MOSQUITOES OF DELAWARE COUNTY, INDIANA[1]

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INTRODUCTION: HISTORY OF MOSQUITO INVESTIGATIONS IN INDIANA. Hart (1944) published records of 24 species of mosquitoes found in Indiana. In the same year Christensen and Harmston (1944) published a list which includes all the species reported by Hart, and records of five additional species.

Carpenter's paper (1952) includes collection records of 21 species of mosquitoes taken during 1944 and 1945 at five military installations in Indiana. Carpenter's paper includes records of two species not reported either by Hart, or by Christensen and Harmston. Figure 1 shows the locations of the collecting sites reported in these three papers.

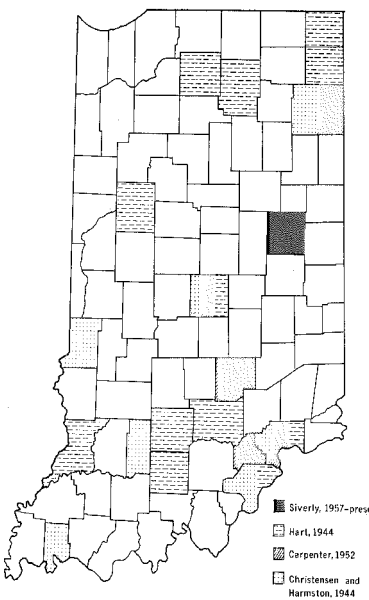

FIG. 1.—Locations of previous and current mosquito studies in Indiana.

Records had thus been published of 31 species of Indiana mosquitoes from 1952 until 1958. Evidently, these records are based mainly on light trap collections. Since 1958, Siverly (1958, 1959, 1961, 1963, 1964), and Siverly and Burkhardt (1965) have published records of seven species previously unreported from this state. Three additional species will be reported in this paper, which brings to 41 the total number of species of mosquitoes known to occur in Indiana at the present time.

OBJECTIVES OF THE PRESENT STUDY. The objectives of this study were to determine (1) the species of mosquitoes which occur in the study area, (2) the sites of mosquito production, (3) when mosquito populations occur, (4) mosquito prevalence as related to ecological factors, and (5) pertinent biological data, particularly biting habits and modes of overwintering.

METHODS: LOCATION, DESCRIPTION OF STUDY AREA. Delaware County is located in the east central portion of Indiana (Figure 1). The area comprises approximately 400 square miles. The terrain is nearly level to gently rolling; elevation varies from approximately 800 to 1,100 feet above sea level. Muncie, the county seat, is approximately 950 feet above sea level.

According to the Soil Conservation Service, about 65 percent of soil is in cultivation. Delaware County is in a glaciated area. Between 60 and 70 percent of the soil now under cultivation imposes drainage problems. The northern part of the county contains peat bogs and numerous pockets which may hold water a good part of the year. Approximately, the northeastern one-third of the county drains northward into the Mississinewa River. The remainder of the county drains southward into the White River.

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POPULATION SAMPLING. An attempt was made to set up one sampling site in each of the 12 townships in the county. Numbers of the sampling sites were assigned in the same sequence as the assignment of section numbers in townships. The northeast township (Niles) was assigned site numbers 1–10. The township west of Niles township was assigned site numbers 11–20, and so on (Figure 2). Of the 21 sites originally selected, 10 remained productive well into the summer.

Larval studies were started as soon as ice broke in the spring. The first surveys were conducted the first week in April, in 1964. These studies continued throughout the season, but received emphasis in April and May.

