TABLE 5.—Toxicity of acetone-water suspensions of DDT to fourth-instar *Anopheles quadrimaculatus* larvae when they were starved for 4 hours or fed up to the time of testing

	24-hour exposure			48-hour exposure		
	LC–50 (p.p.m.)	LC–90 (p.p.m.)	Slope	LC–50 (p.p.m.)	LC–90 (p.p.m.)	Slope
Fed	0.0065±.0013	0.013±.0010	4.31±.24	0.0044±.0010	0.010±.0007	3.72±.55
Unfed	0.0065±.0008	0.012±.0010	4.38±.56	0.0047±.0005	0.011±.0010	3.74±.39

of acetone were added to the water, the LC–50 and LC–90 were not as high as when the volume of acetone was kept constant and the concentration varied. However, the slopes of the regression lines were not significantly different, and the LC–50 and LC–90 obtained at a constant volume were no higher than those in some other tests with varying volumes, such as those given in the first line of table 2. It is therefore concluded that when acetone is used as the solvent the two methods give equal results.

EFFECT OF FEEDING LARVAE. As shown in table 5, there was no significant difference in mortality between larvae fed up to the time of testing and those starved for 4 hours.

Literature Cited

HAWKINS, W. B. 1956. The joint action of DDT and ethyl alcohol upon anopheline larvae in bioassay suspensions. Jour. Econ. Ent. 49(4): 433–5.

HAWKINS, W. B., and KEARNS, E. W. 1950. The stability of a DDT suspension. Bul. Ent. Res. 47(1):197–203.

KRUSE, C. W., LUDVIK, G. F., and HAWKINS, W. B. 1952. Factors affecting evaluation of insecticides against *Anopheles* larvae. Jour. Econ. Ent. 45(4):598–601.

SCHMIDT, C. H., and WEIDHAAS, D. E. 1958. Absorption and toxicity of three radioactive insecticides in larvae of two species of mosquito. Jour. Econ. Ent. 51(5):640–44.

THE STRATIFICATION OF MOSQUITOES

G. J. LOVE AND W. W. SMITH

Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Atlanta, Georgia, and Emory University Field Station, Newton, Georgia

INTRODUCTION. As part of studies on the bionomics of mosquitoes in southwestern Georgia, collections were made at six elevations from 3 feet to 50 feet in an effort to determine the extent of natural stratification among mosquito species.

Previous studies on the vertical distribution of mosquitoes have been made in this country (MacCreary, 1941; Gjullin *et al.*, 1950; Snow, 1955) and in other parts of the world (Davis, 1944; Bates, 1944; Haddow *et al.*, 1945 a and b, 1947, 1948, 1949; Garnham *et al.*, 1946; Kumm *et al.*, 1946, 1951; Galindo *et al.*, 1951), but in these investigations attractants were employed. Studies conducted in this area of Georgia on the stratification of mosquitoes at various times throughout the night as measured by light traps are reported elsewhere (Love *et al.*, manuscript). The present report gives the results of mosquito collections made without attractants.

MATERIALS AND METHODS. From May 1954 to July 1956 collections of mosquitoes were made one night each week with mechanical sweeping devices at elevations of 3-, 6-, 15-, 25-, 40-, and 50-foot elevations in a wooded area adjacent to a breed-

ing site. The mechanical nets, attached to a specially constructed tower, were rotated at approximately 25 r.p.m. from 6 p.m. until about 9 a.m. the following morning. A complete description of the sweep nets has been given previously (Love and Smith, 1957).

Only collections made on the 85 nights when all nets operated successfully were used in this analysis. After the numbers of mosquitoes collected had been totaled by species and listed in tabular form, the collections for those species which showed similar distribution characteristics were then totaled and plotted graphically to illustrate the differences in patterns of vertical distribution. To eliminate the abundance factor from the graphic presentation of the data, the maximum collections of all patterns were plotted on a common axis. The remaining points were then shown as percentages of these maxima.

