OBSERVATIONS ON THE SPATIAL DISTRIBUTION OF MOSQUITOES IN SOUTHWESTERN GEORGIA

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INTRODUCTION. The disease-transmitting potential of mosquitoes is evaluated in part from knowledge of their relative susceptibility to infection, and, in part from knowledge of their association with infected and susceptible hosts. Recent studies have shown that many of the mosquitoes which occur in southwestern Georgia are susceptible to viral infections, particularly the encephalitides (Chamberlain *et al.*, 1954). Further investigations probably will reveal that additional species may be involved. The ecology of most of these potential vectors is incompletely known, particularly their feeding habits, resting places, flight ranges, and diurnal activity.

Studies initiated during 1952 in Baker County, southwestern Georgia, were designed to furnish some of this ecological information on local species (Platt, 1955; Platt *et al.*, 1957; Love and Smith, 1957). Of primary concern in these studies was the development of methods of sampling mosquito populations that would permit analyses of seasonal, daily or hourly population fluctuations in terms of climatic or environmental factors. The present paper reports observations on spatial distribution of mosquitoes made as a preliminary to study on the microenvironment of adult mosquitoes.

The vertical distribution of mosquitoes has been studied previously in this country by MacCreary (1941), who made light-trap collections at ground level and 100 feet above the ground; by Meyers (1959), and Blakeslee *et al.* (1959), who made light-trap collections at various elevations; by Gjullin *et al.* (1950), who exposed human bait in the tree canopy in the lower Columbia River Valley; and by Snow (1955), who used human bait on the ground and at 30-ft. elevation in a forest area, and at ground level and 75-ft. elevation at the edge of the forest at Reelfoot Lake, Tennessee.

MATERIALS AND METHODS. Collections during 3-hour intervals. All mosquitoes were collected with New Jersey type light traps equipped with 25-watt bulbs. These traps were operated at 6-, 25-, and 40-foot elevations on a tower in an oak hammock (Fig. 1) and at 6- and 25-foot elevations on a tree stripped of foliage in an adjacent open field (Fig. 2). Simultaneous collections were made at these locations for consecutive 3-hour periods at 6–9 p.m., 9–12 p.m., 12–3 a.m., and 3–6 a.m. from one to three times a week for 12 months.

Analyses consisted of comparisons of catches from each elevation and each period of the night. In a period when any of the 5 traps failed to operate properly, all of the data for that particular period were discarded. As a result, the numbers of observations available for the various periods were not equal. When the intervals were compared, the data were not limited to those nights when all 5 traps were operated successfully in all 4 periods. Instead, the intervals were compared with each other, two at a time, and all the simultaneous observations were employed. Consequently, for each trap during each period, an average number of mosquitoes of each species was calculated three times. Since the averages differed very little, the sum of the three (for each species in each trap during each period) was the basic figure used as the index of mosquito activity (Table 1). Since the data used were necessarily obtained at all elevations on the

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same nights, the indices calculated for the various elevations may be compared directly.

Collections during 6- and 12-hour intervals. Additional collections were made in an effort to determine the reliability of light-trap collections as indicators of mosquito activity for successive periods through the night. Five traps placed in the habitats and at elevations previously described were operated 3 nights a week for 12 weeks as follows: One of the nights from 6 p.m.