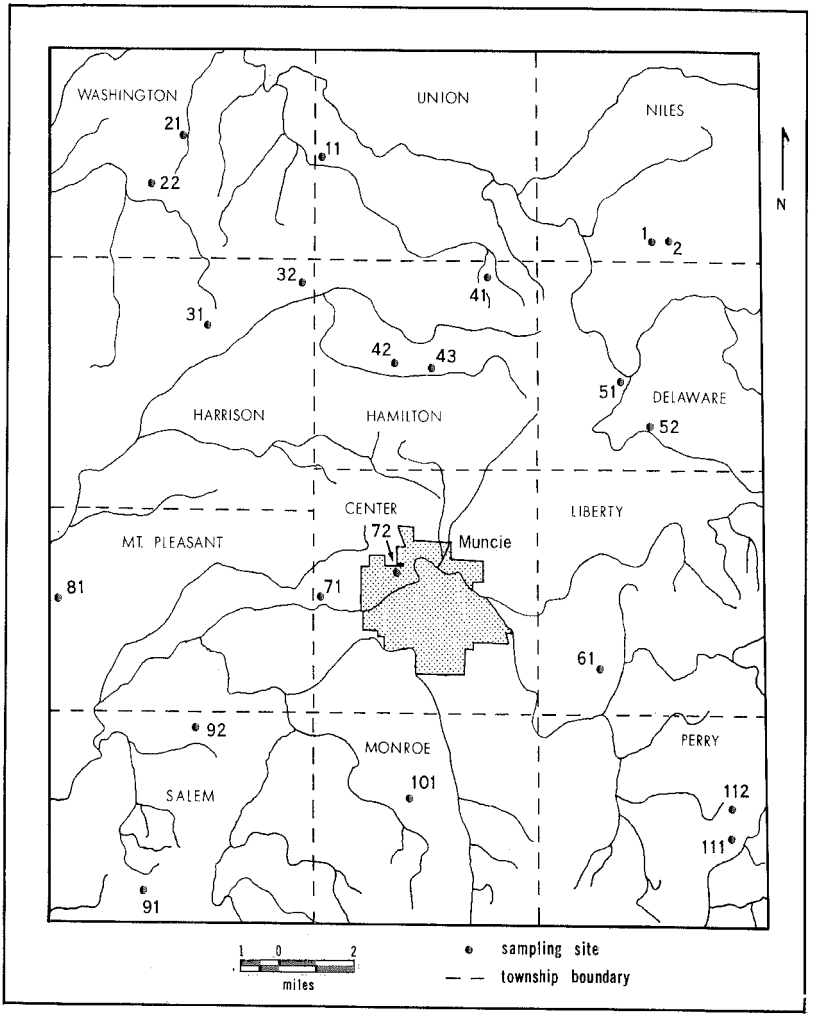

FIG. 2.—Delaware County, Indiana. Sampling sites used in 1964 mosquito study.

Field observations at the time of the larval surveys included notation of air and water temperatures, sky, wind and shade factors. Habitats were classified as: temporary pool, permanent pool, bog, stream, tree hole, or artificial container. Vegetation was classified as emergent, submerged, shore, or floating. Bottom classifications included mud, sand, or gravel. The extent of utilization was estimated in cubic feet.

A quantification, based on extent and degree of utilization, was attempted on each survey. Where utilization was homogeneous, continuous, and dimensions of the habitat readily estimated, this quantification could be accomplished. However, larval habitats often were not homogeneous in utilization, or were discontinuous, or were too vast for reasonable estimation in terms of cubic feet, and quantification could not be achieved.

In addition to 51 larval surveys, the study included 72 biting collections, 70 New Jersey light trap collections, 6 resting collections, 5 CDC trap collections and 6 animal trap collections from 16 different collecting sites.

Resting studies, CDC trap samples, and animal-bait trap studies were largely experimental, and the results are too preliminary for detailed discussion here. Boxes, constructed from marine plywood, and painted red on the interior were used in the resting studies. Dimensions of the boxes were 2 feet long, 1 foot wide, and 1 foot deep. The CDC miniature light trap has been described by Sudia and Chamberlain (1962). The animal-bait trap used was of the double-baited type described by Worth and Jonkers (1962).

RESULTS: DESCRIPTIONS OF SELECTED SAMPLING SITES. Not all sampling sites used in this study are described in this paper. Two sites, however, are noteworthy: sites 21 and 31.

Site 21 is a peat bog, over 200 acres in extent. The northern end of the bog contains cattails and second-growth willows. During flood periods in early spring, water in this northern end of the bog may attain a depth of 5 feet or more. Several inches of fine silt have been deposited in this localized area. Northern *Aedes* spp. and *Culiseta inornata* have been taken here.

The southern end of the bog is characterized by mature willows, much floating vegetation and both submerged and emergent vegetation. This end is more shallow than at the northern extreme, and has never been highly productive of mosquitoes in early spring. However, enormous numbers of temporary pool *Aedes* spp. are produced here later in the season, as water recedes (Figure 3). During later summers of 1963 and 1964 this bog became completely dry.

Site 31 is a smaller peat bog, approximately 25 acres in extent (Figure 4). Formerly, it contanied cranberries, sphagnum, and pitcher plant. Likely, *Wyeomyia smithii* occurred here. This mosquito has been reported in Indiana, but not from Delaware County (Siverly, 1964).

