SEASONAL ABUNDANCE OF MOSQUITOES IN SOUTHEASTERN MASSACHUSETTS[1]

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One of the most important aspects of an encephalitis surveillance program is information about the distribution and seasonal abundance of mosquitoes. Since 1956 the Encephalitis Field Station has been collecting mosquitoes in order to measure mosquito populations systematically and to correlate the variations of these populations to eastern encephalitis (EE) and western encephalitis (WE) activity within southeastern Massachusetts. Hayes (1961) has reported on the mosquito population in the study areas from 1957 to 1960. He reported the population indices for *Aedes, Culex,* and *Culiseta,* but not for individual species.

This paper reports (1) the seasonal distribution of selected mosquito types in southeastern Massachusetts based upon 6-year monthly averages, (2) the yearly variations of annual populations of given mosquito species, and (3) the relationships between the annual amounts of precipitation and the annual population indices of the various types of mosquitoes.

MATERIALS AND METHODS. The seasonal range of selected species of mosquitoes was obtained from mosquito collection records for the 10-year period from 1956 through 1965. The mosquitoes were collected by New Jersey and CDC miniature light traps, shed traps, wood and lard-can bait traps, natural and artificial shelter collections, sweep nets, and biting collections. Most of the mosquitoes were collected in Bristol and Plymouth Counties although some were taken from elsewhere in the state.

The monthly and annual mosquito population indices were calculated by determining the average number of female mosquitoes collected per trap night each month throughout the period June through October during the 6-year period from 1960 through 1965. These population indices were from collections made at two study sites in Raynham (Bristol County), Massachusetts. The first site was in a 658 acre, white cedar and red maple freshwater swamp. The second site was in a rural residential area at the edge of a small open field and near a wooded area comprised of black oak, red maple, and white pine. At each site a New Jersey light trap and a shed trap, in conjunction with a sentinel chicken flock (Rainey *et al.,* 1962), were operated simultaneously. These traps usually were operated two nights per week during the mosquito season.

The mosquito population data obtained were analyzed statistically to determine correlation between the observed total annual count of a mosquito species and total precipitation from April through June and from total precipitation from April through September. The regression equation which was used was: $Y_1 = aY^b_{i-1}P^c_i$, where Y_i=total count for current year; Y_{i-1}=total count for previous year; P_i=precipitation in inches; and a, b, and c are constants determined from the data. Correlation between the annual number of female mosquitoes of a given

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species collected and the amount of annual rainfall was considered to be significant at the 5 percent level if the coefficient of correlation equaled or exceeded 0.805 using three degrees of freedom.

The climatological data utilized were taken from the records of the United States Weather Bureau. They were obtained at the Taunton Water Works Station, which is located approximately two miles from the study sites.

The mosquitoes were grouped for the analysis of their seasonal distribution according to their life history type, as described by Pratt (1959). Species of the "Northern *Aedes* Type" overwinter as eggs, lay their eggs on moist earth, and produce only one generation a year. The species belonging to this type in southeastern Massachusetts include *Aedes abserratus, A. aurifer, A. fitchii, A. excrucians, A. canadensis, A. cinereus,* and *Culiseta morsitans.*

The "Temporary pool *Aedes* Type" mosquitoes are similar to the preceding in that they overwinter as eggs, but dissimilar in producing several generations each year. This type is divided into several groups based upon the larval habitat. These include groups in temporary freshwater pools (*A. vexans*), in salt or brackish water (*A. sollicitans* and *A. cantator*), and in tree-holes or artificial containers (*A. triseriatus*).

Species belonging to the *"Culex pipiens* Type" overwinter as adults, lay eggs on a water surface, and produce several generations each year. Adults may therefore be collected throughout the year. In southeastern Massachusetts, they include *C. pipiens, C. restuans, C. salinarius,* and *Uranotaenia sapphirina.*

The *"Culiseta impatiens* Type" overwinter as inseminated adult females, lay eggs on a water surface, but produce only one generation a year. *Culex territans* and *Culiseta minnesotae* are the only mosquitoes of this type collected regularly in southeastern Massachusetts.

The *"Mansonia perturbans* Type" overwinter as larvae attached to the roots of certain aquatic plants, lay eggs on the underside of leaves, and produce one or more broods each year. As the name implies, *M. perturbans* is the species concerned.