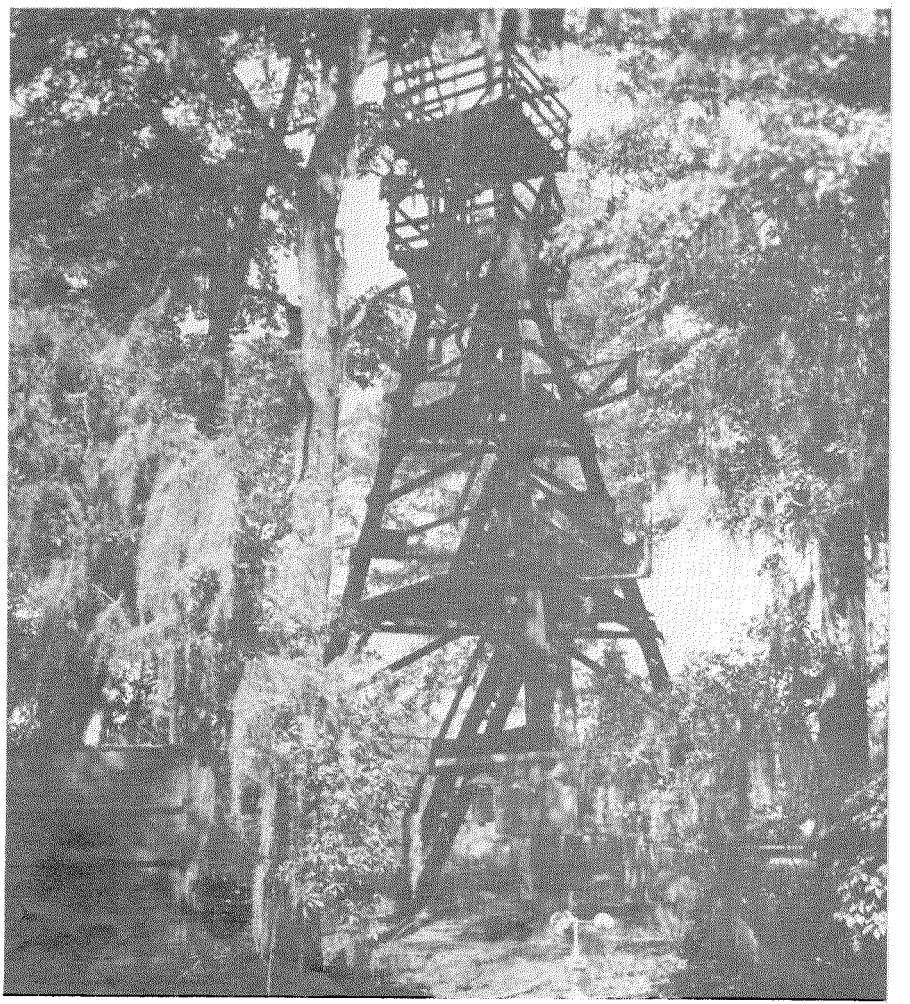
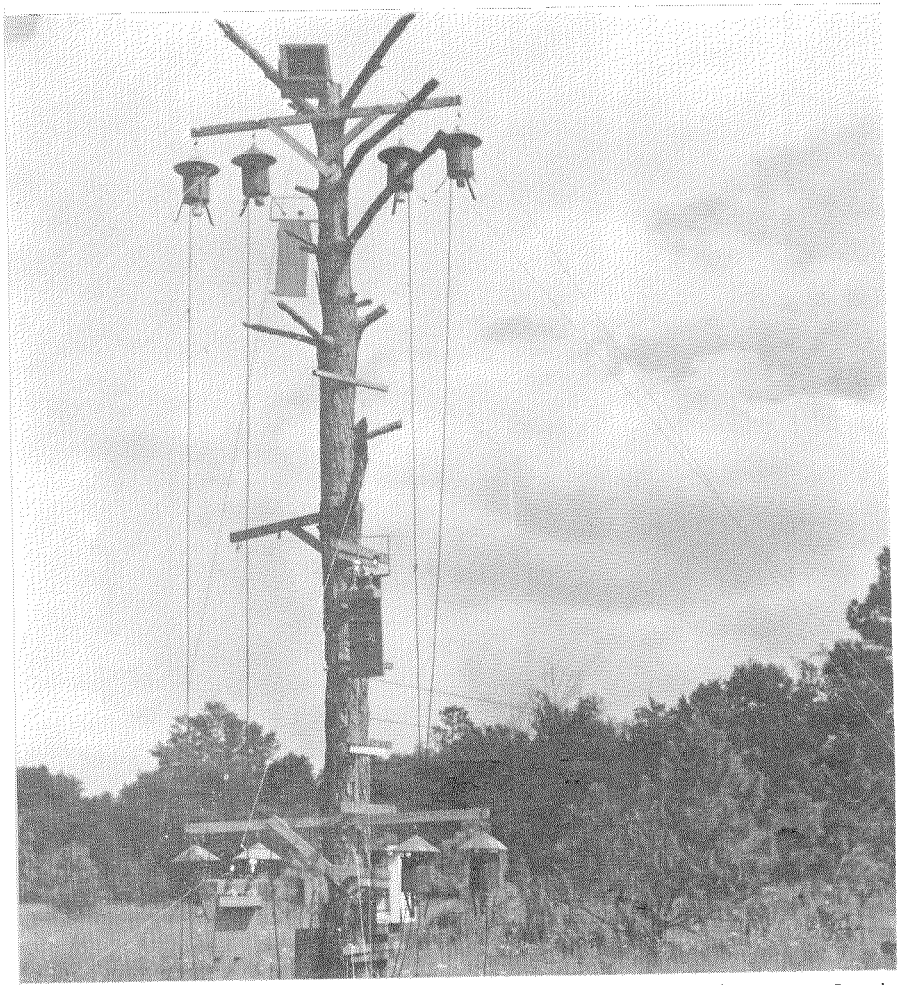