Much of this bog has become filled in. Quite a variety of mosses still may be found here. The dominant deciduous tree is red maple. During the dry periods in late summer and fall, this bog becomes dry, exposing tree roots to desiccation. High winds have blown over several of these trees, creating shaded pockets or earth cavities in which larvae of *Culiseta melanura* are found following rains. In early spring, northern *Aedes* spp. larvae have been taken from within moss-covered hummocks scattered throughout the bog. Of all sites in the study area, this site produced the greatest variety of mosquitoes. Of the 28 species collected in the county to date, 19 have been taken from this site.

ACCOUNT OF SPECIES. A listing of the mosquitoes found in Delaware County, by species, is given in Table 1.[3] Larval prevalence is expressed in descriptive terms.

[3] Table 1 includes 27 species. *Culex Salinarius* was collected in previous years in Delaware County, but was not collected in the present study.

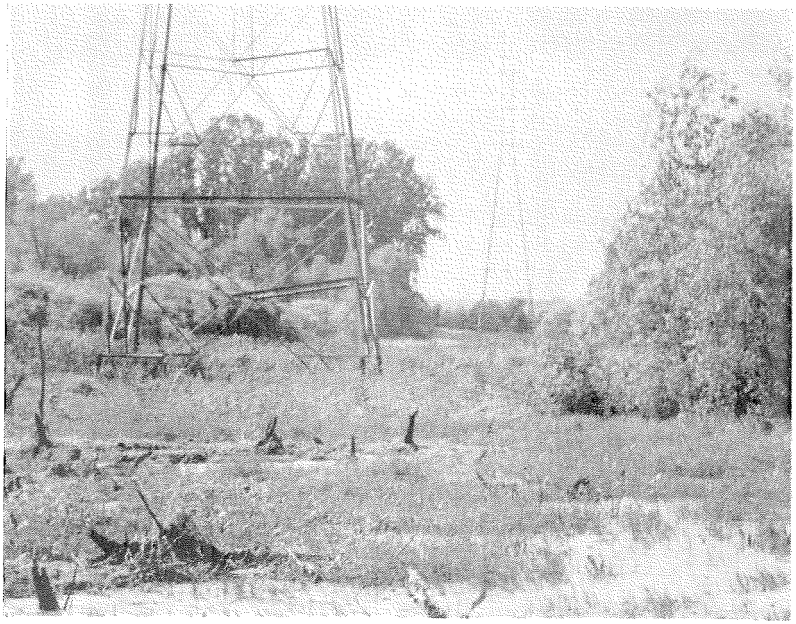

FIG. 3.—Site 21, Delaware County, Indiana.

FIG. 4.—Site 31, Delaware County, Indiana.

While these descriptions are not quantitative, they provide some basis for comparison of larval prevalence between species.

A brief account is given of those species listed in Table 1 which constitute new state records. Larvae of *Aedes fitchii* (Felt and Young) were taken at both Site 1 and Site 21, in deep, open pools with emergent vegetation. Adults were taken at eight different sites in the study area. This species appears attracted both to man and to light traps. Along with *Aedes stimulans,* females are vicious biters. There appears to be but one generation a year. Males become scarce in June, but females persist in diminishing numbers until the latter part of July.

Aedes flavescens (Felt and Young) was taken in the pupa stage in a cattail pond at the north end of Site 21 on May 4, 1964. Immature stages of these mosquitoes were collected by dipping under mats of dead, floating vegetation. Emergence of *Aedes flavescens* occurred on May 5 in the laboratory. The site was re-visited on May 6 for the collection of larvae or pupae of *Aedes flavescens,* but none were to be found. Subsequent adult collections at this site were negative for this species. Undoubtedly, *Aedes flavescens* is rare in Indiana, and this state may represent a southern limit in its distribution.

Aedes stimulans is clearly the dominant mosquito species in early spring. Its presence in Indiana was reported by Siverly at the Indiana Academy of Science meeting in 1959, but the abstract of this paper was not published. This is the first published record of the occurrence of *Aedes stimulans* in Indiana. The larvae are abundant in shaded woodland pools, sloughs and

TABLE 1.—Mosquito prevalence according to species in Delaware County, Indiana—1964.

