LIFE HISTORY STUDIES ON ARTIFICIALLY PRODUCED BROODS OF FLOODWATER MOSQUITOES IN THE TENNESSEE VALLEY

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INTRODUCTION. Several of the most important species of pest mosquitoes occurring in the Tennessee Valley are those of the floodwater group in the genera *Aedes* and *Psorophora,* principally *Ae. vexans, P. confinnis,* and *P. cyanescens.* Interest in this group has accelerated in recent years, paralleling the general realization of its economic and public health significance. TVA's Vector Control Branch is concerned primarily with the control of these mosquitoes under reservoir conditions, i.e., with nuisance populations resulting from TVA waters or conditions created by TVA activities. There are two basic types of breeding situations meeting these criteria in the Valley: (1) extensive flats associated with heads of tributary creeks and streams which are occasionally inundated by high water above drainage levels, and (2) river bottoms adjacent to main river reservoirs which may be inundated by overflowing river water or heavy rainfall. The latter sites are frequently found near concentrations of people (towns, cities, and recreational sites) and for this reason have received particular emphasis.

The principal objective of the current study is to investigate factors in the life history of a natural population of floodwater mosquitoes which are considered important to their control under river bottom conditions, particularly hatching rates, developmental time, blood feeding, and oviposition rates. The work is being conducted in a large river bottom (McFarland Bottom, Florence, Alabama) on Pickwick Reservoir near Wilson Dam, a convenient site which typifies several problem areas existing in various parts of the Valley.

METHODS. An experimental pool, actually a low depression of about three-fourths of an acre, was artificially flooded by pumping water from the adjacent Tennessee River during each month of the mosquito breeding season, May through October 1962, resulting in six broods of mosquitoes. No natural broods occurred during the period. Prior soil sampling indicated this depression to be a favored oviposition site, harboring eggs of several species (*Ae. vexans, Ae. atlanticus, Ae. trivittatus, P. confinnis, P. cyanescens, P. ciliata, P. ferox, P. discolor*). Dominant vegetation was *Carex lupulina, Juncus effusus,* and *Polygonum hydropiperoides.* Represented were *Isnardia palustris, Rumex crispus, R. verticillatus, Panicum agrostoides, Campsis radicans,* and a species each of *Aster* and *Ranunculus* as well as a moderate amount of Bermuda grass.

Sandbox-type frames constituted eight test plots of 96 square feet each (8' x 12' x 12"). The plots were selected to reflect contour and habitat differences within the pool. Half of the frames were fitted with tight-fitting aluminum wire screens to prevent further oviposition. This allowed an evaluation of the hatching pattern of overwintering eggs through the breeding season. These screens were removed when water had filled the plots during each flooding and replaced immediately after adult emergence was complete. In each case the screened plot was a counterpart of an unscreened plot in regard to contour and vegetation. The resulting broods of mosquitoes were studied in the field from eclosion to adult emergence and blood feeding. Field investigations were supplemented by insectary studies of isolated, wild-caught females produced by the floodings and collected by aspirator during the blood-feeding period at the site.

These females were allowed to take a full blood meal in the field, were then aspirated, caged, and taken the same night to the TVA insectary in a common cage provided with sugar water. Healthy, well-fed females were subsequently isolated, one each, in quart-size, paper ice cream cartons with a lid at each end. The bottom lid contained a thin layer of water-saturated, clean, white sand. The top lid was screened with wire. These containers were numbered consecutively, provided with a sugar-water pad on the screen top, and checked daily. Each day, each female was offered a blood meal (finger on screen top) and provided fresh sugar water. Each carton was checked for eggs which, if present, were counted, recorded, and stored in color-coded (by species), cupcake liners in muffin pan depressions lined with water-saturated sand. This allowed retention of moisture for 24–48 hours which is believed to be a requisite for embryonic development after egg deposition. Pertinent data on each specimen were recorded daily. Shorthand pads were found extremely useful for both field and insectary data. An isolation was considered successful when the female had lived for at least one week and/or had taken a full blood meal in confinement. Blood-feeding and oviposition records were obtained in this manner on 150 females representing four species (*Ae. vexans, P. confinnis, P. cyanescens,* and *P. ciliata*).

