Factors Influencing the Species Composition of Mosquito Populations in Indiana[1]

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Abstract

Climate, and natural features such as forests, bodies of water, soils, vegetation and shade are location-dependent factors which influence species composition of mosquito populations in Indiana. Other factors include: urbanization, suburban development, deforestation, drainage, and tillage of soil.

The mosquito fauna of Indiana has both northern and southern climatic elements. Indiana is the northern range limit for certain southern species (e.g. *Psorophora cyaneseens, P. howardii*), and the southern limit for certain northern species (*e.g., Aedes abserratus, A. exerucians*).

Indiana's mosquito fauna is characteristically sylvan, plains species being few and limited in distribution. *Aedes stimulans*, a northern forest mosquito, is well established north of the Wisconsin glacial boundary. South of this boundary it is largely limited to beech-maple tracts in the Southwestern Till Plain.

About 12 of the 50 species of Indiana mosquitoes are produced in permanent water. Included are species of *Mansonia, Anopheles, Culex*, and *Uranotaenia*. Temporary pools in depressions produce both univoltine and multivoltine *Aedes* and *Psorophora*. Recurrent rains during summer disposes continual production of multivoltine members of these two genera.

Some species are directly dependent on certain plants either for production or as sources of carbohydrate. Indirect effects of vegetation include shade and humidity.

Soils underlying depressions used by early spring mosquitoes contained clay loam and were poorly drained. In one instance, soil disturbance appeared to enhance mosquito production. The need for further studies of relationships between soil characteristics and mosquito production is stressed.

Urbanization tends to substitute one set of mosquito problems for another, rather than eliminate all problems. Species diversity decreases, with attendant increase in density of adaptive species. Domestic species (*e.g., Culex pipiens*, the house mosquito) can attain dominance as a result of improper liquid waste and solid waste disposal practices. *Aedes triseriatus, A. vexans, A. sticticus, A. trivittatus* and *Psorophora confinnis* are some of the para-domestic mosquitos which annoy suburban dwellers.

Because of diverse conditions in Indiana, one set of recommendations for mosquito abatement will not suffice for all localities, and control recommendations for a given community will require periodic revision.

Introduction

The species composition of mosquito populations varies from one part of Indiana to another. Presently, 50 species are listed for Indiana. Twenty-seven species were reported from Delaware County (8) and 30 species are listed for Wayne County (J. H. Hart, personal communication).

Some species are limited to one or more of the northernmost tier of counties. Other species are known to occur only in the extreme southern parts of Indiana. Species composition even varies between adjacent counties. Evidently, not one factor (e.g., climate), but a com-

[1] This investigation was supported in part by a grant from the Indiana State Board of Health, funded by PL 89-749, Section 314(d).

plex of factors influences these patterns of distribution. This paper identifies some of the factors responsible for variations in species composition of mosquito populations in Indiana, and makes some predictions, based upon these observations, regarding species composition of mosquito populations in future years. Factors are considered as location-dependent and location-independent.

Location—Dependent Factors

Climate

Members of the genus *Psorophora* generally are considered as southern mosquitoes which develop rapidly in temporary bodies of water following summer rains. In years with cool or dry summers, some of the eight species which represent this genus in Indiana may be absent, at least in the northern part of the state. *Psorophora ferox*, *P. varipes* and *P. horrida* were not found in Delaware County during an intensive survey in 1964 (8). These species were taken in biting collections during the summer of 1969 at one of the sampling sites used in the 1964 survey. Thus, climatic variations from year to year will influence the species make-up of mosquito populations in a given area.

Neither *P. cyanescens* nor *P. howardii* has been reported north of Bartholomew County. From state distribution records (1, 2) it appears that both of these species are rare or absent north of 40° latitude.

Conversely, some northern species attain the southern limit of their ranges in northern Indiana. *Aedes abserratus*, one of the black-legged, univoltine, cold-hardy mosquitoes, had not been reported as occurring south of LaPorte, Lagrange, and Steuben Counties. Nationwide, it has not been reported south of 40° latitude. One of the band-legged *Aedes*—*A. excrucians*—is found in kettles and bogs in northern Indiana, but it fades out in numbers, and its occurrence is infrequent or rare in central Indiana. As in the case of *A. abserratus*, Illinois and Indiana appear to be the southern limit of its range.