	Prevalence of larvae	Biting		Light trap		Total	
		Number	Percent	Number	Percent	Number	Percent
Aedes aurifer	infrequent	21	1	1	<1	22	<1
Aedes canadensis	infrequent	43	2	1	<1	44	<1
Aedes cinereus	negative	2	<1	0	..	2	1
Aedes excrucians	rare	3	<1	0	..	3	1
Aedes fitchii	infrequent	78	4	26	<1	104	1
Aedes flavescens	rare	0	..	0	..	0	..
Aedes grossbecki	infrequent	8	<1	1	<1	9	<1
Aedes sticticus	infrequent	163	8	104	1	267	3
Aedes stimulans	abundant	716	36	121	1	837	8
Aedes thibaulti ..	infrequent	2	<1	0	..	2	<1
Aedes triseriatus	common	3	<1	13	<1	16	<1
Aedes trivittatus	infrequent*	413	20	1032	12	1445	14
Aedes vexans	abundant	547	27	5767	68	6314	60
Anopheles barberi	rare	0	..	0	..	0	..
Anopheles crucians	rare	0	..	5	..	5	<1
A. punctipennis	common	2	<1	282	3	284	3
A. quadrimaculatus	infrequent	2	<1	82	1	84	<1
Culex erraticus	rare	0	..	49	<1	49	<1
Culex pipiens	abundant	3	<1	800	9	803	8
Culex restuans	common	1	<1	84	1	85	<1
Culex territans	abundant	0	..	12	<1	12	<1
Culiseta inornata	infrequent	3	<1	2	<1	5	<1
Culiseta melanura	infrequent	0	..	0	..	0	..
Psorophora ciliata	infrequent	7	<1	23	<1	30	<1
P. confinnis	infrequent	0	..	2	<1	2	<1
P. discolor	rare	0	..	0	..	0	..
Uranotaenia sapphirina	common	0	..	36	<1	36	<1
Total	.....	2017	..	8443	..	10460	..

* Discussion in text.

ponds where bottoms of these bodies of water are covered with decaying leaves, plant debris and other humus. Fourth instar larvae were taken in densities of 25–50 per dip during the first part of April, from water which was covered with a thin layer of ice.

A temporary pond in a farm woodlot at Site 43 was heavily productive for *Aedes stimulans*. It was possible to make a quantitative estimate at this site. Based upon degree and extent of utilization, it was estimated that this particular pond produced in excess of 600,000 *Aedes stimulans* during April, 1964.

Evidently there is one generation a year, but females persist until late July. This is a vicious mosquito, attacking in open and in shaded areas during daytime as well as evening. *Aedes stimulans* was the leading species taken in biting collections, even exceeding *Aedes vexans* in prevalence. This species may be of considerable economic importance, due to its attacks on man and livestock around wooded areas during spring and early summer.

WEATHER FACTORS. Temperature for the entire year of 1964 averaged 52.2° F., slightly above the normal average of 51.5° F. established by the Ball State University Weather Bureau. Average temperature for April (51.1° F.) was very close to the yearly temperature average.

Precipitation deviated from established norms more than temperature. Total precipitation for the entire year of 1964 was 41.78 inches, as compared with normal precipitation of 40.49 inches. The months of August, September, and October were unusually dry. Had heavy rains not occurred in March and April, 1964 would have been one of the driest years on record, with a precipitation deficiency. Total precipitation for months of March and April was 7.18 inches and 12.72 inches respectively, as compared with norms of 4.02 and 3.46 inches for those two months. Consequently, many pastures, bogs, and woodland pool areas were flooded in April. Undoubtedly this flooding contributed to heavy emergent populations of early spring *Aedes* spp. which overwinter in the egg stage. On the other hand, populations of *Psorophora* species and multivoltine species of *Aedes* probably were repressed because of absence of recurrent rains during late summer and fall.

MOSQUITO POPULATIONS. Although 27 species of mosquitoes were collected in this study, 4 species—*Aedes vexans, Aedes trivittatus, Aedes stimulans,* and *Culex pipiens*—made up close to 90 percent of numbers of specimens collected (Table 1). The profiles of these four mosquito populations are shown in Figure 5. In Figure 5, percentages of total collections, and average weekly temperatures are shown as 3-week moving averages. Collections during May were all biting collections. Figures for the remainder of the collecting period represent combined biting collections and light trap collections.

Adult collections began the week of May 10, and terminated the week of August 9. Figure 5 includes observations previous to May 10, and for late August, September and October. These observations are included to provide continuity, and are shown as extrapolations in broken lines.