FIELD RESULTS. The data of Table 1 show that, in spite of six consecutive monthly floodings of the same depression, the mosquito fauna continued to survi throughout the season. The fact that larv counts during any brood were not signi cantly different in the screened vers open plots indicates that a sufficient nur ber of overwintering eggs were in the s to allow a substantial mosquito populati to be produced through six floodin without additional eggs being deposite Furthermore, the population density, shown in the table, did not steadily decli with successive floodings as might be e pected, there being more larvae per squa foot in September (40) after five floodin than in June (4) after only two flooding The October decline possibly reflects cold weather. The species composition of ea brood is seen in Figure 1. Screened plo were covered at the end of the Octob brood and remained in place throug the winter of 1962–63. It was planned continue these experiments as long as eg continued to hatch in the hope of discove ing how long the eggs can remain viab in the soil and how many floodings th can withstand before hatching. It is a ready obvious that eggs deposited as f back as the fall of 1961, and perha earlier, hatched as late as the fall of 196 after failing to do so in five earlier month floodings.

Figure 1 further shows the develo mental time of each of the monthly broo for the composite population, as well the species composition of each brood. can be seen that the May brood was a most pure *Ae. vexans* with very fe *Psorophora* and no *P. confinnis* in th

TABLE 1.—Sampling results, experimental plots of artificially produced broods of floodwater mosquitoes, Florence, Alabama, 1962.

Brood	Population density [1]	Number of dips [2]	Number of larvae per dip	
			Screened plots	Open plo
I (May)	100	120	7.0	9.1
II (June)	4	200	1.7	1.9
III (July)	30	200	3.9	3.5
IV (Aug.)	30	400	4.4	4.0
V (Sept.)	40	280	7.3	6.4
VI (Oct.)	4	280	2.0	2.0

[1] Field estimate of larvae per square foot, entire flooded depression.
[2] Equal number in screened and open plots.