FIG. 1.—Oak hammock and tower from which mosquitoes were collected, Baker County, Georgia.

midnight, one from midnight to 6 m., and one from 6 p.m. to 6 a.m. The me schedule was randomized so that the aps were operated in a different order ach week. The total number of each ecies collected before midnight was compared with those taken after midnight, and the sum of these compared with the total collected during the entire night.

RESULTS. Collections during 3-hour intervals. The indices calculated for each elevation by species of mosquitoes, location of traps, and time intervals are shown in Table 1. The totals on the horizontal



IG. 2.—Open field and defoliated tree from which mosquitoes were collected, Baker County, Georgia.

TABLE 1.—Indices of mosquito activity showing relation to time of night, elevation, and habitat as indicated by light trap collections. See pp. 15, 17 for explanation of calculations.

Species	Habitat	Elevation (in feet)	Period				
			6–9 p.m.	9–12 p.m.	12–3 a.m.	3–6 a.m.	12 hours from 6 p.m.–6 a.m.
Aedes atlanticus	F	6	0.0	0.0	0.0	0.0	0.0
	F	25	0.0	0.0	0.0	0.0	0.0
	W	6	0.5	1.2	0.9	0.0	2.6
	W	25	0.0	0.8	0.0	0.9	1.7
	W	40	0.0	1.2	1.7	0.0	2.9
	Total	..	0.5	3.2	2.6	0.9	...
Aedes mitchellae	F	6	35.6	122.4	17.0	44.5	219.5
	F	25	21.3	51.0	29.4	39.0	140.7
	W	6	4.5	12.4	7.8	11.0	35.7
	W	25	11.6	13.0	10.7	14.9	50.2
	W	40	22.1	38.3	23.2	57.9	141.5
	Total	..	95.1	237.1	88.1	167.3	.....
Aedes vexans	F	6	35.7	61.2	18.8	18.3	134.0
	F	25	71.2	73.5	41.7	22.7	209.1
	W	6	42.7	29.8	26.8	21.6	120.9
	W	25	103.2	79.9	30.5	37.5	251.1
	W	40	237.9	238.0	101.9	209.1	786.9
	Total	..	490.7	482.4	219.7	309.2	.....
Anopheles crucians	F	6	6.9	18.7	12.3	15.4	53.3
	F	25	5.1	6.6	8.5	3.0	22.6
	W	6	58.7	72.8	33.3	39.9	204.7
	W	25	22.6	30.5	18.3	10.9	82.3
	W	40	25.4	46.7	20.9	19.4	112.4
	Total	..	118.7	174.7	93.3	88.6	.....
Anopheles quadrimaculatus	F	6	0.9	1.5	2.1	1.0	5.5
	F	25	0.3	0.6	0.5	0.5	1.9
	W	6	3.1	2.3	1.8	1.5	8.7
	W	25	1.2	1.4	0.6	0.6	3.8
	W	40	0.7	1.9	0.4	1.0	4.0
	Total	..	6.2	7.7	5.4	4.6	.....
Culex restuans	F	6	2.0	1.2	3.7	1.5	8.4
	F	25	0.8	0.3	2.9	1.4	5.4
	W	6	2.6	3.8	2.3	1.9	10.6
	W	25	3.0	2.8	1.6	1.8	9.2
	W	40	7.0	12.7	4.9	8.3	32.9
	Total	..	15.4	20.8	15.4	14.9	.....
Culex (Melanoconion) sp.	F	6	*	*	*	*	*
	F	25	*	*	*	*	*
	W	6	78.0	34.4	11.0	7.4	130.8
	W	25	26.7	51.2	14.9	17.3	110.1
	W	40	57.3	79.5	27.9	23.7	188.4
	Total	..	162.0	165.1	53.8	48.4	.....