The necessity for water in mosquito development is axiomatic. Rise and decline in number of some species is directly dependent upon patterns of precipitation in summer. Production of *Aedes* and *Psorophora* species from forest tracts during August often is prevented—not because of insufficient warmth—but because of insufficient rainfall. Rainfall of three inches or more within a 24-hour period may be required to inundate soil depressions containing eggs, and to provide standing water for a week or more thereafter. With other species, numbers produced in a given year remains about the same, regardless of whether summers are wet or dry. This applies both in Indiana and Wisconsin. (8, 9).

Although other factors undoubtedly play a role, climate probably is the overriding influence in the distribution of sub-tropical *Psorophora* and certain Nearctic *Aedes* in Indiana. Mean daily minimum temperatures and mean daily maximum temperatures vary 10° F or more between northern and southern Indiana (6). This suggests sufficient gradient for differences in species composition in the two areas; such is true with mosquitoes.

Natural Features

Natural features which influence the species make-up of local mosquito populations include forests, bodies of water, soils, and vegetation.

Forests. In northern, and in certain parts of central Indiana, the immature stages of one forest mosquito, *Aedes stimulans*, occur in cattail ponds and roadside ditches, as well as in woodland pools. With some exceptions, the most recent Wisconsin glacial boundary (10) is the southern limit of its range.

A. stimulans was collected south of this boundary in southeastern Indiana in the spring of 1969, but only in relict populations in forested tracts over wet soils. On the other hand, this species was absent in wet-soil areas, which formerly were forested, just north of the Wisconsin glacial line. In such habitats it apparently is displaced with competitive species such as *A. canadensis* or *A. vexans*, which tolerate exposure in unshaded areas. The distribution of *A. stimulans* is discussed further in connection with soils and vegetation.

Aedes triseriatus is another forest mosquito, widely distributed in Indiana. It is commonly known as the treehole mosquito since it utilizes rot holes containing water in stumps, as well as cavities which develop on trunks and limbs and hold water as a result of natural processes.

Stumps need to be in the right stage of decay to hold water. With extensive decay, the stump becomes entirely hollow and no water is retained. This suggests a time span for a stump hole as a larval habitat. Over a 10-year period, a stump hole in Delaware County yielded *Anopheles barberi* and *Culex restuans* as well as *Aedes triseriatus*. After 10 years the cavity rotted through, and no longer held water.

Aedes triseriatus lately has come into prominence because of its implication as a potential vector of California encephalitis. Small forest mammals, such as squirrels, are believed to act as a reservoir for the causative arbovirus. This vector is not limited to forest tracts, however, since immature stages also are found in artificial containers, such as old tires. The negative association between California encephalitis and urban environment may result from limited numbers of reservoir hosts instead of limited numbers of suitable vectors in towns and cities.

Bodies of Water. The simplest classification of bodies of water is permanent or temporary. Permanent water describes a site where water stands all year during most years. Temporary bodies of water contain water for shorter periods.

Contrary to popular belief, the size of the mosquito crop is not directly proportional to the expanse of water. Only about a dozen of Indiana mosquitoes can utilize permanent water as production sites. Such species have adaptations which permit them to complete development in a habitat which is alive with predators. Larvae and pupae of *Mansonia perturbans* attach anal siphons to the subterranean tracheal systems of such aquatic plants as cattails and sedges, and acquire oxygen in this way. They never need to surface except for the brief period required for emergence of the adult.

Steuben County has about 7% of its area in wetlands, much of it in dry marshes, open water, shallow and deep shrub swamps, all in the permanent water category (4). Adult trap collections made in this county in 1969 contained relatively high percentages of *Mansonia perturbans* (42%) and *Anopheles* species (8%).

Larvae of *Anopheles* mosquitoes are commonly found in emergent vegetation and in mats of floating vegetation where fish and other predators do not easily gain access. The resemblance of these larvae to floating sticks may have some protective value. The same general habitat used by *Anopheles* is also used by *Culex* species.