RESULTS AND DISCUSSION. Ten species of mosquitoes were used in the analysis. Most of these were present regularly in the collections but some, particularly the *Culiseta* spp., were taken sporadically and in small numbers. The vertical distribution indicated for the *Culiseta* was distinctive enough, however, to justify inclusion. The numbers of specimens of each species collected at each elevation are shown in Table 1. Four types of distribution patterns were observed. Species showing similar distribution characteristics were grouped together and their collections totaled, as follows: pattern 1—*Anopheles crucians, A. quadrimaculatus,* and *Uranotaenia sapphirina;* pattern 2—*Aedes infirmatus, Ae. vexans,* and *Psorophora ferox;* pattern 3—*Culex restuans* and *C. (Melanoconion)* sp.; and pattern 4—*Culiseta inornata* and *Cu. melanura.* Too few representatives of other species were present in the collections to warrant use in this study.

These four types of distribution patterns are shown diagrammatically in Figure 1. Each pattern is typical for a particular genus or for ecologically related genera. The maximum numbers of *Anopheles* and *Uranotaenia* were collected at 6 feet, 51 percent of maximum at 3 feet, with a marked decrease at 15 feet continuing through higher elevations. The maximum numbers of *Aedes* and *Psorophora* were collected at 40 feet, with near maximum collections also taken at 25 feet and 3 feet. Fewer but still appreciable numbers were collected at 6 feet, 15 feet, and at the high 50-foot level. The greatest number of *Culex* was collected at 3 feet, the numbers decreasing at higher elevations, except for a secondary peak at 25 feet. *Culiseta* was collected most frequently at 3 feet, with collections at other elevations varying only from 64 to 73 percent of this maximum.

These distribution patterns indicate that *Anopheles* and *Uranotaenia* are predominantly low fliers, and only rarely get as high as 15 feet above the ground. The *Aedes* and *Psorophora* fly more uniformly at higher elevations, being rather evenly distributed throughout the vegetative canopy. *Culex* apparently flies at higher elevations than do *Anopheles* or *Uranotaenia* but not as high as *Aedes* or *Psorophora. Culiseta* is evenly distributed from 6 feet to 50 feet. The larger proportions of the collections taken at 3 feet probably indicate that most specimens of the genera studied rest during the day in low vegetation and are therefore subject to capture at the time nocturnal activity commences and the following morning when individuals are again seeking suitable diurnal resting places.

Although no attractant was used to collect the specimens for this study, undoubtedly there were motivating factors which determine the approximate elevation at which the greatest number of individuals was active. Bates (1949) listed factors believed to influence the vertical distribution of mosquitoes as gradients in temperature, humidity, and light; specific resistance to desiccation; search for oviposition sites; swarming and mating activities; and the location of their larval habitats. It appears that the activity of food seeking

TABLE 1.—Number of mosquitoes collected in mechanical sweep nets located from 3 feet to 50 feet above the ground, Baker County, Georgia, May 1954-July 1956

Pattern 1: *Anopheles* and *Uranotaenia*

Elevation (in feet)	*Anopheles crucians*	*Anopheles quadrimaculatus*	*Uranotaenia sapphirina*	Total
3	196	130	451	777
6	345	139	1,029	1,513
15	28	10	16	54
25	7	5	11	23
40	1	1	5	7
50	2	0	7	9
Total	579	285	1,519	2,383

Pattern 2: *Aedes* and *Psorophora*

Elevation (in feet)	*Aedes infirmatus*	*Aedes vexans*	*Psorophora ferox*	Total
3	144	890	183	1,217
6	48	526	98	672
15	24	743	62	829
25	32	1,166	47	1,245
40	66	1,132	72	1,270
50	61	928	69	1,058
Total	375	5,385	531	6,291

Pattern 3: *Culex*

Elevation (in feet)	*Culex restuans*	*Culex* (*Melanoconion*) sp.	Total
3	100	71	171
6	70	48	118
15	49	33	82
25	75	51	126
40	55	35	90
50	22	23	45
Total	371	261	632