F—open field habitat.
W—woodland habitat.
*—Species taken in small numbers.

TABLE 1.—(continued)

Species	Habitat	Elevation (in feet)	Period 6–9 p.m.	9–12 p.m.	12–3 a.m.	3–6 a.m.	12 hours from 6 p.m.–6 a.m.
uliseta inornata	F	6	1.3	1.6	2.2	1.0	6.1
	F	25	0.0	0.0	1.3	1.6	2.9
	W	6	0.8	0.9	0.6	0.7	3.0
	W	25	0.3	0.0	0.0	0.0	0.3
	W	40	0.5	2.5	0.0	2.8	5.8
	Total	..	2.9	5.0	4.1	6.1	.....
uliseta melanura	F	6	0.0	0.0	0.0	0.0	0.0
	F	25	0.0	0.0	0.0	0.0	0.0
	W	6	3.9	5.4	7.8	2.0	19.1
	W	25	2.4	1.1	0.8	1.8	6.1
	W	40	1.9	2.9	1.3	2.6	8.7
	Total	..	8.2	9.4	9.9	6.4	.....
orophora confinnis	F	6	1.5	1.5	1.8	0.9	5.7
	F	25	0.9	1.5	0.3	0.3	3.0
	W	6	0.2	0.5	1.3	0.0	2.0
	W	25	1.2	0.3	0.4	0.0	1.9
	W	40	3.0	1.1	1.3	0.0	5.4
	Total	..	4.1	4.9	5.1	1.2	.....
anotaenia sapphirina	F	6	4.2 *	27.0 *	15.0 *	18.2 *	64.4 *
	F	25					
	W	6	140.5	144.1	72.0	18.7	375.3
	W	25	103.4	133.4	58.0	16.4	311.2
	W	40	52.9	132.7	31.2	17.2	234.0
	Total	..	301.0	487.2	176.2	70.5	.....

F—open field habitat.
W—woodland habitat.
*—Species taken in small numbers.

ows for each species are indices of collections for the various time intervals at ach elevation; totals in the vertical columns are indices of collections from the arious elevations. Comparisons of collections were made from these indices.

This information indicates that in collections made with light traps:

Aedes were generally more abundant the highest traps. The one exception as *Aedes mitchellae,* which was collected greater numbers at 6 feet than at 25 et in the open field. More *Aedes* were llected before midnight than after.

Anopheles were more abundant in the wer traps, and, although they were active throughout the night, the largest collections were obtained before midnight.

Culex were more abundant in the higher traps. *Culex restuans* was distributed uniformly throughout the night, but the *Culex (Melanoconion)* group was most abundant before midnight. The *C. (Melanoconion)* group was predominantly *Culex erraticus* but contained some *Culex peccator* and some *Culex pilosus.* Foote (1954) revived the subgenus *Mochlostyrax* for some species of *Culex* including *C. pilosus,* but adult female *C. pilosus* are indistinguishable from the *C. (Melanoconion)* and were grouped with them in this study.