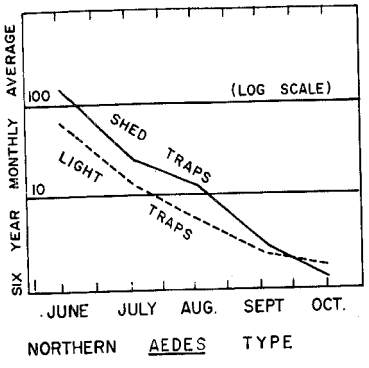
The *"Culiseta melanura* Type" pass the winter as larvae buried in the mud, lay eggs on the water, and produce several generations per year. This type also is represented by the single species in Massachusetts.

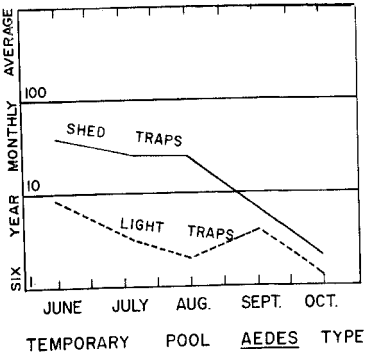
SEASONAL DISTRIBUTION. The seasonal distribution of the six mosquito types was determined upon the basis of mosquito collection records obtained during the years 1956 through 1965. These average monthly shed trap and light trap indices during the period June through October are illustrated in Figure 1.

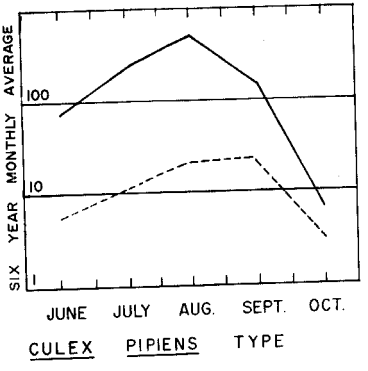
The seasonal distribution of the "Northern *Aedes* Type" adult mosquitoes was observed to begin with the appearance of *A. abserratus* early in spring, usually beginning in April. The remaining *Aedes* species usually appear in May, but *C. morsitans* first appear in June. The average monthly population index for the six mosquito species comprising this life history type attained its peak in both light trap and shed trap collections during June. *A. abserratus* adults were not collected after July, the other *Aedes* species were rarely collected after August; whereas, *C. morsitans* occasionally was collected in October.

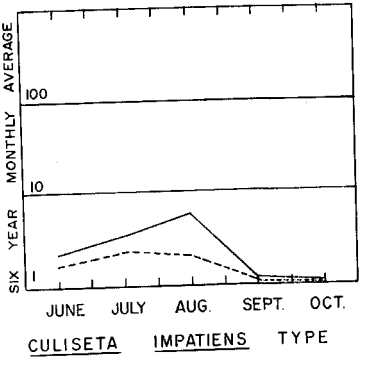
The "Temporary pool *Aedes Type"* earliest species were *A. cantator* and *A. sollicitans* which appeared in May. The other species were not collected until June. The peak population indices obtained for this life history type from both light trap and shed trap collections were during June. A bimodal curve was obtained from the light trap collections (Fig. 1) due to a population index peak attained in September 1961 by *A. vexans.* The temporary pool *Aedes* were obtained in small numbers as late as October.

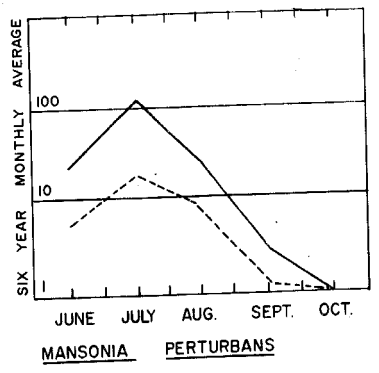
The *"Culex pipiens* Type" included three species of *Culex,* and these may be collected in traps from May through No-