Pattern 4: *Culiseta*

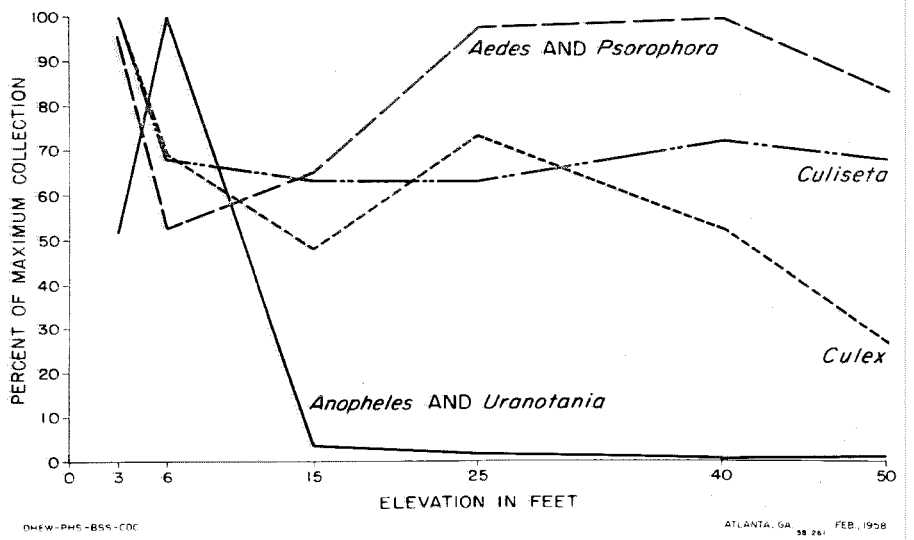
Elevation (in feet)	*Culiseta inornata*	*Culiseta melanura*	Total
3	6	16	22
6	3	12	15
15	5	9	14
25	3	11	14
40	4	12	16
50	6	9	15
Total	27	69	96

might well be added, since the availability of preferred hosts at a relatively constant height might indicate the level at which the majority of the females fly.

Results of thousands of precipitin tests have shown that *Anopheles* rarely feeds on hosts other than man or domestic mammals. *Uranotaenia* is thought to feed exclusively on cold blooded animals. All of these hosts occur near the ground in close association with the indicated distribution of these mosquito genera.

FIGURE 1

DISTRIBUTION PATTERNS FOR MOSQUITOES AS INDICATED BY MECHANICAL SWEEP NET COLLECTIONS, BAKER COUNTY, GEORGIA; MAY 1954-JULY 1956



The feeding habits of *Culex* are not so well known. In rural areas, greatest numbers of adult female *C. quinquefasciatus* and *C. erraticus* may be found associated with poultry. While chickens usually do not roost very far above the ground, this association may indicate the preference of these species for avian blood. The colonization of *C. quinquefasciatus* and the laboratory feeding of *C. restuans* is greatly facilitated by the use of birds as a source of blood. In the western United States *C. tarsalis* is the chief vector of encephalitis, the pathogen of which occurs in birds. Since this species transmits the infection to man, the indicated association is with both birds and man, with birds probably being the preferred hosts. A preferred avian host which consistently roosts in the tree canopy might require the *Culex* mosquitoes to fly at a higher elevation than *Anopheles* and *Uranotaenia*.

Several species of *Aedes* have been found naturally infected with encephalitis, although they are not thought to be important in transmitting infections to man. Many species of both *Aedes* and *Psorophora* have been shown capable of direct transmission of encephalitis virus in the laboratory (Ferguson, 1954).

If *Aedes* and *Psorophora* are predominantly higher fliers as indicated by their distribution pattern, they would be expected to feed primarily on birds. They could be very important then in maintaining encephalitis in the avian reservoir and be found infected with the virus, but still be of little importance as far as human infections are concerned. However, there is some evidence that *Ae. vexans* does not feed primarily on birds. Of approximately 35 freshly engorged specimens collected in the course of this study and tested to determine the source of the blood meal, not

one had fed on avian blood. Burroughs and Burroughs (1954) reported that 77 percent of 202 *Ae. vexans* collected in the upper Mississippi Valley had fed on domestic mammals as indicated by precipitin tests.

The only information concerning the feeding habits of *Culiseta* is the reported incrimination of *Cu. melanura* as the vector of encephalitis in domestic pheasants in New Jersey. Both *Cu. melanura* and *Cu. inornata* were fed successfully on birds in the laboratory.

The observations point out that in some cases there may be correlation between the vertical distribution of mosquitoes and their feeding preferences, but that much additional work on the subject is desirable.