Larvae of *Culex territans*, a rather ubiquitous mosquito which feeds on cold blooded animals, also may be found along with *Uranotaenia sapphirina*, in permanent bodies of water.

Farm ponds seldom serve as production sites for mosquitoes when clean shore lines are maintained, where there is little if any emergent vegetation, and when fish and other predators are present.

Many kinds of depressions—some man-made—hold temporary pools of water which serve as production sites for mosquitoes after spring thaw, snow melt or rains. There may be a predator problem for those which develop slowly. For the most part, mosquitoes which develop in pools and puddles either have a lower temperature threshold for development than their predators, or they simply are geared for more rapid development. The univoltine *Aedes* which develop during early spring while the water is 40-50°F include: *A. abserratus, A. aurifer, A. canadensis, A. cinereus, A. excrucians, A. fitchii, A. flavescens, A. grossbecki, A. stimulans*, and *A. thibaulti*. These are off the water and on the wing before crayfish, predaceous beetles, dragonfly nymphs and other predators become established in the temporary pools and puddles.

Multivoltine *Aedes* and *Psorophora* which undergo rapid development in temporary water impoundments following spring and summer rains include: *A. trivittatus, A. sticticus, A. vexans* and all of the *Psorophora*. A week to 10 days is sufficient for these mosquitoes to complete development, assuming normal summer temperatures. They may utilize the same habitats as the univoltine *Aedes* which developed earlier in the year.

The importance of temporary bodies of water should not be underrated. One woodlot pool in Delaware County was estimated to produce more than 600,000 *Aedes stimulans* (8). Flood plains, such as the Wabash in Vigo County, are notorious for mosquito production. *Aedes vexans* is a prime contributor to this kind of mosquito problem.

Soils. Probably no one factor is more important in mosquito production than soil, yet no factor is more poorly understood. Soil characteristics and numbers and kinds of immature mosquitoes present in the water overlaying these soils were studied in the spring of 1969. Soil samples were taken with a soil auger at the approximate center of the depressions where mosquito collections were made. Soil cores approximately 7½ inches long and 1¼ inches in diameter were transported in plastic bags to the Soil Conservation Office in Muncie for soil descriptions.

TABLE 1. *Soil characteristics of mosquito production sites in Indiana, Spring, 1969.*

County Location	Texture	Organic matter	Drainage	Position and Series	Number and species of immatures collected
Putnam	silty clay loam, high in silt	high	very poor	depressed till plain; possibly lacustrine sediments in upper 10"; Brookston	25 *Aedes vexans*
Shelby	silty clay loam	low	very poor	probably upland till plain; Brookston	6 *Aedes stimulans*, 1 *A. vexans*
Shelby	silty clay loam with sand and gravel pebbles	moderate	poor	probably glacial till plain; probably borderline between Crosby and Brookston	3 *Aedes canadensis*, 3 *A. stimulans*, 2 *A. vexans*
Morgan	silty loam surface; clay loam subsoil	high in subsoil	very poor	probably sandy outwash plain or sandy influenced till plain	Many *Culiseta inornata*
Morgan	silty clay loam and clay loam	low	somewhat poorly drained	probably upland till plain; Brookston	41 *Aedes stimulans*
Morgan	clay loam	moderate	poorly drained	till plain or outwash depression	11 *Aedes vexans*, 11 *Culiseta inornata*
Franklin	silty clay loam	high	very poor	depressed area, probably in upland position; Brookston	7 *A. stimulans*, 10 *A. vexans*
Franklin*	heavy silt loam, less clay and more silt than sample above	very high	very poor	same as above; Brookston	1 *A. strictieus* None
Steuben	organic	high (over 20%)	very poor	bog (peat) probably Carlisle Muck	4 *Aedes abserratus*, 50 *A. canadensis*
Steuben	organic	high (over 20%)	very poor	bog (peat) Edwards or Warner	3 *Aedes canadensis*, 14 *A. flavescens*, 1 *A. stimulans*
Vigo	silty clay loam surface; heavy silty clay loam to light silty clay subsoil	high	very poor	probably a loess capped till plain. High in silt and clay	1 *Aedes stimulans*, 14 *A. vexans*
Vigo	silt loam surface (noticeable sand content) clay loam to sandy clay loam subsoil	moderate	poor	stratified sand and silt outwash plain	8 *A. canadensis*, 20 *A. vexans*
Washington	silty clay surface; silty clay loam subsoil	low	somewhat poorly drained	probably loess capped till plain. Stendal silty clay loam	3 *Aedes aurifer*, 4 *A. canadensis*, 10 *A. vexans*

