NOTES ON THE BIONOMICS AND SEASONAL OCCURRENCE OF MOSQUITOES IN SOUTHWESTERN GEORGIA

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Introduction. Observations on the abundance and distribution of mosquitoes in southwestern Georgia have been made since 1939 in connection with studies on the natural history of arthropod-borne diseases. Results of most studies and observations have been reported separately (see bibliography) but much material which was collected incidentally or resulted from preliminary experiments has not been made available. The purpose of this paper is to record pertinent unpublished observations made over an eighteen year period, 1939 to 1957. Some material is fragmentary and some of the comments concerning bionomics of various species are speculative. It is believed, however, that the data presented are of interest and value to culicidologists.

In 1951, an extensive, long-range study on the microhabitat of mosquitoes was inaugurated (Platt, 1955). The present report does not give details of this recent work since it is developing rapidly and progress to date has been reported adequately. (Platt, 1957; Platt *et al.*, 1957; Platt *et al.*, 1958; Love *et al.*, 1958).

Topography and Climate of Study Area. All observations were made in the experimental area of the Emory University Field Station. The topography and climate were described in detail by Hendricks and Goodwin (1952a). The area covers approximately 200 square miles of Baker and Early Counties, Georgia. The center of the area is approximately latitude 31° 20′ N., longitude 84° 20′ W., about 190 miles west of the Atlantic Ocean and 90 miles north of the Gulf of Mexico. The elevation ranges from 100 to 250 feet above sea level. The area lies within the Dougherty Plain which covers about 7,000 square miles. Limestone, which once overlay the area, has been removed by the solution of ground water leaving a residuum of sands and clays ranging in thickness from 70 to 100 feet. Beneath the residuum are undissolved remnants of Oligocene and Eocene limestones. Numerous sinks and surface depressions occur in the area. It is believed that these sinks result from the collapse of the overburden when the deep-lying limestone is dissolved. Depressions thus formed have gentle sloping sides and lack evidence of fracture of the surface strata. Limestone sinks, which are caused by solution at or near the surface, have steeper sides and show evidence of slumping of the surface strata. Formation of the lime-sink ponds was described by Goodwin and Lenert (1943).

The climate of the study area, in common with that of the rest of the region, is warm and moist. Normal annual precipitation is about 50 inches. The heaviest precipitation occurs ordinarily during July and August and a secondary peak usually is reached during February and March. The fall season is the driest of the year. Wide variations in amounts of annual rainfall are experienced.

For the years 1892 to 1957, annual rainfall in the southern division of Georgia ranged from 28.97 to 66.53 inches (U. S. Weather Bureau, 1958). The July precipitation ranged from 3.56 to 14.69 inches. Average monthly precipitation figures in inches for three stations near the area having 50 years or more of records are shown in Table 1.

The average annual temperature at Bainbridge, located about 24 miles south of the center of the area, is 67.7° F. (Table 2). Very changeable temperature conditions prevail in winter; daily maxima

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TABLE 1.—Average monthly precipitation in inches at Albany, Blakely, and Bainbridge for period 1882–1957

Month	Albany[1]	Blakely[2]	Bainbridge[3]
January	3.90	4.44	3.80
February	4.59	4.96	4.33
March	5.01	5.54	4.68
April	4.00	4.51	4.18
May	3.81	3.63	3.28
June	4.31	4.50	4.76
July	5.96	6.82	6.64
August	5.36	5.77	5.66
September	3.52	3.97	4.41
October	2.26	2.56	2.19
November	2.50	3.08	2.37
December	3.90	4.44	4.30
Annual	49.12	54.22	50.60

[1] Twenty-one miles N. E. from center of study area.
[2] Eighteen miles W. from center of study area.
[3] Twenty-four miles S. from center of study area.

TABLE 2.—Mean monthly air temperature in degrees Farenheit at Bainbridge, Georgia, based on records for 1882–1957

January	52.7
February	54.8
March	61.0
April	67.5
May	74.9
June	80.6
July	81.7
August	81.5
September	78.1
October	68.3
November	58.3
December	52.7
Annual	67.7

are rarely below 32° F., and frequent warm periods occur. The highest recorded January mean temperature exceeds the lowest by about 20° F. Summer temperatures are more consistent. The highest recorded July mean temperature exceeds the lowest by about 6° F. The average date of the first killing frost is November 15 and of the last is March 10. The average length of the growing season is 250 days. Snowfall is rare.

Relative humidity is highest in winter, and a secondary peak occurs in midsummer. Spring and fall have the driest atmosphere, conforming to the pattern of rainfall distribution. Evaporation from a U. S. Weather Bureau Class A pan at the Emory University Field Station averaged 55.74 inches annually for 12 years (1946–1957).

METHODS OF COLLECTING MOSQUITOES. From 1939 to 1941 adult mosquitoes were collected only from houses, barns, culverts, hollow trees, and similar natural resting places. In 1941 an artificial resting station, primarily for the study of *Anopheles quadrimaculatus,* was developed by Goodwin (1942). These stations, one-foot cubical boxes with one end open and painted red inside and out, provided a comparatively uniform resting place which could be located near breeding areas and in other situations where mosquitoes congregate. Also in 1941, use of battery and power-line operated New Jersey type light traps was commenced. Beginning in 1952, mechanical sweep nets were employed. These traps used no attractant and thus had advantages over other traps in sampling all species active within range.

During the winters of 1944–45 and 1945–46, collections of *Anopheles* spp. and some culicine species were made by fumigating hollow trees on days following nights during which the temperature fell below freezing (Zukel, 1949a, 1949b).

Mosquito larvae were usually collected from ponds and other large areas by skimming the water surface with an enamel pan or dipper. Larvae were collected from tree holes with a siphon. In cases where larvae could not be removed directly from artificial containers, because of small orifice or presence of debris, most of the water was decanted and the remainder, containing the larvae, was poured into a shallow white pan.

Mosquito collections from 1938 to 1948 were made primarily in connection with studies of malaria and anophelines. During this period no regular effort was made to collect all species in the area. A sufficient number of collections was made over the nine-year period, however, to obtain tenable data on seasonal distributions of prominent species. After 1948, collec-