SUMMARY. Mosquito collections made with mechanical sweeping devices which utilized no attractant indicated that the aerial distribution of various genera conforms to different patterns. *Anopheles* and *Uranotaenia* rarely attained an altitude of 15 feet. *Aedes* and *Psorophora* were more active at higher elevations, and *Culex* occurred most frequently at intermediate elevations. *Culiseta* was evenly distributed from 6 feet to 50 feet. There are correlations between the indicated vertical distribution and known feeding preferences.

References Cited

BATES, M. 1944. Observations on the distribution of diurnal mosquitoes in a tropical forest. Ecology 25:159–170.

BATES, M. 1949. The natural history of mosquitoes. I-XV, 1–379. Macmillan Co., New York.

BURROUGHS, A. L., and BURROUGHS, L. N. 1954. A study of the ecology of western equine encephalomyelitis virus in the upper Mississippi Valley. Amer. J. Hyg. 60:27–36.

DAVIS, D. E. 1944. A comparison of mosquitoes captured with an avian bait at different vegetational levels. Rev. Ent., Rio de Janeiro 15:209–215.

FERGUSON, F. F. 1954. Biological factors in the transmission of American arthropod-borne virus encephalitides. Pub. Health Monograph No. 23, 37 pp.

GALINDO, P., CARPENTER, S. J., and TRAPIDO, H. 1951. Ecological observations on forest mosquitoes of an endemic yellow fever area in Panama. Amer. J. Trop. Med. 31:98–137.

GARNHAM, P. C. C., HARPER, J. O., and HIGHTON, R. B. 1946. The mosquitoes of the Kaimosi Forest, Kenya Colony, with special reference to yellow fever. Bull. Ent. Res. 36:473–494.

GJULLIN, C. M., YATES, W. W., and STAGE, H. H. 1950. Studies on *Aedes vexans* (Meig.) and *Aedes sticticus* (Meig.) floodwater mosquitoes in the lower Columbia River Valley. Ann. Ent. Soc. Amer. 43:262–275.

HADDOW, A. J. 1945a. The mosquitoes of Bwamba County, Uganda. II. Biting activity with special reference to the microclimate. Bull. Ent. Res. 36:33–74.

HADDOW, A. J. 1945b. The mosquitoes of Bwamba County, Uganda. III. The vertical distribution of mosquitoes in a banana plantation and the biting cycle of *Aedes* (*Stegomyia*) *simpsoni* Theobald. Bull. Ent. Res. 36:297–304.

HADDOW, A. J., and DICK, G. W. A. 1948. Catches of biting Diptera in Uganda with anaesthetized monkeys as bait. Ann. Trop. Med. Parasit. 42:271–277.

HADDOW, A. J., and MAHAFFY, A. F. 1949. The mosquitoes of Bwamba County, Uganda. VII. Intensive catching on tree-platforms, with further observations on *Aedes* (*Stegomyia*) *africanus* Theobald. Bull. Ent. Res. 40:169–178.

HADDOW, A. J., GILLETT, J. D., and HIGHTON, R. B. 1947. The mosquitoes of Bwamba County, Uganda. V. The vertical distribution and biting cycles of mosquitoes in rain-forest, with further observations on microclimate. Bull. Ent. Res. 37: 301–330.

KUMM, H. W., and CERQUIERA, N. L. 1951. The *Haemagogus* mosquitoes of Brazil. Bull. Ent. Res. 42:169–181.

KUMM, H. W., OSORNO-MESA, E. and BOSHELL-MANRIQUE, J. 1946. Studies on mosquitoes of the genus *Haemagogus* in Colombia (Diptera, Culicidae). Amer. J. Hyg. 43:13–28.

LOVE, G. J., PLATT, R. B., and GOODWIN, M. H., JR. 1957. Preliminary observations on the spatial activity of mosquitoes in southwestern Georgia (Manuscript).

LOVE, G. J., and SMITH, W. W. 1957. Preliminary observations on the relation of light trap collections to sweep net collections in sampling mosquito populations. Mosq. News 17(1):9–14.

MACCREARY, D. 1941. Comparative density of mosquitoes at ground level and at an elevation of approximately one hundred feet. J. Econ. Ent. 34:174–179.

SNOW, W. E. 1955. Feeding activities of some blood-sucking Diptera with reference to vertical distribution in bottomland forest. Ann. Ent. Soc. Amer. 46(6):512–521.