The *Aedes stimulans* population was distinctly unimodal, reflecting one generation a year which reached its peak in May and gradually diminished during successive weeks, becoming scarce in late July and absent after the first week in August. This curve, as shown in Figure 5, probably is fairly typical for *Aedes stimulans* in the study area. Different precipitation patterns in spring and summer should not have a significant effect upon this distribution.

The first emergence of *Aedes vexans* and *Aedes trivittatus* occurs at about the same time. *Aedes vexans* is surprisingly cold-hardy. First instar larvae were collected when the water was covered with a skim of ice. Mass emergence occurred the first week in May. As indicated in Figure 5, *A. vexans* was dominant during June and past mid-July. There are several factors to account for the dominance of this mosquito in the study area. Besides

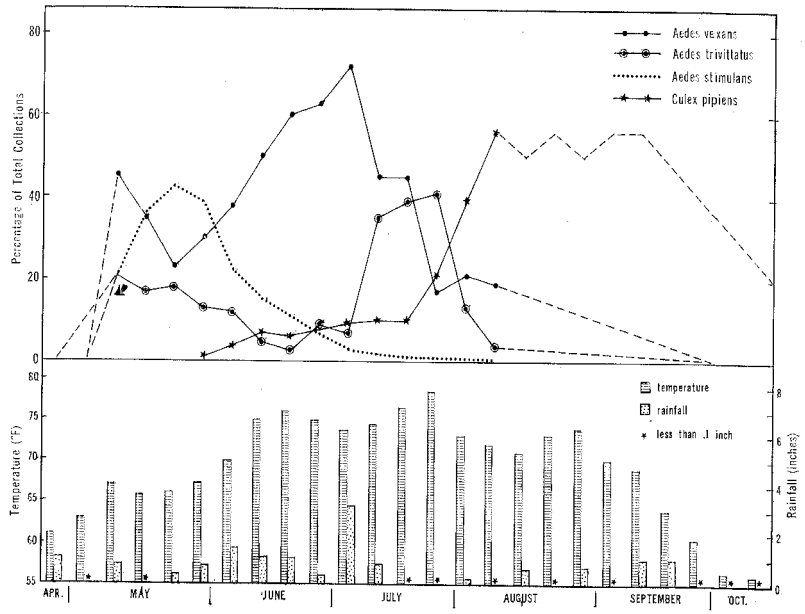

FIG. 5.—Profiles of mosquito populations in Delaware County, Indiana—1964.

being cold-hardy, larvae can adjust to summer temperatures as well. Larvae are found in woodland pools, sloughs, in bogs, and in exposed, flooded pasture sites. It is multivoltine, evidently producing several overlapping broods.

The total rainfall during August was 1.65 inches, whereas the average amount of rainfall is 3.86 inches. Had a normal amount of rainfall occurred in 1964, *Aedes vexans* likely would have maintained a high population through August and into September. *Aedes vexans* is highly important as a pest mosquito in central Indiana.

Aedes trivittatus was distinctly bimodal in occurrence during 1964. The first peak in population occurred the middle of May, the second population peak the first week in July. This species was second in prevalence, contributing approximately 20 percent of specimens taken in biting collections, and approximately 12 percent of light trap collections (Table 1). No larvae were collected in this study, although adult prevalence would indicate that the larvae were plentiful. According to Ross (1947), larvae are infrequently collected in Illinois, and then in small numbers. Development reportedly is rapid (Adbel-Malek, 1948), and timing of larval collections may be an important element in estimating prevalence of larvae in nature.

In Figure 5, the arrow indicates continuity for *Aedes trivittatus*. The first peak was attained at the same time as *Aedes vexans,* then numbers gradually diminished until the third week of June. Evidently rains that occurred the first week in July gave impetus for production of a second generation, which attained its peak during the last week in July. Specimens taken during the second population peak were in excellent condition, appearing as young, unrubbed specimens with intact scale patterns.

Culex pipiens appears to be a late summer and early fall mosquito. Larvae of *Culex pipiens* are found in a wide variety

of situations, chiefly in water with a high organic content. The White River and some of its local tributaries are highly polluted. These streams support mass production of *Culex pipiens*.