Culiseta were collected only in small numbers, but *Culiseta inornata* appeared to be evenly distributed in all traps throughout the night. *Culiseta melanura*

TABLE 2.—Abundance of the more common mosquito species by habitat, time of night, and elevation—August 1952–July 1953.

Species	Order of abundance by species		Order of abundance by periods for each species								Order of abundance by elevation for each species (in feet)				
			F				W				F		W		
	F	W	6–9	9–12	12–3	3–6	6–9	9–12	12–3	3–6	6	25	6	25	40
Aedes															
atlanticus	11	11	*	*	*	*	4	1	2	3	*	*	2	3	1
mitchellae	1	5	3	1	4	2	4	2	3	1	1	2	3	2	1
vexans	2	1	2	1	3	4	1	2	4	3	2	1	3	2	1
Anopheles															
crucians	3	4	4	1	2	3	2	1	3	4	1	2	1	3	2
quadrimaculatus	7	6	4	2	1	3	2	1	4	3	1	2	1	3	2
Culex															
restuans	4	7	3	4	1	2	2	1	4	3	1	2	2	3	1
(Melanoconion) sp.	10	3	*	*	*	*	2	1	3	4	*	*	2	3	1
Culiseta															
inornata	5	10	4	3	1	2	3	1	4	2	1	2	2	3	1
melanura	9	8	*	*	*	*	3	2	1	4	*	*	1	3	2
Psorophora confinnis	6	9	2	1	3	4	1	3	2	4	1	2	2	3	1
Uranotaenia sapphirina	8	2	4	1	3	2	2	1	3	4	1	2	1	2	3

F—open field.
W—wooded area.
*—insignificant number collected.

was not trapped in the open field and was more abundant in the lower trap than in the higher traps in the woods. This species also occurred uniformly throughout the night.

Uranotaenia sapphirina was one of the more abundant species in the woods, but relatively few were collected in the open field. In the woods, *U. sapphirina* was most abundant in the lower traps and was taken in greater numbers before midnight than after.

The order of abundance of 11 of the more common species of mosquitoes in the woods and in the open field is shown in Table 2. In the table, the most abundant species is listed as 1, the second most abundant species as 2, and so on. The four time intervals are listed 1, 2, 3, and 4 for each species according to the abundance of the species throughout the night. Similar ranks show the elevation of greatest abundance for each species.

Analyses of these data reveal that in the open field only one species, *A. vexans,* was more abundant in the 25-foot trap. In the woods, every species of *Aedes* or *Culex,* as well as *Psorophora confinnis,* was most abundant in 40-foot traps; all *Anopheles* and *U. sapphirina* were most abundant in 6-foot traps. *Culiseta inornata* was most abundant at 40 feet and *C. melanura* was most abundant at 6 feet. In the woods no species occurred in greatest numbers at 25 feet. Three species (or groups) occurred in the open field in significant numbers; one of these, *C. (Melanoconion)* spp., was the third most abundant entity in the woods. In the open field, all species taken in significant numbers were most abundant between 9 p.m. and 3 a.m. Collections in the woods showed that 9 of 11 species were most abundant between 6 p.m. and midnight. These variations in the time of greatest activity from the woods to the open field suggest that many species of mosquitoes are probably limited to the woods until conditions become favorable in the open field.

The distribution patterns for three of the more abundant species are shown graphically in Figure 3. The numbers of mosquitoes are the totals for 73 nights of collection distributed over the 12-month period. The total number of each of three species and number by sex are plotted for each time interval with reference to the horizontal scale. Differences were noted in population densities in the open field and in the woods through successive 3-hour periods through the night for each of the three elevations. Since the traps were not operated at the 40-foot level in the field, only data from traps in the woods are shown for this elevation.

Collections during 6- and 12-hour intervals. Over the entire 12-month period, light traps generally collected much larger numbers of mosquitoes between 6 p.m. and midnight than from midnight to 6 a.m. The collections during intervals of 6 and 12 hours were made to determine whether the smaller catches in the latter part of the night when traps were run for 3-hour periods were actually due to reduced mosquito activity or to depletion of the population during the preceding trapping periods. A comparison of the collections taken on nights when traps operated only between 6 p.m. and midnight or only from midnight to 6 a.m. with the collections obtained from 6 p.m. to 6 a.m. is shown in Table 3.