Soil results are summarized in Table 1. One characteristic shared by all soil samples was poor drainage. With the exception of the samples taken in Steuben County, all soils had a clay component. Amounts of organic matter in the samples were quite variable. In cases where development had passed the larval stage, pupae or adults were collected. With the exception of Steuben County samples, all soil samples were taken from forest soils.

Samples collected in Franklin County are noteworthy. One soil sample was taken in a water-filled depression where no mosquitoes were present; another soil sample was taken in a ditch nearby, where larvae were present. According to the Soil Conservation Service, the ditch sample revealed more evidence of disturbance than the soil taken from the depression. Conceivably more minerals and nutrients were available in the ditch, having been brought to the soil surface as a result of excavation. This same phenomenon was observed in northern Wisconsin where greater density of larvae was observed in a borrow pit adjoining a logging road than in an adjacent swamp.

Aedes flavescens is rare in Indiana (8). Although peat overlaying marl probably is not prerequisite for production of this mosquito, the unusual density of both immatures and adults near Orland, in Steuben County, suggests that *A. flavescens* may be produced over Edwards or Warner Muck in other areas.

Less definite is the association between *A. stimulans* and Brookston soils. These are timber soils formed from fine textured till from recent (Wisconsin) glaciation. South of the Wisconsin glacial boundary *A. stimulans* was found in minority numbers in Clark and Ripley Counties. The associated soil series were Avonburg and Clermont, respectively. These are timber soils formed on old (Illinoian) glacial till.

From Table 1, one could generalize that mosquitoes are likely to be produced in depressions in poorly drained forest soils which have clay loam components. Undoubtedly, some species are tolerant of a wide variety of soils, others less so. More precise information regarding soil characteristics of habitats will have to be obtained before predictions can be made relative to species occurrence. This subject warrants further investigation.

Vegetation. The association of *Wyeomyia smithii* with the pitcher plant, *Sarracenia purpurea*, is an example of direct influence. *W. smithii* is not known to occur in the absence of this pitcher plant. *W. smithii* was reported in LaPorte County in 1964 (8) and subsequently collected in Steuben County. The direct dependence of *Mansonia perturbans* on plants such as cattail, water lily and sedge has been mentioned.

Plants may be of direct benefit to adult mosquitoes as a source of nectar for food. Preliminary observations in Delaware County indicate that *Aedes stimulans* feeds on nectar of *Phlox divaricata* (wild phlox). The occurrence of nectar-yielding plants near its sources of production may influence its distribution.

Aedes stimulans is associated with both oak-hickory and beech-maple climax forests in the northern part of the state but is limited in its occurrence to beech-maple tracts south of the Wisconsin glacial line. *Aedes canadensis* and *A. vexans* usually are dominant in oak-hickory forests on Illinoian drift.

Some of the most influential effects of vegetation on species composition are the indirect effects of shade and humidity. Some mosquitoes are more tolerant of open, well-lighted conditions than others. A given species may seek shade in the southern part of its range, but tolerate unshaded conditions in the northern part of its range. This has been observed with *Aedes aurifer*. Larvae were found under dense shade along the Muscatatuck Flats in Washington County, but also in a peat bog, near button bush, in fairly open water in LaPorte County. *Aedes aurifer* were also collected from very open, unshaded pools in a bog near Tomahawk, Wisconsin.

Culiseta melanura and *Culex territans* larvae were collected from the same pools in Delaware County. *Culex territans* larvae occupied the open portions of the pools. *Culiseta melanura* larvae were found in the darker recesses, close by hollow rotting bases of trees or in densely shaded root holes in the forest floor. However, in northern Wisconsin, *C. melanura* larvae were collected in sphagnum-leatherleaf bogs, quite similar in appearance to habitats utilized by *A. aurifer*.