There is a slow but steady build-up of population, and in 1964, the population peak was attained about the first week in August. Although no regular collections were carried on in 1964 after the middle of August, trap collections in previous years and general observations over a period of years indicate that there are several overlapping generations which contribute to maintenance of the prevalence of this mosquito throughout August and September. In 1963, light trap collections were made at Site 71 at weekly intervals from September 23 until November 4. *Culex pipiens* made up over 90 percent of these collections. Male specimens of *Culex pipiens* were predominant. The largest collection, made on October 14, 1963, contained 590 identified specimens. Of the 575 *Culex pipiens* in this collection, 558 were males and 17 were females.

Depending upon the weather conditions, male *Culex pipiens* may still be active until the latter part of October or even early November, but evidently females start going into hibernation the latter part of September or in early October. These females are not attracted to light traps, but during the fall season, may be found in abundance in culverts, crawl spaces under houses, storm cellars, and other damp, sheltered, over-wintering sites in proximity to their sites of production.

No adult specimens were taken in biting counts during the study interval in 1964.

Since *Culex pipiens* is produced in polluted streams, created (at least in part) by effluent from septic tanks, and other artificial bodies of water, this population is more independent of rainfall conditions than *Aedes vexans*. Likely, the same general population pattern should prevail each year.

Data shown in Figure 5 are preliminary data. Obviously, no given year would show identical profiles of populations with another year, even if no additional sampling techniques were employed. For accurate quantification, studies should be carried on over a number of years, employing animal traps baited with representative hosts, as well as the conventional sampling methods employed in the present study. However, Figure 5 does provide a rough analysis of the main components of mosquito populations in terms of place and time, as reflected by biting counts and light trapping methods.

DISCUSSION: MIGRATION OF MOSQUITO POPULATIONS. In Hart's paper (1944) mosquito collections are reported from twelve counties in Indiana. Christensen and Harmston (1944) reported collections from seven Indiana counties. Carpenter (1952) reported collections made in 1944 and 1945 from five localities in Indiana (Figure 1).

Except for a possible "corridor" extending southeastward from Lake Michigan, the composite coverage of these three studies should have yielded a good sampling of the mosquito populations of Indiana. However, ten species (previously mentioned in this paper) have been added since 1957, and judging from records in Illinois, there may be at least ten more species occurring in Indiana which are unrecorded at this time.

In cases of this kind, it is a moot question whether this is a reflection of incompleteness of former sampling methods, or whether recent records are indeed evidence of recent migrations. The inadequacy of light trapping alone as a sampling method is axiomatic, so it is entirely possible that several species were overlooked in the earlier studies. On the other hand, most, if not all, of the species collected since 1957 have been reported by various workers as being attracted to light.

FURTHER STUDIES. Extensions of ranges of mosquitoes is a subject mentioned in recent papers by Ross (1964) and by Reeves (1965). This problem appears worthy of further investigation in Indiana. It is hoped that further studies of this nature can be conducted, and if recent state records do in fact reflect recent migrations into the state, some explanation can

then be offered for these extensions of ranges.

Additionally, Indiana offers a challenging area of investigation for mosquito studies involving systematics, biting-feeding habits, and relationships between mosquito ecology and transmission of arboviruses.

ACKNOWLEDGMENTS

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SUMMARY AND CONCLUSIONS

1. Other investigators, in 1944 and 1945, reported a total of 31 species of mosquitoes in Indiana. Six of the seven additional species reported from this state from 1957 to 1964 were collected in Delaware County. Three species, previously unreported from Indiana, were collected in the present study: *Aedes fitchii* (Felt and Young), *Aedes flavescens* (Muller), and *Aedes stimulans* (Walker).

2. In 1964, 4 of the 27 species collected in Delaware County constituted 90 percent of the collections: *Aedes stimulans, Aedes vexans, Aedes trivittatus,* and *Culex pipiens.* Occurrences of peak populations of *Aedes vexans* and *Aedes trivittatus* are related to patterns of precipitation in spring and summer, while peak populations of the other two predominant species are less likely to be influenced by periods and amounts of precipitation during these seasons of the year.

3. *Aedes vexans* is most contributive to the pest mosquito problem, but univoltine and bivoltine *Aedes* species also occur in significant numbers. *Aedes stimulans* is well established in the study area.

4. Bog sites in the study area yielded the greatest diversity in species of mosquitoes.

5. Recent records may indicate recent migrations into the state. Indiana appears to be an extreme in range for several northern species of mosquitoes. Statewide studies may extend the present total of 41 species to include 10 or more additional species which occur in Indiana.

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