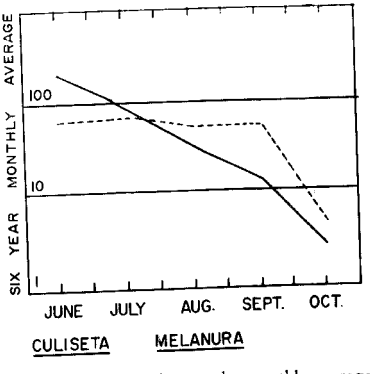


FIG. 1.—Seasonal distribution for mosquitoes of six life history types based upon the monthly average of female specimens collected per trap night in light traps and shed traps in Taunton, Massachusetts, from 1960 through 1965. The scale used is semi-logarithmic.

vember. Since these mosquitoes overwinter as adults, they may be collected from natural resting places throughout the year. The seasonal distribution for mosquitoes within this life history type followed the pattern of a population build-up during the summer months, reaching a peak in August. The adults were collected in the traps until November. There was no collection of *U. sapphirina* from shed traps that utilize chickens as an attractant.

The *"Culiseta impatiens* Type" was represented by two species and neither is abundant in southeastern Massachusetts. *Culiseta minnesotae* was collected only in shed traps and *Culex territans* was obtained only from light trap collections. Both species were initially trapped in June, but could be obtained earlier by aspirator collection of the overwintering adults from natural resting places. The shed trap population index for this life history type was highest in August; whereas, the light trap index peaked in July. *C. minnesotae* was not trapped after September, but *C. territans* was trapped infrequently during October.

Mansonia perturbans initially appeared as adults during June, reached a population peak during July, and were not trapped after September.

Culiseta melanura appeared as early as May and were trapped from June through October. The shed trap average monthly collections declined each month throughout the mosquito season each year except 1963 when they peaked in August. The *C. melanura* light trap population peak indices varied greatly, and during the 6-year period these peaks occurred two times each during July and September and once each during the months of June and August. Neither the light trap population indices nor the shed trap indices were indicative of a bimodal population curve for this species during any of the six years.

ANNUAL PRECIPITATION AND SPECIES PREVALENCE. The long-term average annual precipitation for Taunton, Massachusetts was 43.98 inches at the end of 1965. There was a significant drop in total annual rainfall over the 6-year period. In each of the first three years of this study the annual precipitation was above the average, and in the last three years it was below average (Fig. 2).

The annual population indices obtained in light trap and shed trap collections also are given in Figure 2. The shed trap and light trap collections for all species combined showed a statistically significant positive correlation, at the 5 percent level, with the amount of precipitation for total annual rainfall.

The Northern *Aedes* Type mosquitoes are the first six species listed in the figure. During two of the three years with above normal amounts of rainfall, the *A. abserratus* light trap and shed trap indices were higher than during the years with subnormal amounts of precipitation. Shed trap populations for *A. canadensis, A. excrucians,* and *A. cinereus* also were highest two of the three years with above normal amounts of rainfall.

Aedes abserratus, A. canadensis, and *C. morsitans* were the only Northern *Aedes* Type species collected in sufficient numbers to permit analysis by use of the regression equation. The correlation was significant at the 5 percent level only for the *A. canadensis* collected in light traps.

Of the four temporary pool *Aedes* found in the study areas, only *A. cantator* and *A. vexans* were obtained in sufficient numbers for inclusion in Figure 2. No statistically significant positive correlation at the 5 percent level was shown between the rainfall data and either the light trap or shed trap collection indices for either of these species. The annual light trap population indices for both species were highest during two of the three years with above normal amounts of precipitation, and the shed trap collections showed similar relationships.

The *C. pipiens* Type light trap indices were higher in two of the three years with above normal rainfall. The shed trap index for the *Culex* species also was high-