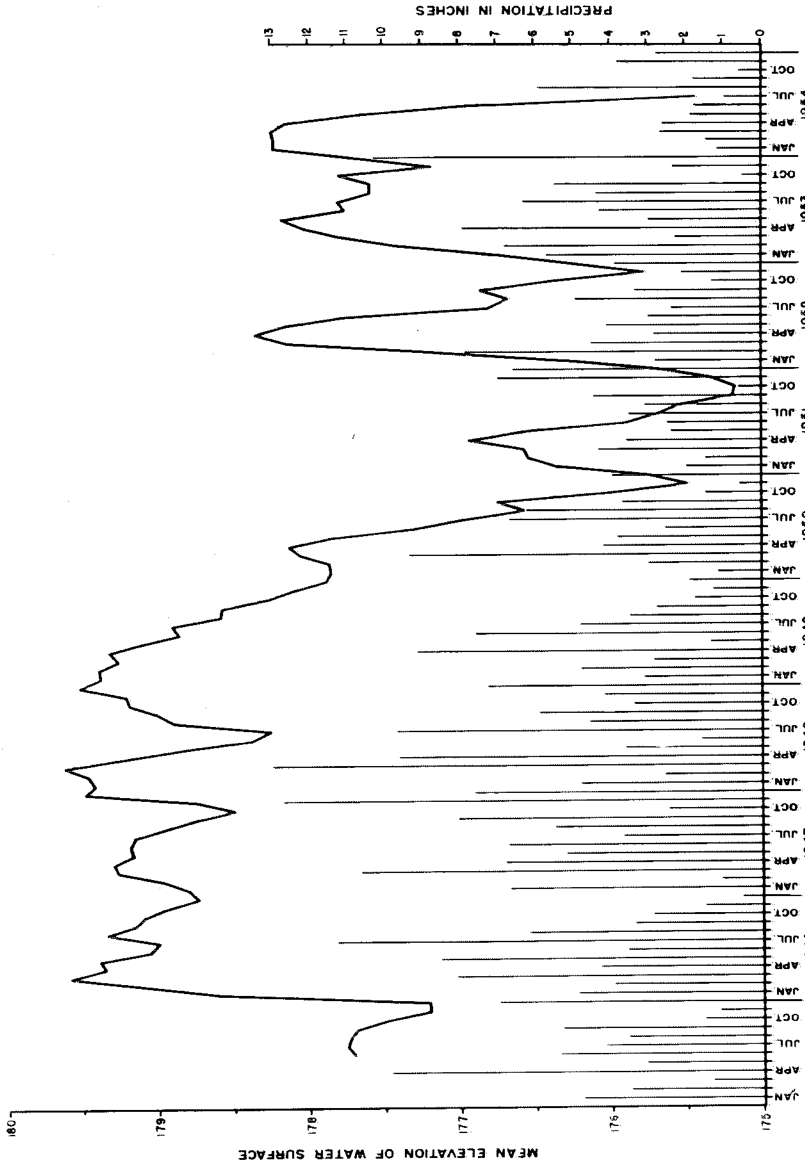

FIG. 1.—Monthly mean elevation of water surface in Mossy Pond, Baker County, Georgia and monthly precipitation, 1945–1954. This pond was dry during 1955, 1956 and 1957.

tions were designed to obtain all culicine species.

The nomenclature used in this report is based on Pratt's Check List of North American Mosquitoes (1956).

DESCRIPTION OF BREEDING AREAS. The mosquito breeding places in southwestern Georgia consist of "permanent" ponds, temporary pools, roadside ditches, tree holes, and many types of artificial containers. With the exception of tree holes and artificial containers, the character of most breeding areas is determined by topography and by climate, particularly precipitation and temperature. The character of a particular breeding area and the fauna supported, may vary from year to year.

An example of variations in climatic factors and the associated variations in a breeding area is shown by the monthly precipitation data and water level fluctuations at Mossy Pond (Figure 1). This pond is representative of the "permanent" limesink ponds, the most important habitat for mosquitoes in the area. From 1939 until 1949 Mossy Pond held water continuously (Figure 2) and the mosquitoes produced were characteristic of the fauna in relatively permanent, mature limesink ponds. *Anopheles crucians* Wied., *A. quadrimaculatus* Say, *Culex erraticus* (D. and K.), *Uranotaenia sapphirina* (O. S.), and *Mansonia perturbans* (Walk.) were common during the summer months. In the cooler portions of the year *A. crucians, A. punctipennis* (Say), and *C. territans* Walk. were abundant (Table 3). In these years, the water level in the pond receded during the summer (growing season) and rose during winter (water-storage period).

FIG. 2.—Permanent limesink breeding area, Baker County, Georgia

TABLE 3.—Species of mosquito larvae collected from various types of breeding areas in southwestern Georgia

Permanent	Temporary	Intermittent	Tree holes	Artificial containers
A. crucians *	*A. crucians*	*A. punctipennis*	*A. barberi* *	*A. crucians*
A. georgianus *	*A. punctipennis*	*C. pilosus* *	*O. signifera* *	*A. punctipennis*
A. punctipennis	*C. erraticus*	*C. restuans* *	*T. r. septentrionalis* *	*C. p. quinquefasciatus* *
A. quadrimaculatus	*C. peccator* *	*Ae. atlanticus* *	*Ae. triseriatus* *	*C. restuans*
A. walkeri *	*C. territans*	*Ae. canadensis* *		*C. territans*
Culex erraticus *	*Ae. atlanticus*	*Ae. dupreei* *		*O. signifera*
C. nigripalpus *	*Ae. canadensis*	*Ae. infirmatus* *		*T. r. septentrionalis*
C. territans *	*Ae. cinereus* *	*Ae. mitchellae* *		*Ae. triseriatus*
Culiseta inornata *	*Ae. dupreei*	*Ae. sticticus* *		
C. melanura *	*Ae. fulvus-pallens* *	*Ae. thibaulti* *		
M. perturbans *	*Ae. infirmatus*	*Ae. tormentor* *		
U. sapphirina *	*Ae. mitchellae*	*Ae. vexans* *		
U. lowii *	*Ae. vexans*	*P. ciliata* *		
	P. ciliata	*P. confinnis* *		
	P. confinnis	*P. cyanescens* *		
	P. discolor	*P. discolor* *		
	U. sapphirina	*P. ferox* *		
	U. lowii	*P. horrida* *		
		P. howardii		
		P. varipes		

* Indicated type breeding area in which the species most commonly occurs.

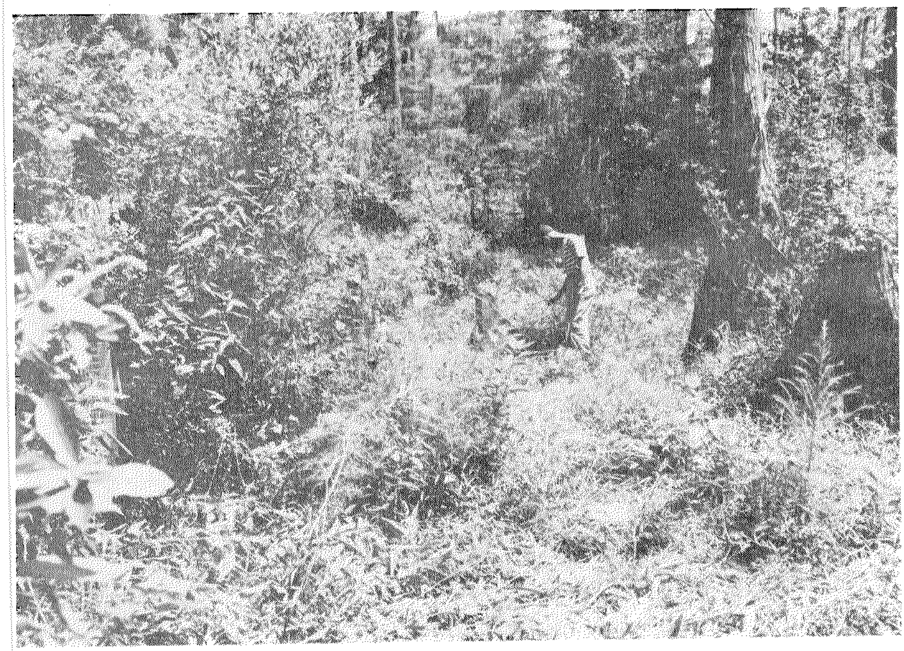

FIG. 3.—Typical limesink breeding area following several years of drought

In the fall of 1949 and spring of 1950 precipitation was insufficient to restore the water level to the normal spring stage and the usual depletion during the summer further lowered the level. In the winter of 1950–51 rainfall was again deficient and the pond became completely dry late in the summer of 1951 (Figure 3). During 1951 and most of 1952 the mosquito fauna was completely different. The prominent species were *Aedes vexans* (Meig.), *Ae. atlanticus* D. and K., *Ae. infirmatus* D. and K., *Psorophora ferox* (Humb.), *P. confinnis* (L.-A.), *P. ciliata* (Fab.), *P. cyanescens* (Coq.), and during the cooler periods of the year *Aedes mitchellae* (Dyar), *Ae. canadensis* (Theob.), and *Culex restuans* Theob. In the latter part of 1953, the pond level was higher than during any fall month since 1949. Rainfall was greatly deficient in the first months of 1954, the water level dropped during the growing season, and by July the pond was again dry. In 1954, species which develop in "permanent" ponds were produced from January until June; afterward species associated with temporary pools were present.