During warm weather the tolerance for exposure to light is an indication of capacity for rapid development, since lighted pools are also exposed to the warmth of the sun's rays. Several *Psorophora* species and some *Aedes* (especially *A. trivittatus*), which develop in open shallow sunlit pools, are able to complete development before depressions become dry through drainage and evaporation.

Because of their small size and high surface:volume ratio, adult mosquitoes are particularly subject to desiccation. The association of adult mosquitoes and shrubbery is well known. Here again, the effect of vegetation for mosquitoes is an indirect one, through providing more humid conditions for harborage than would be encountered in unshaded areas. In general, Indiana's mosquito fauna reflects its history of a predominant forest vegetation. Plains mosquitoes are infrequent or absent in the state.

Location-Independent Factors

Urbanization

In a strict sense, whether towns eventually become cities may depend upon location, but cities of 50,000 or more occur in all regions of the state. Regardless of location, the most significant feature of urban mosquito problems is their striking similarity. Mosquito problems in these urban communities arise mainly from solid waste and liquid waste.

Litter is solid waste, including artificial receptacles which hold water such as cans, buckets, and old tires. Old tires hold water for surprisingly

long periods, and are utilized as production sources by *Culex pipiens, C. restuans, Aedes triseriatus,* and other species of mosquitoes. Used tires, stockpiled in the open at junk yards and service stations, often serve as production foci for domestic mosquitoes. Urbanization and heavy traffic do not appear to be a deterrent, especially for *C. pipiens.* The implication of this species, the northern house mosquito, in the transmission of St. Louis Encephalitis will be discussed later.

The yellow fever mosquito, *Aedes aegypti,* was reported from Charlestown, in Clark County, in 1941 (3). A visit to Clark County in the spring of 1969 revealed no trace of *A. aegypti.* There was no litter along the creek where early collections were made. Other production sites were plentiful in adjacent areas, and tires were positive for house mosquito larvae. Later in 1969, tires at an open dump in Posey County were checked for *A. aegypti,* but none were collected. Other mosquitoes, chiefly *Culex pipiens,* were present. The availability of artificial containers, particularly in areas within its former range, poses a threat of recurrence of *A. aegypti* within the state.

Not all artificial water-holding receptacles are litter. Bird baths, eave troughs and garden pools also may serve as production sources for domestic mosquitoes. These tend to be less important than litter receptacles, and more residential than commercial.

The discharge of household sewage into streams is a common practice in towns and cities in the midwest. Often, the water in these streams moves slowly or tends to stagnate. Organic enrichment and stagnation provide conditions which are ideal for production of *Culex pipiens.* Heavy house mosquito production, in proximity to concentrations of both human and bird populations are the basic ingredients for epidemics of St. Louis encephalitis. The isolation of St. Louis encephalitis virus from *Culex pipiens* in Evansville and Boonville in 1964 was reported by Newhouse and Siverly (5).

Water polluted by human sewage is not the only medium created by urbanization and used by domestic mosquitoes. Liquid waste from meat packing plants may be a potent source of mosquitoes, whether run into standing ponds, lagoons, or other bodies of water.

Obviously, the solution to these mosquito problems created by urbanization is through sanitation programs and adequate waste disposal systems. My purpose is not to discuss how this can be done, but to show that species composition of mosquito populations does change with industrialization, urbanization, and concentrations of human population.

Suburban development, and the tendency for families to live in or near wooded tracts has intensified certain mosquito problems. Such species as *Aedes vexans, A. trivittatus, A. sticticus, Psorophora confinnis* and *Anopheles punctipennis*—once regarded as country mosquitoes—now may also be regarded as para-domestic, coming onto lawns, porches, and even inside dwellings to obtain blood meals. Residents inadvertently aggravate this situation by watering lawns and providing favorable condi-

tions for mosquito harborage in their lush, ornamental shrubs. Residents who are subjected to this kind of mosquito annoyance often strongly assert there is no standing water in their entire neighborhood. Usually this is not the case. On the other hand, there is insufficient information on flight range and dispersal habits of many para-domestic species. Until such evidence is obtained, one should not rule out the possibility that such mosquitoes might have travelled several miles from production sites.