During the 12-week period, 27,420 mosquitoes representing 23 species were collected, but data on only 5 species, *A. crucians, A. quadrimaculatus, A. vexans, C. (Melanoconion)* sp., and *U. sapphirina,* were adequate for analyses. Larger numbers were collected from 6 p.m. to midnight than from midnight to 6 a.m. for all species except *A. mitchellae, C. inornata,* and *P. ferox.* As shown by collections made for intervals of 3 hours, *C. inornata* was uniformly active throughout the night. The number of *P. ferox* in all collections was too small to provide important data, and the variations in the catches of *A. mitchellae* resulted from one unusually large collection between midnight and 6 a.m. The total number of

mosquitoes in the 6 p.m. to 6 a.m. collections and the totals of each of the 5 more abundant species approximate the totals collected during the two collecting periods, 6 p.m. to midnight plus midnight to 6 a.m. These data indicate that smaller numbers of mosquitoes were collected after midnight regardless of trapping activity earlier in the nights, and that the population was not progressively depleted by previous collections.

DISCUSSION. The data show that different species of mosquitoes exhibit different patterns of nocturnal activity. However, relationships between these behavior patterns and climatic factors are yet to be determined. In the preliminary studies reported here, it appeared that the methods used for collecting specimens may be satisfactory, but the intervals during which collections were made must be shorter to permit adequate correlations with climatic or environmental data.

These data suggest that activity from 3 to 6 a.m. increased at 40 feet in the woods and at 6 feet in the open field but decreased at the other elevations, i.e., in the early morning mosquitoes move upward in the woods but downward in the open field. Similar observations were made by Snow (1955).

C. (Melanoconion) sp. was the third

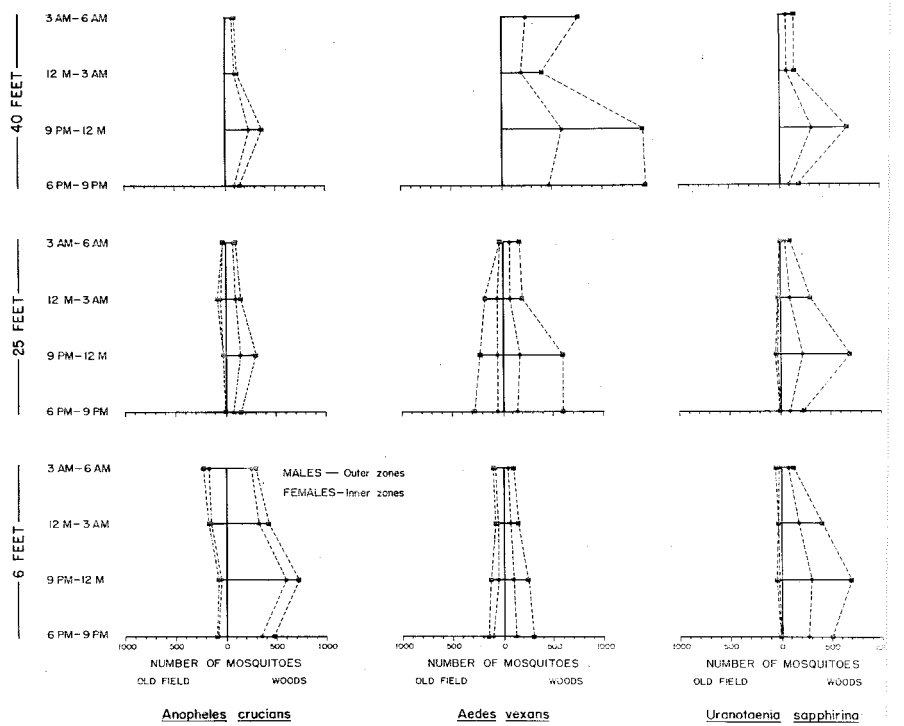


FIG. 3.—Nocturnal distribution pattern for three species of mosquitoes as indicated by light tra collections, Baker County, Georgia, 1952–1953.

most abundant mosquito in the woods during the period covered by the 3-hour collections (Table 2). During the same period this species ranked tenth in abundance in the open field, where very few specimens were collected. In later collections, during 6- or 12-hour periods (Table 3) *C. (Melanoconion)* sp. was equally prominent in the field and in the woods.

