=*A. canadensis*=*A. cinereus*. These data may have some application in predicting sequence of adult emergence. Mosquito production in the study area is both extensive and intensive. The hundreds of acres of lowland bog contain countless pockets and pools which provide ideal production sites for early spring *Aedes*.

The situation is similar in the region of Southern James Bay (Jenkins and Knight, 1952). There, also, the most abundant larvae collected were reported to be *Aedes punctor* and *A. excrucians*. Not treated in this report, but of considerable importance, is the extremely high production of *Mansonia perturbans* from permanent and semi-permanent lakes and ponds scattered throughout the area. Thus, there is an enormous mosquito production potential in this northern Wisconsin area.

The relative inaccessibility of many of the wet lowland areas which produce mosquitoes and the economic infeasibility of reclaiming infertile land for agricultural purposes are limiting factors if conventional methods of control are considered. The advice of Jenkins (1958) regarding consideration of use of predators and parasites in control programs for arctic and subarctic mosquitoes seems applicable here, as well as consideration of radiosterilized male control and other biological control methods which augment conventional control practices.

SUMMARY AND CONCLUSIONS. A total of 1189 mosquito larvae, comprising 84 samples were collected in Lincoln and Forest Counties, Wisconsin, during the spring months of 1966 and 1967. Of the 13 species of early spring *Aedes* collected, *A. punctor, A. excrucians,* and *A. communis* were most abundant. Larvae were present from the first week in April until the third week in October. There is evidence that *A. canadensis, A. cinereus,* and *A. punctor* have delayed hatch, or at least a partial second generation annually.

A sequence of egg hatching for ten species of *Aedes* is estimated. Habitat descriptions are given for several species, including *Aedes implicatus* Vockeroth and *Culiseta silvestris minnesotae* Barr, believed to be new species records for Wisconsin.

The enormous mosquito populations in early summer are accountable by extensive lowlands, containing countless pockets and pools, which are intensively utilized as production sites by cold-hardy *Aedes* species.

ACKNOWLEDGMENTS. Appreciation is expressed to Mr. Nils Dahlstrand, of the U. S. Soil Conservation Service, and to Dr. Forest Stearns, of the USDA Forest Genetics Lab at Rhinelander, Wisconsin for their help with soil descriptions and plant determinations. The larval collections made by Dr. Stearns, and by Mr. Don Lintereur and his high school biology students at Tomahawk, Wisconsin aided materially in this study.

References

BARR, A. RALPH. 1958. The mosquitoes of Minnesota. Univ. of Minnesota Agr. Exp. Station Tech. Bull. 228. 154 pp.

CURTIS, JOHN T. 1959. The vegetation of Wisconsin. Univ. of Wisconsin Press. 657 pp.

DICKINSON, N. E. 1944. The mosquitoes of Wisconsin. Milwaukee Pub. Mus. Bull. 8:269–365.

JENKINS, DALE N., and KENNETH L. KNIGHT. 1952. Ecological survey of the mosquitoes of Southern James Bay. The Amer. Midl. Nat., Vol. 47 (2):456–468.

JENKINS, DALE N. 1958. Ecology of arctic and subarctic mosquitoes. Proc. Tenth Internat. Cong. of Ent., Vol. 1, 1956:627–634.

SMITH, M. E. 1952. A new northern *Aedes* mosquito, with notes on its close ally, *Aedes diantaeus,* H., D., and K (Diptera, Culicidae). Bull. Brooklyn Ent. Soc. 47:19–28; 29–40.