The substrata of temporary ponds and pools were highly porous. The length of time that water was retained depended upon increment and condition of the water table. During years with normal or heavy precipitation many of the ponds (Figure 4) contained mosquitoes characteristic of permanent ponds; e.g. *U. sapphirina*, *C. nigripalpus* Theob., and *C. erraticus*. *Culex peccator* D. and K. was often found in ponds of this type. During periods of extreme drought temporary pools frequently produced few or no mosquitoes since intermittent rains were not

FIG. 4.—Intermittent pond, Baker County, Georgia

sufficient to maintain water in the pools long enough for larvae of *Aedes* and *Psorophora* to mature even though eggs hatched.

Psorophora spp. were the characteristic species found in roadside ditches (Figure 5); *Aedes* spp. and *Culex pilosus* (D. and K.) occurred less prominently in these situations. In common with other types of highly intermittent aquatic habitats, the ephemeral biota in ditches was not consistently characteristic. The mosquitoes found most frequently in roadside ditches occurred also in temporary pools and in "permanent" ponds depending upon the extent of drought.

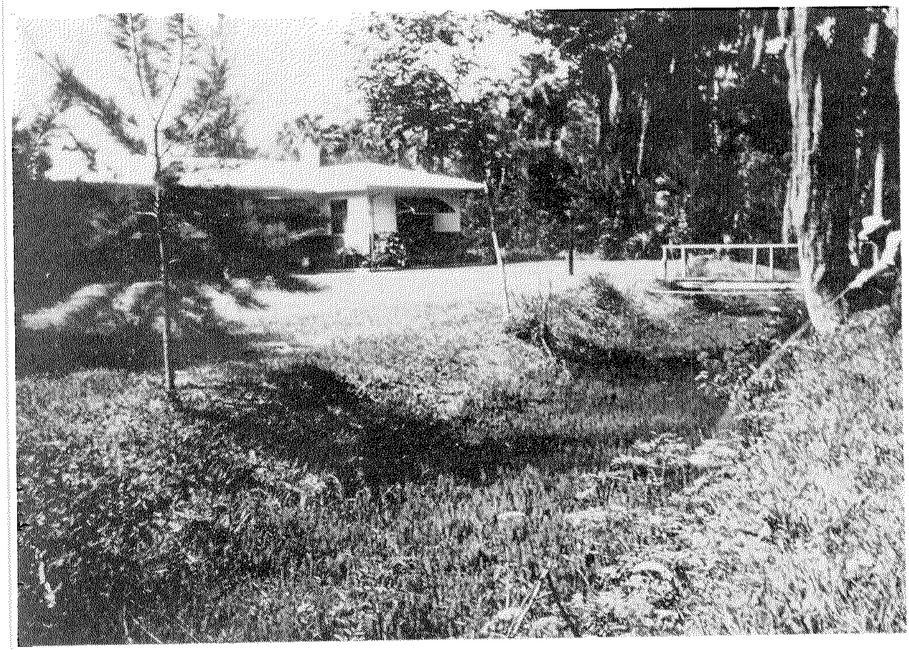

FIG. 5.—Roadside ditch

Artificial containers (Figure 6) produced primarily *Culex pipiens quinquefasciatus* Say in the summer and *C. restuans* in the winter. *Toxorhynchites rutilus septentrionalis* (D. and K.) and *Orthopodomyia signifera* (Coq.) larvae were found throughout the year in artificial containers which held water contaminated with organic materials.

Tree holes (Figure 7) produced *Aedes*

FIG. 6.—Artificial container

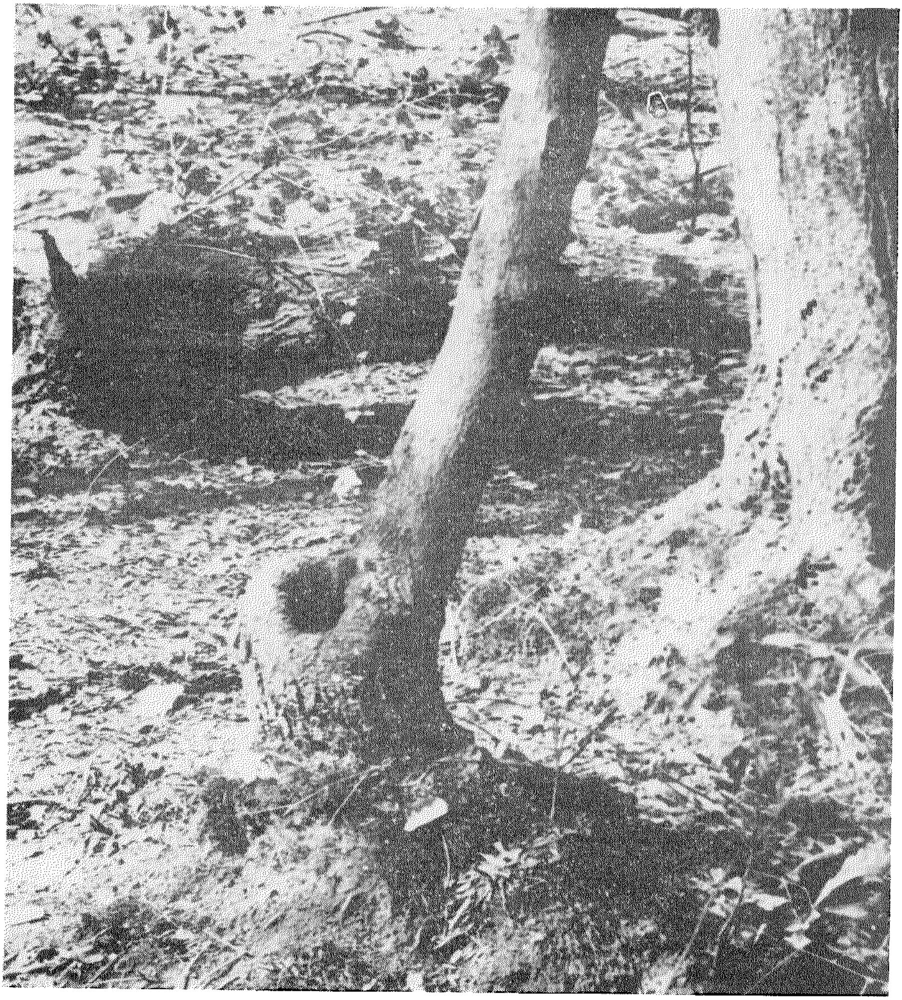

FIG. 7.—Tree hole from which numerous *Aedes triseriatus* larvae were obtained, Baker County, Georgia

triseriatus Say, *Anopheles barberi* Coq., *O. signifera*, and *T. r. septentrionalis*.

SEASONAL DISTRIBUTION OF MOSQUITOES. The collecting techniques used for these studies do not provide an accurate, comparable, quantitative measurement of relative abundance of all species. For example, *A. quadrimaculatus* were taken in large numbers from hollow trees and artificial resting stations, but the numbers of *A. crucians* in these same places were too small to indicate population trends. Conversely, light traps in the same areas collected many *A. crucians* but fewer *A. quadrimaculatus*. Comparative data on abundance are necessarily limited to a single species or to populations which are closely related ecologically. Comparison of trends in populations is more reliable, however. For example, the direction and magnitude of variations in populations of adult *A. quadrimaculatus* was the same whether measured by light trap collections or by enumeration of mosquitoes in artificial resting stations. For other species, however, e.g. *Culiseta melanura, Aedes triseriatus,* or *Psorophora ferox,* insignificant numbers of adults were obtained by light trap collections or by other repetitive techniques, to provide comparative data on abundance.

Bait traps using animals or chemical attractants were singularly unsuccessful in collecting adult mosquitoes in the area studied. Bait traps, as well as light traps, measure taxis rather than comparative abundance and hence have limited usefulness in population measurements.

Probably the most accurate information on the relative abundance of various species was obtained from the mechanical sweep nets. Because of the small number of some species collected each night, however, it may be necessary to use this technique for several months or years to obtain valid information. By comparing collections made with light traps with those made with the sweep nets preliminary indices of attractiveness to light were derived for most of the species which occur in the area (Love and Smith, 1957).