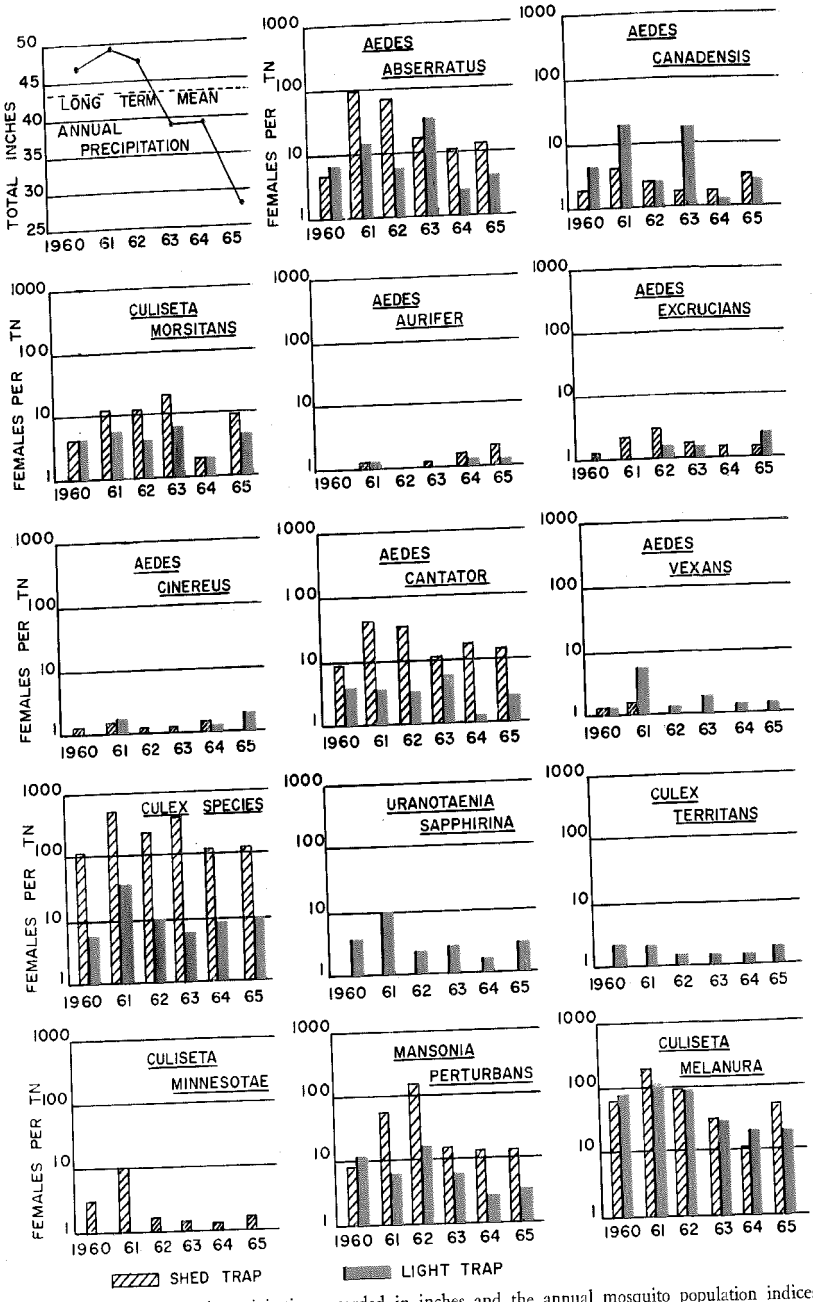


FIG. 2.—Annual total precipitation recorded in inches and the annual mosquito population indices based upon the average number of female specimens collected per trap night in light traps and shed traps in Taunton, Massachusetts, from 1960 through 1965. The scale is semi-logarithmic.

est during two of the three years with above normal precipitation. No *U. sapphirina* was obtained in shed trap collections. No significant statistical correlation between precipitation and population indices was detected for either *C. pipiens* Type species.

The collections of the *C. impatiens* Type mosquito were small. The light trap indices obtained for *C. territans* and the shed trap indices obtained for *C. minnesotae* suggested a direct relationship between rainfall and mosquito abundance each year except 1965.

The other two types of mosquito life histories were represented by species that overwinter as larvae. Both *M. perturbans* and *C. melanura* shed trap and light trap indices were indicative of a relationship between excessive amounts of rainfall and high mosquito populations. Statistically significant positive correlations were found between precipitation and the *M. perturbans* shed trap collection indices and also between precipitation and the *C. melanura* light trap indices.

DISCUSSION. Seasonal abundance of mosquitoes varies from year to year, and these studies adequately demonstrated this fact. Perhaps the largest mosquito population during the 6-year period from 1960 through 1965 occurred during 1961. That year also was the one with the greatest annual precipitation.

The mosquitoes belonging to the Northern *Aedes* Type, which overwinter as eggs and are univoltine, primarily breed in water which is from melting snow deposited during the preceding winter. Therefore, it is not surprising that the relationships between the precipitation accumulated one calendar year and the mosquito population indices for that year are not consistently positive for these species.