Agricultural Practices

Agricultural practices, also, can alter species composition. Draining and deforestation are examples.

Decatur County offers good examples of the effects of drainage on mosquito production. Much of the land in this county is wet soil, and conceivably was well infested with mosquitoes when it was in native forest. Now, only remnants of forest remain, mostly as drained woodlots. In some cases, the drainage leads into farm ponds. Farms are well tiled and crop production is high. The few depressions found positive for mosquito larvae in these wooded tracts in 1969 were producing *Aedes vexans* and *A. canadensis*. These mosquitoes develop more rapidly, and in more temporary type pools than *A. stimulans*, which probably was present, if not dominant, in the native forests of Decatur County.

Shelby County, also, shows effects of drainage and deforestation. Much of the land is in cultivation and few forest tracts remain. *Aedes stimulans* was collected in Meltzer Woods in association with *A. vexans* and *A. canadensis*, and as a single species in a woodlot in the southern part of the county. Mosquitoes in the rural parts of this county appear to have been largely eliminated through deforestation and draining. *Psorophora* and summer *Aedes* may be produced in sites where drainage is blocked. Thus, both Decatur and Shelby Counties afford examples of alteration of species composition through agricultural practices.

Discussion

It is apparent that species composition of mosquito populations in any given locality in Indiana is influenced by a complex of many factors. Superimposed upon such location-dependent factors as climate, natural features and soil are the effects of urbanization and agricultural practices.

A characteristic pattern of species succession in rural areas is as follows: a rather explosive peak of univoltine *Aedes* occurs in late April or early May. This is shortly followed by a succession of overlapping peaks of multivoltine *Aedes* and *Psorophora*, the occurrences of these peaks varying from year to year depending upon patterns of precipitation. These peaks are concurrent with steady but sustained populations of such permanent water breeders as *Mansonia* and *Anopheles*.

This pattern is likely to change quite markedly with urbanization. The univoltine *Aedes* are drastically reduced or entirely eliminated. Some of the multivoltine, para-domestic species are able to survive, especially those which are versatile in utilizing such sites as blocked drainage ditches or artificial containers. There is likely to be a domestic mosquito problem unless municipal ordinances requiring solid waste and liquid waste disposal keep apace with the increase in urban populations.

Thus, a result of severe environmental disturbance associated with construction of streets, highways, shopping centers, schools, housing developments, factories and other trappings of urbanization is reduction in the number of species and increase in the numbers of members of a few species. The effect is similar to that observed in streams. As pollution increases, diversity of species decreases until through selection all that remain are those which tolerate pollution. Representatives of these few species are in much greater abundance than previously.

Can any predictions be made regarding the picture as a whole for Indiana? If current trends continue toward movement of human populations from rural to urban areas, and increased use of land for crop production, one might predict that, for mosquitoes: 1) the number of species will tend to decrease; 2) that reduction will most likely occur in numbers, if not in species of sylvan mosquitoes and permanent water breeders; 3) the numbers of specimens of domestic mosquitoes likely will increase, with attendant likelihood of transmission of diseases commonly associated with domestic mosquitoes; 4) that practices which preserve or maintain the undisturbed environment will tend to dampen the foregoing effects.

The day is rapidly approaching when communities in Indiana will want organized mosquito control. Oddly enough, the recognition of this need is contemporary with increasing sensitivity to the use of pesticides. It should be recognized that any method of control—especially such a sophisticated method as radio-sterilized male techniques, or chromosomal incompatibility, or biological control—can only succeed in a given locality if species composition in that particular locality is known and at least partly understood. The factors mentioned, and undoubtedly others, are worthy of studies in depth.

Acknowledgments

Thanks are extended to A. A. Lindsey, H. P. Ulrich and A. L. Zachary of Purdue University for information received. Also, appreciation is expressed to Keith Huffman and John Hart of the Soil Conservation Service for assistance and suggestions.

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