Larval collection methods employed in this study were selective for certain species. *Anopheles* spp. are easily collected by skimming the water surface with a pan; but some other species, e.g. *Culiseta melanura* (Coq.), *Psorophora* spp. and *Aedes dupreei* (Coq.), dart to the bottom at the slightest movement of the water surface and remain submerged for several minutes. Consequently, larval collections in this study did not provide tenable data on relative abundance of aquatic stages.

These limitations of both larval and adult collections are emphasized to indicate the reservations held in interpreting the following data which were collected as collateral observation rather than as studies designed specifically to provide comparable information on populations.

Of the 51 species of mosquitoes previously reported from Georgia (Table 4), 42 were collected in the southwestern section of the state during the present study. Four of the remaining nine species, *Anopheles atropos* D. and K., *A. bradleyi* King, *Aedes sollicitans* (Walk.), and *Ae. taeniorhynchus* (Wied.), breed in salt marshes, a habitat which does not occur in the area observed. *Ae. trivittatus* (Coq.) was reported from Lee County, Georgia, 35 miles northwest of the area, by Root in 1924 but has not been reported since. Two female mosquitoes collected at Camp Wheeler, Georgia, in 1943 and identified as *Culex tarsalis* Coq. (Middlekauff and Carpenter, 1944) are the only state record for this species. *Culex pipiens pipiens* Linn. has been identified from collections in the northern part of the state but not from the southern section. *Orthopodomyia alba* Baker was identified from Georgia material in 1945 (Carpenter, *et al.*, 1946) and *Toxorhynchites rutilus rutilus* (Coq.) was reported from Georgia before 1920 (Howard, *et al.*, 1912–17). Neither of the latter species was found in southwestern Georgia during this study.

A summary of records on mosquito collection for the period 1939 through 1957 is shown in Table 5. Data are summarized by months; the species collected and the methods used are shown. An indication of abundance also may be obtained from this table since, in most instances, the species present in greatest numbers were collected by more than one method. *Aedes* was most abundant from March through June (Table 5), *Psorophora* from June through October, and *Culex* from July through November. In the field, succession of *Aedes* and *Psorophora* was especially noticeable. Species of both genera occurred in the same larval habitats, but only a few *P. ferox* and *P.*

TABLE 4.—Species of mosquitoes reported from the state of Georgia, and those collected during the present study in southwestern Georgia

Anopheles atropos [1]	*Aedes atlanticus*
barberi	*canadensis*
bradleyi [1]	*cinereus*
crucians	*dupreei*
georgianus	*fulvus-pallens*
punctipennis	*infirmatus*
quadrimaculatus	*mitchellae*
walkeri	*sollicitans* [1]
	sticticus
Culex erraticus	*taeniorhynchus* [1]
nigripalpus	*thibaulti*
peccator	*tormentor*
pilosus	*triseriatus*
pipiens [2]	*trivittatus* [4]
quinquefasciatus	*vexans*
restuans	
salinarius	*Psorophora ciliata*
tarsalis [3]	*confinnis*
territans	*cyanescens*
	discolor
Culiseta inornata	*ferox*
melanura	*horrida*
	howardii
Mansonia perturbans	*varipes*
Orthopodomyia alba [5]	*Uranotaenia lowii*
signifera	*sapphirina*
Toxorhynchites rutilus rutilus [6]	
rutilus septentrionalis	

[1] Salt marsh species does not occur in southwestern Georgia.
[2] Reported only from North Georgia.
[3] Reported from Macon in 1943, not found in southwestern Georgia.
[4] Reported from Lee County in 1924, not found since that time.
[5] Reported from Georgia in 1945, not found in southwestern Georgia.
[6] Reported from Georgia before 1920, not found in southwestern Georgia since 1940.

ciliata hatched when *Aedes* larvae became abundant following early spring rains. After the areas became dry and were subsequently filled, large numbers of *Psorophora,* as well as *Aedes,* were produced.

ANOPHELES. Six species of *Anopheles* were found in southwestern Georgia. *A. quadrimaculatus* occurred in "permanent" limesink ponds throughout the area. This species may breed throughout the winter depending on severity of the cold (Bellamy, 1950). In this area, true hibernation was not observed; males died off and females became inactive during the winter for periods of several days. During the warm intervals, however, the females became active and fed (Zukel, 1949a, 1949b). In some instances ova were produced following winter feedings but frequently only fat bodies were produced. During a mild winter such as 1948–49 breeding apparently was not interrupted; fourth instar *A. quadrimaculatus* larvae and adult males and females were collected each month during the period. In more severe winters neither larvae nor adult males were collected from November until March.

During the winter of 1946–47, over 200 wild *A. quadrimaculatus* females collected from artificial resting stations were isolated individually and held in an area of the insectary which was heated during the day to approximately 70° F. and unheated at night. Each specimen was given an opportunity to feed daily from

TABLE 5.—Summary of information on occurrence of culicidae in southwestern Georgia

Genus and Species	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Anopheles barberi	-	-	-	-	-	-	-	-	IR	-	-	-
crucians	ITR	ITRBS	ITRS	ITBRS	ITBRS	ITRBS	ITBRS	ITRS	ITRS	ITRS	ITRS	ITBRS
georgianus	-	-	-	-	I	-	-	-	-	-	-	-
punctipennis	ITRS	ITRB	ITRS	ITRS	ITRBS	ITRS	ITR	ITR	ITRS	ITBRS	ITRS	ITR
quadrimaculatus	ITBRS	ITR	ITRS	ITRS	ITBRS	ITRBS	ITRS	ITRS	ITBRS	ITBRS	ITRS	ITRS
walkeri	-	-	-	-	-	-	T	T	T	-	-	-
Aedes atlanticus	-	I	-	TBIS	TBS	TBS	ITBRS	ITBS	TBS	TBS	TBS	-
canadensis	IT	IT	IT	ITB	TB	T	-	T	T	TS	-	S
cinereus	-	-	-	B	B	T	-	-	-	-	-	-
dupreei	-	-	-	TS	TS	T	TS	ITS	TS	TS	-	-
fulvus-pallens	-	-	-	-	TBS	TS	TS	TS	TS	TS	S	-
infirmatus	BR	-	ITBS	TBRIS	TBS	TBS	TBRS	TBRS	TBS	TBS	TBS	BS
mitchellae	ITBR	ITBRS	TIBS	ITBS	ITS	TS	TS	ITS	ITS	TS	TS	TBIS
sticticus	-	-	T	TBR	TBS	TBS	-	-	-	-	-	-
thibaulti	-	-	R	BR	RB	TS	TS	S	-	-	-	-
tormentor	-	-	-	-	TB	T	TI	T	T	T	-	-
triseriatus	I	I	ITR	ITBS	ITBS	ITBS	ITBS	ITS	ITS	IST	IS	I
vexans	ITBRS	ITRS	ITRS	ITBRS	ITBRS	ITBRS	TRBS	ITBRS	ITBS	TBRS	TBIS	ITS
Culex nigripalpus	-	-	I	S	TS	-	-	ITS	ITS	TS	T	IS
quinquefasciatus	I	-	IT	I	ITR	IRST	ITRS	ITRS	TIS	TRIS	ITRS	I
restuans	ITBRS	ITRS	ITRS	ITRS	ITS	TRIS	TRS	TS	ITS	ITRS	ITRS	ITRS
salinarius	-	-	-	-	-	-	-	-	-	-	T	-
territans	ITRS	ITRS	ITRS	ITRS	ITRS	ITRS	TS	ITS	TRIS	ITRS	ITS	ITS
(*Melanoconion*) sp.	TRS	TR	TRIS	TIRS	TRIS	TIRS	ITRS	TRIS	TRIS	TRIS	TRIS	RTS
erraticus	TR	R	I	IR	RIT	IR	ITR	ITR	ITR	ITR	IT	T
peccator	-	-	-	-	I	-	I	I	IT	TR	-	-
pilosus	-	-	-	-	-	-	TI	TI	IT	IT	T	-
Culiseta inornata	TIS	ITS	TI	TRS	TS	T	T	T	T	TS	TS	TSI
melanura	TR	TRS	ITRS	TRSI	TRS	TRS	TSR	TS	TS	TS	TS	TS
Mansonia perturbans	-	-	-	TBR	TBRS	ITBRS	TBRS	TRSB	TBS	TBRS	-	-
Orthopodomyia signifera	I	I	IR	ITS	IS	ITS	IS	ITS	ITS	IS	ITS	IT
Psorophora ciliata	-	I	IB	ITBS	TIBS	ITBS	ITBR	IBTS	ITSB	TISB	IT	-
confinnis	IBR	I	I	ITS	TIS	TBI	ITBS	ITBS	ITBS	ITBS	I	IR
cyanescens	-	-	-	ITB	BT	BTS	TI	IBTS	IB	BTS	-	-
discolor	-	-	-	IT	IT	TS	ITS	ITS	IT	T	-	-
ferox	-	I	TI	ITBS	TBIRS	TBRS	ITBS	ITBS	ITBS	TBRS	BST	-
horrida	-	-	-	-	B	TB	T	I	-	-	-	-
howardii	-	-	-	I	-	S	S	IBT	TB	TB	-	-
varipes	-	-	-	T	B	BT	BS	T	-	B	-	-
Toxorhynchites rutilus septentrionalis	I	I	I	I	I	I	IS	I	I	I	I	I
Uranotaenia sapphirina	TR	TR	ITR	ITR	ITRS	ITS	ITS	ITS	ITS	ITS	ITRS	TRS
lowii	-	-	-	-	-	-	-	T	T	T	T	-