The temporary pool *Aedes* mosquitoes light trap indices were indicative of these species' dependence upon rainfall for their breeding habitats, and during the period of the study rainfall was the principal water source for these habitats. *Aedes cantator* is known to breed in brackish water along the margins of the Taunton River, which is affected by tidal action. The study sites are within a few miles of these *A. cantator* breeding areas, and it is possible that some of this species collected at the study sites migrated in from the river margin breeding areas.

The remaining four mosquito life history types were composed of mosquito species that breed in permanent freshwater swamp habitats in southeastern Massachusetts. These population indices generally indicated these species' dependence upon rainfall. Since the water sources were essentially permanent, the variations between the annual mosquito population indices were generally rather small. In Figure 2 it can be observed that the light trap and shed trap indices for these mosquitoes are generally within a ten-fold range on the semilog scale.

Statistical calculations for correlation indices between the amounts of total annual rainfall and the observed mosquito counts were possible for *Aedes abserratus, A. canadensis, A cantator* (shed traps only), *Culex* species, *Culiseta morsitans, C. melanura,* and *Mansonia perturbans.* Only three correlations (*A. canadensis* and *C. melanura* light trap collections and *M. perturbans* shed trap collections) were found to be positive at the 5 percent level of probability. A correlation coefficient of 0.805, or greater, was required for positive correlation at the 5 percent level, and each of the species analyzed had at least either a light trap or a shed trap coefficient of 0.7, or greater. Therefore, it is strongly suspected that more statistically significant observations would have resulted if the study had continued over a longer period of time. The 6-year period imposed severe limitations with respect to the number of degrees of freedom available for statistical analysis.

A relationship between weather conditions and outbreaks of EE in Massachusetts previously was reported by Hayes and Hess (1964). They pointed out that unusually heavy rainfall during the autumn and the following summer was con-

ducive to a build-up of the population of *C. melanura,* the enzootic vector species, and preceded the three major outbreaks of EE in Massachusetts. In the two study sites used in this study both EE and WE viruses have been obtained from mosquitoes and wild birds. EE virus has been isolated from July 27 (1960) to October 19 (1965), and WE virus has been detected from July 24 (1962) to October 14 (1964). Since the years included in this study were non-epidemic years, the associations between mosquito seasonal distribution, mosquito populations, and virus activity may be indicative of which species could serve as enzootic vectors.

Most of the Northern *Aedes* Type mosquitoes reach a peak of abundance too early in the season to be considered as important virus vectors. *A. abserratus, A. excrucians, A. cinereus* and *A. aurifer* are all but absent from the mosquito populations by late summer. However, *A. canadensis* and *C. morsitans* reach their population peaks later and remain in sufficiently high numbers to become possible vectors. WE virus was first isolated from *A. canadensis* collected from the areas included in this study (Hayes *et al.,* 1961).

The temporary pool *Aedes* mosquitoes remain throughout the season of greatest virus activity. The virus of EE has been isolated from *A. vexans* in Connecticut (Wallis *et al.,* 1960) and from *Aedes* spp. (mainly *A. sollicitans*) in New Jersey (Hayes *et al.,* 1962).

C. territans, C. minnesotae, and *U. sapphirina* remain in relatively stable populations during this 3-month virus period, but their role as avian vectors is doubtful because of their feeding habits.

The *Culex pipiens* Type species may be regarded as possible enzootic vectors based on their seasonal prevalence. Furthermore, EE virus was recovered from *C. restuans* (Hayes *et al.,* 1960) and from *C. salinarius* (Chamberlain *et al.,* 1958) in New Jersey; WE virus also has been isolated from *C. pipiens* in Washington (Hammon *et al.,* 1945) and from *C. restuans* in Canada (Norris, 1946).

M. perturbans is another possible vector and is prevalent in late summer and early fall, especially during years with average or above average precipitation. The initial EE virus isolation from a naturally infected mosquito was obtained from this species in Georgia by Howitt *et al.* (1949).