In both series of collections, *U. sapphirina* and *C. melanura* were relatively scarce in the open field, but *A. mitchellae* and *C. inornata* were nearly always more abundant in the field.

The impression was obtained that collections tended to be most uniform at the 6-foot elevation in the woods. At this location mosquito activity appeared to increase to a peak and then taper off slowly towards morning. At higher elevations or in the open field the same species appeared to conform to a bimodal pattern of activity, with one peak occurring before midnight and a second peak between 3 and 6 a.m. This pattern was more apparent in collections of those species which were obtained in greatest numbers at higher elevations.

TABLE 3.—Number of mosquitoes collected by light traps from 6 p.m. to midnight, from midnight to 6 a.m., and from 6 p.m. to 6 a.m., July–September 1953.

Species	6 p.m. to midnight	Midnight to 6 a.m.	6 p.m. to midnight plus midnight to 6 a.m.	6 p.m. to 6 a.m.
Anopheles				
crucians	716	400	1116	1049
punctipennis	2	2	4	8
quadrimaculatus	399	163	562	487
Aedes				
atlanticus	31	16	47	57
canadensis	2	1	3	0
dupreei	4	2	6	4
infirmatus	25	18	43	63
mitchellae	57	103	160	99
tormentor	....	1	1	5
vexans	1033	579	1612	1023
Culex				
(Melanoconion) sp.	1287	362	1649	1269
apicalis	34	26	60	41
nigripalpus	10	5	15	23
restuans	39	7	46	19
Culiseta				
inornata	85	89	174	45
melanura	9	7	16	16
Mansonia perturbans	21	7	28	27
Psorophora				
ciliata	2	3	5	3
confinnis	86	11	97	37
cyanescens	....	....	0	1
ferox	5	21	26	53
Uranotaenia				
lowii	....	....	0	3
sapphirina	6323	1637	7960	9458
Total	10170	3460	13630	13790

The data presented here differ in some instances from the observations of other investigators. In Georgia, *A. vexans* was most abundant at higher elevations in both the woods and the open field; but in Tennessee, biting records indicated that in the forest proper the species was more abundant at ground level than at 30 feet (Snow 1955). When Blakeslee *et al.* (1959) collected *A. vexans* at various elevations between 1.5 and 20 ft. in Maryland, greater numbers of females were obtained at 1.5 ft. in one year but at 20 ft. during the second year. Males were most numerous in the higher traps both years. *Culex erraticus* was a definite ground-level-feeding species in the Tennessee study but in Georgia *C. (Melanoconion)* spp., which were predominantly *C. erraticus,* were more numerous in the 25-foot trap in the open field and in the 40-ft. trap in the woods. However, in the woods they were more numerous at 6 feet than at 25 feet, as were a number of other high-elevation species.

SUMMARY. During a 12-month period, light-trap collections of mosquitoes were made at 6-, 25-, and 40-foot elevations in an oak hammock and at 6- and 25-foot levels in an adjacent open field.

Density indices calculated from consecutive 3-hour light-trap collections from 6 p.m. to 6 a.m. indicated that *Aedes* and *Culex* spp. were more abundant at the higher elevations and the *Anopheles* and *Uranotaenia* were more abundant at lower elevations. Total mosquito activity was greater before midnight than after, but occurred earlier in the woods than in the open field. *Uranotaenia sapphirina* and *Culiseta melanura* were relatively scarce in the open field, but *Culiseta inornata* was consistently more abundant in the field.

Additional light-trap collections indicated that smaller catches after midnight did not result from the depletion of the mosquito population before midnight.

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