T - Adults collected in light traps
R - Adults collected in resting stations
I - Immature stages collected
B - Adults collected biting
S - Adults collected in mechanical sweep nets

the hand or arm of the insectary technician; usually 3 to 5 specimens engorged fully. No ova were obtained, however, from the middle of December through February, although some specimens survived for more than 60 days and fed as many as 5 times. In a similar study conducted during January, February, and March, 1953 more than 100 wild female *A. quadrimaculatus* were collected from the same stations as in 1947 and placed in an open section of the insectary under essentially ambient conditions. In every instance the surviving females fed, developed ova, and oviposited. Low temperatures to which the specimens were exposed were about the same in 1947 and 1953. The high temperatures were different, however, since in 1947 the insectary was heated during the day. The higher daytime temperatures in 1947 may have stimulated more activity and feeding. But the greater temperature variations from day to night in this series may have accounted for the production of fat rather than ova. The mortality rate was low in the 1947 series but exceeded 50 percent in the 1953 series. Mortality in the 1953 series usually occurred among unfed specimens.

In January and February 1953 a series of female *A. quadrimaculatus* from the laboratory colony were fed in the insectary at 78° F. and held at a constant temperature of 50° F. All of these specimens developed ova.

In the field, populations of *A. quadrimaculatus* adults usually began to increase in April and rose sharply during May and June. Reductions usually occurred in July and August as a result of high summer temperatures detrimental to larval development (Goodwin and Love, 1957; Love and Whelchel, 1957) and rose again in September when temperatures moderated. Populations declined sharply when the minimum temperature fell below approximately 40° F.

Variations in the time when maximum density of *A. quadrimaculatus* occurred during comparable years of normal precipitation were related to early spring temperatures. Populations generally were higher in June or early July. The maximum height which the population reached was influenced by the length of time during which favorable developmental temperatures occurred. Moderate temperatures, averaging above 60° F. during February and March, permitted larval development and resulted in higher population levels during June than were noted when winter and early spring temperatures were lower. This effect of early spring temperature on summer populations has been observed also in the Tennessee Valley (Hess and Crowell, 1949).

A. crucians apparently overwintered principally as larvae, as observed in South Carolina (Frohne and Hart, 1949). In southwestern Georgia, however, some specimens complete development during warm periods of the winter, so that adult males and females were collected consistently throughout the winter from artificial resting stations adjacent to the breeding areas. Larvae of both *A. crucians* and *A. quadrimaculatus* developed at temperatures above 50° F.; lower temperatures were apparently lethal to most *A. quadrimaculatus* but not to *A. crucians*. Consequently, *A. crucians* adult populations increased immediately after temperatures moderated in the spring. *A. quadrimacu-*

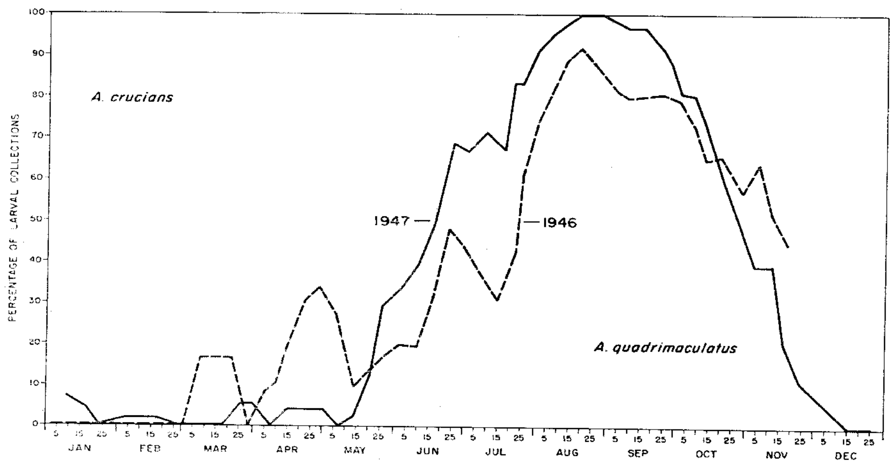

Fig. 8.—Relative abundance of *Anopheles quadrimaculatus* and *A. crucians* larvae in a permanent breeding area during 1946 and 1947. Area below the line shows percent of *A. quadrimaculatus*. Area above line shows percent *A. crucians*.

latus adult populations increased only after temperatures moderated for a period sufficiently long to permit development from egg to adult.

The relative abundance of *A. quadrimaculatus* and *A. crucians,* based on weekly collections of larvae in 1946 and 1947, from an area suitable for heavy production of both species is shown in Figure 8. Temperatures during these years were close to the average. *A. quadrimaculatus* was the predominant species from June through October, but few specimens were collected during the remaining months when *A. crucians* was more abundant. However, this pattern varied considerably in years with abnormal temperatures. During the winters of 1948–49 and 1949–50 monthly mean temperatures ranged from 3 to 12 degrees above the average shown in Table 2. *A. quadrimaculatus* larvae were collected regularly throughout both of these winters. The relative abundance of *A. quadrimaculatus* and *A. crucians* larvae in relation to mean water temperature during 1949 is shown in Figure 9. Above 75° F. the proportion of *A. quadrimaculatus* rose rapidly. Below 75° F. larval collections were always predominantly *A. crucians.*

A. punctipennis larvae and adults were most abundant during the winter months, but could be found in considerable numbers in suitable breeding areas throughout the year. In southwestern Georgia, *A. punctipennis* s.l. was represented by both the typical form and the "single haired" form, *A. p. perplexens* Ludlow. Bellamy (1956), after an exhaustive study, concluded that each form represents a distinct species. Ova of the two forms are easily recognized by the size and shape of the dorsal exposure of endochorion. In *A. punctipennis* ova this exposure is slipper-shaped and smooth-edged while in *perplexens* ova a much narrower area is exposed and the sides of the exposure are wavy. On fourth instar *perplexens* larvae, hair 2 on abdominal segments IV and V is predominantly single but is generally branched on *punctipennis.* Adults of *punctipennis* have longer wings than *perplexens* and the light subcostal spot is reduced in *perplexens.* Ecologically, *A. punctipennis* was found in a wide variety of temporary and permanent waters, but *A. perplexens* was apparently restricted to limestone springs and the streams formed by them.