C. melanura probably is the most important vector of EE and WE in the avian transmission cycle. It reaches its highest abundance late in the season and this correlates well with virus recoveries within the study area. Both EE virus and WE virus have been recovered from this species (Chamberlain *et al.,* 1951; Hayes *et al.,* 1961), including 41 isolations of WE virus from *C. melanura* collected from the areas included in this study.

SUMMARY. A study of the mosquito collection records obtained during the 10-year period from 1956 through 1965 indicated that the mosquito breeding season extended from May through October in southeastern Massachusetts. A seasonal distribution of mosquitoes representing six types of mosquito life histories was made on the basis of the average monthly mosquito collections obtained in light traps and shed traps at two study sites near Taunton, Massachusetts. The seasonal distribution for the two *Aedes* life history types and the *C. melanura* type consisted of an early summer population peak followed by a gradual decline. The two life history types that overwintered as adult mosquitoes generally had a population build-up from June that peaked in August and declined in September and October. The *M. perturbans* type peaked in July and thereafter steadily declined. The annual mosquito population indices obtained indicated that large amounts of annual rainfall generally were associated with large mosquito populations; however, there were exceptions, especially among the *Aedes* mosquitoes. The seasonal distributions and the population indices were compared to the periods of

known EE and WE virus activity in the study sites and were discussed with respect to the potential role of the various species as virus vectors.

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References Cited

CHAMBERLAIN, R. W., RUBIN, H., KISSLING, R. E. and EIDSON, M. E. 1951. Recovery of virus of eastern equine encephalomyelitis from a mosquito *Culiseta melanura* (Coquillett). Proc. Soc. Expt. Biol. & Med. 77:396–397.

CHAMBERLAIN, R. W., SUDIA, W. D., BURGUTIS, P. P. and BOQUE, M. D. 1958. Recent isolations of arthropod-borne viruses from mosquitoes in eastern United States. Mosq. News 18(4):305–308.

HAMMON, W. M., REEVES, W. C., BENNER, S. F. and BROOKMAN, B. 1945. Human encephalitis in the Yakima Valley, Washington, 1942, with 49 virus isolations (western and St. Louis types) from mosquitoes. J.A.M.A. 128:1133–1139.

HAYES, R. O., LAMOTTE, L. C., WHITE, L. A. and BEADLE, L. D. 1960. Isolations of eastern encephalitis virus from the mosquito *Culex restuans* collected in New Jersey during 1959. Mosq. News, 20:190.

HAYES, R. O. 1961. Studies on eastern encephalitis in Massachusetts during 1960. Proc. N. J. Mosq. Exterm. Assoc. 48:59–62.

HAYES, R. O., DANIELS, J. B. and MACCREADY, R. A. 1961. Western encephalitis virus in Massachusetts. Proc. Soc. Expt. Biol. & Med. 108:805–808.

HAYES, R. O., BEADLE, L. D., HESS, A. D., SUSSMAN, O. and BONESE, M. J. 1962. Entomological aspects of the 1959 outbreak of eastern encephalitis in New Jersey. Amer. J. Trop. Med. & Hyg., 11:115–121.

HAYES, R. O. and HESS, A. D. 1964. Climatological conditions associated with outbreaks of eastern encephalitis. Amer. J. Trop. Med. & Hyg., 13:851–855.

HOWITT, B. F., DODGE, H. R., BISHOP, L. K. and GORRIE, R. H. 1949. Recovery of the virus of eastern equine encephalomyelitis from mosquitoes (*Mansonia perturbans*) collected in Georgia. Science. 110:141–142.

NORRIS, M. 1946. Recovery of a strain of western equine encephalitis virus from *Culex restuans* (Theobald) (Diptera: Culicidae). Canad. J. Res., Sect. E. 24:63–70.

PRATT, H. D. 1959. A new classification of the life histories of North American mosquitoes. Proc. N. J. Mosq. Exterm. Assoc. 46:148–152.

RAINEY, M. B., WARREN, G. V., HESS, A. D. and BLACKMORE, J. S. 1962. A sentinel chicken shed and mosquito trap for use in encephalitis field studies. Mosq. News 22:337–342.

WALLIS, R. C., TAYLOR, R. M. and HENDERSON, J. R. 1960. Isolation of eastern equine encephalomyelitis virus from *Aedes vexans* in Connecticut. Proc. Soc. Expt. Biol. & Med., 103:442–444.