Since no effort was made to separate the two forms before 1949, only *A. punctipennis* s.l. is considered in this report. Adult populations were low from June to September (Figure 10), rose sharply to a peak in October, receded in December when low midwinter water temperatures occurred, increased in February and reached the highest peak in March or April. The trend of larval abundance was the same as that of adults.

In the laboratory, ovarian development of *A. punctipennis* proceeded at reduced temperatures, but oviposition did not occur until the temperature was raised. Engorged adult females held at a constant temperature of 56° F. produced no ova within 15 days. However, specimens which were removed after 6 to 13 days' exposure to 56° F. temperature and placed at a constant temperature of 75° F. always oviposited within 2 to 16 hours.

The remaining three species of *Anopheles* in the area were collected infrequently. *A. barberi* was found occasionally in tree holes, the characteristic habitat of this species, but successive collections of *A. barberi* larvae could rarely be made from the same tree hole. *Anopheles georgianus* King was identified only once in larval material collected in the study area. Adults of this species are indistinguishable from *A. crucians.* During the winter of 1937–38 Bellamy (1939) collected *A. georgianus* larvae from Brooks, Sumter, Terrell, and Thomas Counties, all within 50–75 miles of the study area. Additional collections made subsequently in these counties indicate that larvae may be collected almost any time during the year. The classic habitat of this species is pasture-land seepage areas which are headwaters of small streams. In these habitats *A. georgianus* may be associated with a few *A. crucians*

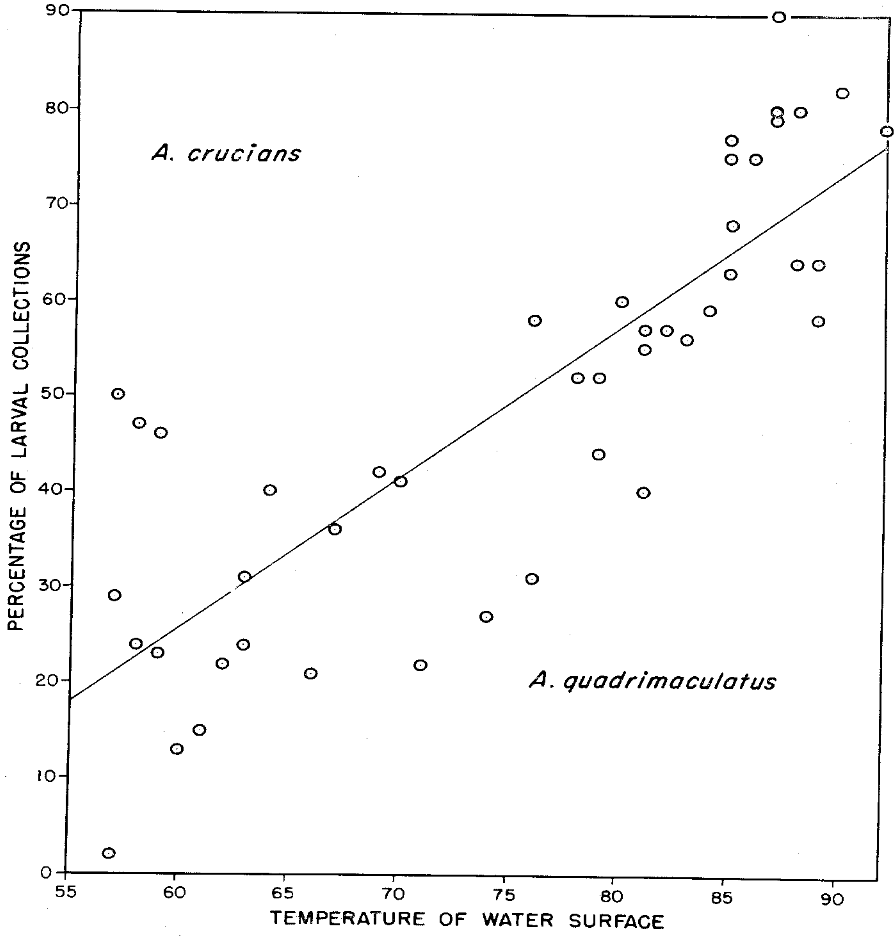

FIG. 9.—Relative abundance of *A. quadrimaculatus* and *A. crucians* larvae in a permanent breeding area during 1949 in relation to surface water temperature. Shown are individual collections (circled points) and line of least squares. Area below the line (or point) shows percent of *A. quadrimaculatus*. Area above line shows percent of *A. crucians*.

but seldom with any other species of *Anopheles*. *Anopheles walkeri* Theob. was collected with light traps 5 times in 18 years; larvae were not collected.

Ova of both *A. crucians* and *A. punctipennis* were observed to withstand desiccation. A soil sample removed from a pond basin which had been dry for the 10 previous days was held at room temperature and approximately 50 percent relative humidity in the laboratory for 24 hours to allow further drying. Fifty

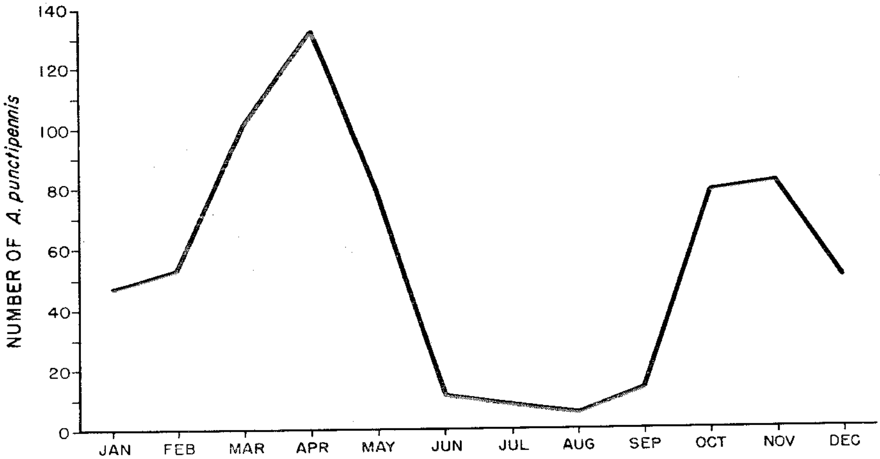

FIG. 10.—Average season abundance of *A. punctipennis,* Baker County, Georgia

anopheline larvae, both *crucians* and *punctipennis,* hatched when the soil was flooded. Subsequent insectary studies showed that, as long as mud was sufficiently moist to maintain a film of water on the surface, *A. quadrimaculatus* ova would hatch in the usual time. Under the same conditions larvae would develop to the pupal stage although the rate of mortality was high (90–95 percent). No adults were obtained.

During 1947 and 1948 precipitin tests were made on ingested blood in freshly engorged *Anopheles.* Of 4,971 *A. quadrimaculatus* and 4,244 *A. crucians* tested, 4,616 *A. quadrimaculatus* and 3,897 *A. crucians* reacted to human, equine, porcine, bovine, or avian antisera. Results indicated that approximately 1 percent of each species had fed on humans, slightly more than 1 percent on birds, and nearly 98 percent on horses, cows, or pigs. Most specimens were collected in barns and sheds; few were found in or under houses.

CULEX. In southwestern Georgia, the genus *Culex* is represented principally by *C. territans* and *C. restuans* in the winter and by *C. p. quinquefasciatus, C. nigripalpus, C. erraticus, C. peccator,* and *C. pilosus,* during the summer.

C. territans and *C. restuans* are predominantly northern species, and south Georgia is near the southern limit of distribution. These species were seldom collected except during the late fall and early spring probably because of unfavorable high temperature during the remainder of the year. The seasonal occurrence of each species paralleled the distribution of *A. punctipennis* (Figure 10). Adults were most abundant from March to May and were collected rarely during the summer. The number of adults and larvae increased in August or September and the adults usually reached a secondary peak during November. The annual pattern of occurrence was consistent but density varied from year to year. During mild winters, e.g. 1948–49 and 1949–50, larval development apparently was not interrupted and adult populations were sustained at high levels from November through April. During more severe winters, the lower temperatures inhibit development but do not cause serious mortality among larvae. Adults are less active, however, less oviposition occurs, larval populations are smaller, and adults emerge during a comparatively shorter period than during mild winters.

Larvae of both species were common throughout the winter months, *C. territans* in the ponds and *C. restuans* in artificial containers and small temporary rain pools. During dry periods *C. territans* also was found in artificial containers. Apparently, this species was highly selective in choice of oviposition sites. Egg rafts were obtained from pools 10 to 25 feet in diameter which contained decaying leaves but no eggs were present at the same time in similar adjacent pools which contained no debris.

The developmental time of *C. restuans* larvae varied with temperature; less mortality occurred at low than at high temperatures. At a constant temperature of 78° F. or higher, less than 40 percent of the *C. restuans* developed to the pupal stage. Those which survived completed the cycle from ova to adult in 10 to 15 days. When larvae were alternated at 24-hour intervals between water baths at 85° F. and 55 to 60° F., the developmental period was lengthened to 20 to 25 days and mortality was reduced to less than 20 percent. Larvae reared at a constant temperature of 55° F. to 60° F. required more than 30 days for development to the pupal stage, but mortality was only 14 percent.

Results of the laboratory studies were consistent with field observations. The average mean air temperatures during the periods when adult *C. restuans* were most abundant were 68.3° F. and 58.3° F. in October and November and 61.0° F. and 67.5° F. during March and April (Table 2, Figure 10). The higher spring peak was attributed to the longer period of temperatures favorable for larval development than preceded the fall peak.

The periods of maximum adult activity and oviposition, as indicated by light trap collections and daily collections of ova from selected breeding sites, occurred when the temperature was between 50° F. and 60° F. Activity declined steadily with lowering temperatures, and, at approximately 40° F., ova and adults were not collected.

In the summer, *C. restuans* in artificial containers was succeeded by *C. p. quinquefasciatus*. This species became very abundant around houses and barns but was found rarely in woodland areas. *C. p. quinquefasciatus* adults were taken in traps from March through November, and larvae were collected regularly from March through October; one collection of larvae was made in January 1950. A few hibernating adults were collected during the winter months by fumigating hollow trees.

Chickens apparently were the principal source of blood. This impression was corroborated by a laboratory study conducted during the summer of 1954. A large colony, reared from specimens collected in nature, was established in a cage 10 by 10 by 15 feet. Rabbits and birds were placed in the cage as constant sources of blood. Human blood was offered for one-hour intervals two or three times each day between 8 a.m. and 8 p.m. The locations of the rabbits and birds within the cage were changed each 24 hours so that the animals were placed at all possible elevations in relation to one another. Each morning a sample of freshly engorged females was collected and prepared for precipitin tests. None of nearly 200 specimens tested fed on either human or rabbit blood.

Culex nigripalpus was usually rare. With the exception of a single collection of larvae in March, specimens were observed only from August through November. Larvae occurred most frequently in ditches and small open pools but occasionally during the late summer months, large numbers were obtained from permanent ponds which had receded to depths of one to two feet. At this stage lush growths of floating and emergent vegetation were present. In these areas, more than one egg raft per square foot of water surface was sometimes oviposited in a single night. During periods of such heavy production, which lasted from 6 weeks to 2 months, *C. nigripalpus* adults accounted for more than 50 percent of all mosquitoes in light trap collections.

Culex salinarius was collected in light traps in November 1942. A single male was identified early in the month and one female was found in a collection made approximately two weeks later. The two collecting stations were 15 miles apart. These two specimens represent the only record of this species from the study area.

The difficulty in specific identification of the *C. (Melanoconion)* group poses a problem to mosquito ecologists in the area. Until recently three species in south Georgia, *C. erraticus*, *C. peccator*, and *C. pilosus*, were considered members of this group. Each species apparently occupies a separate ecological niche but the three are indistinguishable as adults except by study of the male genitalia. After an intensive study of *C. (Melanoconion)* larvae, Foote (1954) revised the subgenus *Mochlostyrax* for some species including *C. pilosus*.

C. erraticus larvae succeeded *C. territans* in permanent ponds during the summer months. *C. erraticus* was the most common *Culex* in ponds from May to October; larvae were not collected in December, January, or February. *C. peccator* larvae were found most frequently in semipermanent, sunlit ponds which contained heavy growths of emergent vegetation. *C. pilosus* was collected only from roadside ditches and small temporary pools. Observations corroborated reports of others (King, *et al.*, 1939) that ova of *C. pilosus* withstand desiccation. Larvae were collected within a few hours after flooding from areas which previously were dry. Positive identifications of *C. pilosus* and *C. peccator* adults were made from light trap material collected from July to November. *C. erraticus* adults were identified from material obtained during each month of the year. Both *C. erraticus* and *C. peccator* were collected by fumigating hollow trees during the winter months. Because of the time involved, many collections were identified only as *C. (Melanoconion)*.

CULISETA. Two species of *Culiseta* occurred in the area, *inornata* (Will.) and *melanura* (Coq.). Both were most abundant during the winter and early spring; *inornata* was readily attracted to light traps, but *melanura* was taken only occasionally (Love and Smith, 1957). However, in collections with mechanical sweep nets which utilized no attractant, the species were equally abundant. Both species were collected in greatest numbers with light traps during April, but specimens were collected occasionally throughout the year.

Female *Culiseta inornata*, collected in the field, oviposited readily in the insectary. Adults were held in 18- by 18- by 24-inch screen cages, and clear glass finger bowls half filled with tap water were placed on the bottom of the cages to receive the eggs. After hatching in 2 to 4 days at 78° F., larvae were placed in an aquarium. Larval development was completed in approximately 15 days, and adults emerged 6 to 10 days later. Mortality was low among larvae and pupae reared in the aquarium but was high when enamel pans were employed as for rearing *A. quadrimaculatus*. Mating was observed in many instances, but few females fed when offered rabbit, pigeon, human, and fox blood from cotton pledgets. No eggs hatched from several egg rafts obtained in the insectary.

Culiseta inornata larvae darted to the bottom of rearing pans or aquariums at the slightest disturbance and remained motionless for several minutes. This behavior probably accounted for the infrequency with which larvae of this species were obtained in routine larval collections.

Larvae of *Culiseta melanura* were collected infrequently from small grassy marshes or shallow permanent pools. Although light traps are only slightly attractive for this species, adults were taken in this manner each month during the year but were most abundant from February through May. In some years adults were not collected with light traps from April through December.

Laboratory studies substantiated the observations of Chamberlain *et al.* (1955)

that larvae collected from a cool environment require a short period of conditioning to enable survival at higher temperatures in the insectary. Larvae collected in November or December required as long as two months to complete development from third or fourth instar to adult. Development time was not affected by variations in length of the photoperiod. Females fed on a pigeon, but mating apparently did not occur in a cage 18 by 18 by 24 inches. The egg rafts deposited were distorted and failed to hatch. Reared adults survived as long as 3½ months under insectary conditions.

URANOTAENIA. *U. sapphirina* was generally the most common species of mosquito in permanent ponds from spring until fall. Larvae were found in almost any situation suitable for *Anopheles* and also in open sunlit ponds. Probably because larvae of *Uranotaenia* can survive and develop at higher temperatures than can *Anopheles,* adult populations did not drop during the hotter months as did anopheline populations. Larvae were usually found from March to November but were never collected in December, January, or February. Collections with light traps, which are strongly attractive to *Uranotaenia,* indicated that adults are first active in March and increased rapidly to a peak in July, when as many as 5,000 specimens were taken by a single light trap in one night. Populations receded slowly through September and dropped rapidly during October and November. Few adults were collected in light traps throughout the winter but many hibernating *U. sapphirina* females were collected by fumigating hollow trees. In one instance over 400 specimens were recovered from one tree. Largest numbers of specimens were found in trees having large hollow areas with small entrance openings (Zukel, 1949a). Few *Uranotaenia lowii* Theob. were identified.

MANSONIA. *M. perturbans* is the only species of this genus found in southwestern Georgia. Most of the permanent ponds provide suitable habitats for larvae of this species. Plants commonly associated with *Mansonia* were *Sururus cernuus* and *Pontederia cordata.* Adults of the single annual generation first emerge in April and almost immediately become abundant around breeding areas. Adults were prominent in light trap collections through June and were collected occasionally through October. Biting records indicate that adults are most active at dusk before light traps can be utilized effectively. *M. perturbans* fed readily on humans in shaded situations adjacent to breeding areas at any time of the day. Adults were never collected from October until April, which was probably the minimum time of larval development in this area. In the insectary at 78° F. ova were obtained from wild-caught females 6 to 8 days after feeding and in every instance ova required 5 days for hatching.

AEDES. Thirteen species of *Aedes* were found in southwestern Georgia. Their distribution and abundance was apparently governed by temperature and rainfall.

Ae. mitchellae and *Ae. canadensis* occurred primarily during the cooler months, but *Ae. mitchellae* was collected occasionally in light traps throughout the year. *Ae. vexans* was found from early spring until late fall. The remaining species of *Aedes* occurred primarily from April through August, but during mild winters breeding sometimes continued without interruption.

Deficient precipitation during the water-storage period (January, February, and March) from 1949 to 1954 depleted breeding areas. During one or more years of this period almost all ponds became dry. Suitable conditions for breeding of *Aedes* and *Psorophora* developed in most ponds when water levels were reduced. Consequently, populations of these mosquitoes were unusually large during the summers of 1950 to 1954 compared with populations from 1945 to 1950 when pond levels were high. During the years of normal precipitation *Aedes* and *Psorophora* spp. comprised less than 10 percent of light trap collections but during the dry years these species accounted for more than 90 percent of the specimens collected. Also, during the drier years, total mosquito catches in light traps were 80 percent higher than in the years when average breeding conditions existed (Smith and Love, 1956).

The seasonal distribution and abundance of *Ae. mitchellae* and *Ae. canadensis* was similar to *A. punctipennis* (figure 10). Larvae of these species were found in temporary grassy pools. Ova were deposited in areas subject to flooding and larvae hatched when water accumulated after winter or early spring rains. Hatching was sometimes delayed and development of larvae prolonged by severe cold. As observed for the winter *Culex* species, larvae sometimes accumulated during the winter and caused an explosive increase in adult populations early in the spring. *Ae. vexans* sometimes occurred early in the spring, but became most abundant in April or later. At the peak of production some rain-filled depressions literally teemed with larvae. *Ae. atlanticus* and *Ae. infirmatus* sometimes became locally abundant from May through September when woodland pools were filled. *Ae. sticticus* (Meig.), *Ae. tormentor* D. and K., *Ae. thibaulti* D. and K., *Ae. fulvus pallens* (Ross), *Ae. dupreei* (Coq.), and *Ae. cinereus* Meig. occurred in lesser numbers but became locally abundant for short periods between May and July. *Ae. triseriatus* overwintered as larvae observed in tree holes at most times of the year. Larvae were also found in artificial containers in shaded situations. Adult *Ae. triseriatus* were collected infrequently by light traps or by biting collections from March through summer. Most other *Aedes* were readily attracted to light traps.

Ae. aegypti (L.) occurred in artificial containers only in the urban areas. A survey of one city in October 1956 revealed larvae in 88 percent of the city blocks and at over 40 percent of the individual residential or business premises examined. Studies in this area indicated that *Ae. aegypti* larvae probably survived the winter in outdoor containers (Smith and Love, 1958).

Insectary studies showed that drying and reflooding were not necessary for hatching of all *Aedes* ova. *Ae. vexans* ova, which were deposited directly on water and remained for 10 days without hatching, usually hatched readily after transfer to a hatching medium consisting of an infusion of dog biscuits and water which had aged for two or three days to reduce oxygen concentration. Ova did not hatch until they were submerged in the medium. This occurred readily when a drop of water fell on the egg. Hatching followed within 15 minutes. Studies of hatching also showed that *Ae. vexans* ova in nature did not hatch when flooded during the winter when temperatures were low. However, ova remained viable for at least several months. In one instance, samples were removed in May from the bottom of a pond which had held water for four months following a winter rain. *Ae. vexans* larvae hatched after the samples were dried thoroughly and reflooded.

Studies were made on the effect of light on development of *Ae. triseriatus* following observations that larval stages were prolonged in a laboratory colony (Repass, 1953) during the fall (Love and Whelchel, 1955). It was found that shortening the photoperiod in the fall stimulated production of ova from which photosensitive larvae developed. These larvae pupated only when the duration of daylight was approximately 12 hours or more. Larvae from ova produced at other times of the year did not show such sensitivity and were capable of completing development in total darkness. In the insectary where the photoperiod approximated that in nature, the first pupae were obtained from overwintering larvae in late January. Pupation continued through February and 50 to 60 percent of the larvae pupated during March. Field collections made concurrently with the laboratory study showed that 70 to 80 percent of the *Ae. triseriatus* in natural tree holes were in the pupal stage when pupation in the laboratory was complete. Two weeks later no larvae or pupae were present in the same tree holes. As a result of these studies, continuous production of larvae was obtained by regulation of the photoperiod to which adults were exposed.

PSOROPHORA. In southwestern Georgia, the genus *Psorophora* is represented by 8 species (Table 3). Larvae developed in temporary wheel ruts and roadside ditches. Under favorable conditions many species developed from ova to adult in 5 to 7 days. *Aedes* sp. usually predominated in the intermittent ponds but *Psorophora* sometimes occurred in these situations.

Ciliata, confinnis, and *ferox* were the most common *Psorophora* with respect to frequency of collection, number of specimens, and period of occurrence. The average seasonal distribution was from May through October, but moderate temperatures in early spring or late fall extended this range from February or March through November. Although encountered less frequently, *P. cyanescens* and *P. discolor* sometimes became locally abundant following summer rains. *P. horrida, P. howardii,* and *P. varipes* were collected infrequently and in small numbers. Prior to 1955 *P. discolor* had been collected on only two occasions. During this year specimens were identified regularly, and, in 1956 *P. discolor* was as prominent as *P. confinnis* in breeding areas which had previously produced only *P confinnis.* In 1957 *P. discolor* was collected regularly but was not so abundant as during the two previous summers.

Females of all *Psorophora* spp. in the area were fierce biters and fed readily at any time of the day in shaded situations near breeding areas. Specimens rarely were observed biting other than in wooded areas during the day. Of the more common species of *Psorophora, confinnis* and *ciliata* were readily attracted to light traps but few *ferox* were collected in this manner.

ORTHOPODOMYIA and *TOXORHYNCHITES*. *O. signifera* and *T. r. septentrionalis* were found throughout the area in tree holes and shaded artificial containers. Adults of *O. signifera* were collected infrequently in light traps. Specimens rarely fed in the laboratory. A few individuals fed on an immobilized bird held overnight in the cage, but none fed on humans, rabbits, chickens, or caged birds or from cotton pledgets soaked with blood from these animals. *O. signifera* overwintered as photosensitive larvae and pupated only when days lengthened in the spring (Baker, 1935). Larvae were collected each month of the year.

T. r. septentrionalis adults were rarely observed in nature. Specimens were collected twice in light traps and on two occasions a single adult was observed on the wing in a densely wooded area. Larvae of the species can withstand temperatures below freezing. Specimens held at approximately 30° F. in a block of ice for a period of one week apparently suffered no ill effect. Larvae were killed within 24 hours, however, when exposed to temperatures of approximately 0° F. The species overwinters as larvae or ova. Some overwintering larvae of *T. r. septentrionalis* collected in the field remain in the fourth instar for several weeks after being placed in the insectary at 80° F. Other specimens, however, pupate within a few days.

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