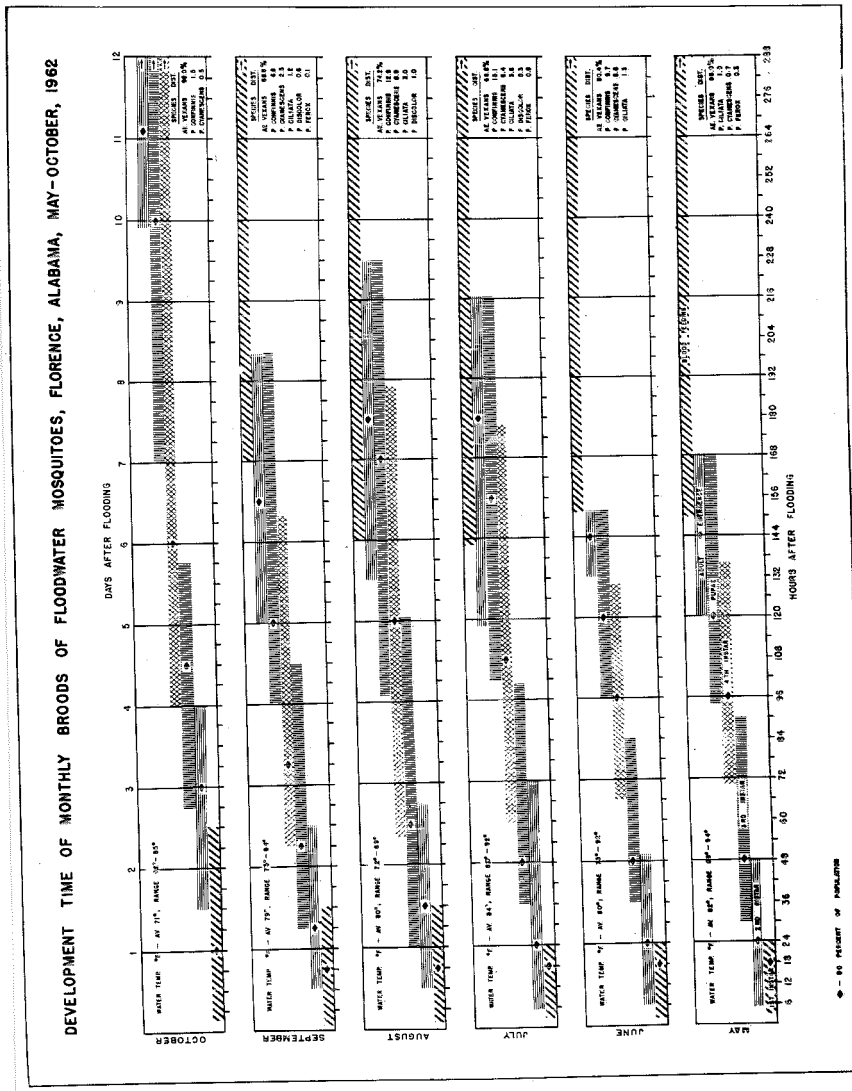

DEVELOPMENT TIME OF MONTHLY BROODS OF FLOODWATER MOSQUITOES, Fflorence, ALABAMA, MAY-OCTOBER, 1962
DAYS AFTER FLOODING
HOURS AFTER FLOODING
OCTOBER
SEPTEMBER
AUGUST
JULY
JUNE
MAY
WATER TEMP °F - AV 71°, RANGE 38°-85°
WATER TEMP °F - AV 75°, RANGE 72°-84°
WATER TEMP °F - AV 80°, RANGE 72°-88°
WATER TEMP °F - AV 84°, RANGE 69°-98°
WATER TEMP °F - AV 80°, RANGE 57°-93°
WATER TEMP °F - AV 80°, RANGE 60°-94°
SPECIES DIST.
AE. VEXANS 98.1%
P. COMPANIS 1.5
P. CONNECTANS 0.4
AE. VEXANS 88.9%
P. COMPANIS 3.5
P. CONNECTANS 3.5
P. COLUMBIANA 1.5
P. OLIATA 1.5
P. FEROX 0.1
AE. VEXANS 71.1%
P. COMPANIS 18.9
P. COLUMBIANA 8.0
P. OLIATA 2.0
P. FERENS 1.0
AE. VEXANS 58.8%
P. COMPANIS 16.1
P. COLUMBIANA 8.4
P. OLIATA 8.4
P. FERENS 8.9
AE. VEXANS 80.4%
P. COMPANIS 8.8
P. CONNECTANS 8.8
P. OLIATA 1.9
AE. VEXANS 69.3%
P. COMPANIS 29.3
P. COLUMBIANA 0.7
P. FEROX 0.3
0 12 18 24 36 48 60 72 84 96 108 120 132 144 156 168 180 192 204 216 228 240 252 264 276 288
1 2 3 4 5 6 7 8 9 10 11 12
● - 90 PERCENT OF POPULATION

FIGURE 1

population. Thereafter, until October, the *Psorophora* ratio was more apparent, especially in July, when it represented about one-third of the total population. *Ae. vexans,* however, dominated each population. It is interesting that distribution of the species in this experimental pool reflects the pattern in the Valley as a whole: *Ae. vexans* > *P. confinnis* > *P. cyanescens* > *P. ciliata.*

The May and June broods represent what appears to be "the usual"; i.e., general hatching within 2–3 hours, a first stage larval population at 18 hours, a second stage larval population at 24 hours, a third stage larval population at 48 hours, a fourth stage larval population at 96 hours, a pupal population at 120 hours, and an adult population at 144 hours (6th day), with emergence complete at 168 hours (7th day). Blood feeding reaches a peak on the 8th day but may be observed as early as the 6th day and continues for several days thereafter until migration occurs.

The July and August broods showed a slower development than the earlier two, but the reason is unknown; perhaps food supply was a factor since mosquitoes of these broods were noticeably smaller than those of other broods. The September brood approached the May and June broods in developmental time, while the October brood was noticeably slowed by cool temperatures.

Figures 2, 3, 4, and 5 show developmental times of *Ae. vexans, P. confinnis, P. cyanescens,* and *P. ciliata,* respectively. Of note is the following:

Aedes vexans (Fig. 2)

Hatching occurred within three hours in all broods and as early as one hour in September. The earliest group development of mature larvae occurred at 90 hours in September, with some fourths noted as early as 60 hours. Pupation was general at 120 hours in June, with some noted as early as 96 hours. The earliest emerging adults occurred at 120 hours in May, and the earliest blood feeding was noted at 142 hours in July. In general, the pattern fo this species was that of the population.

Psorophora confinnis (Fig. 3)

Hatching occurred within three hou in the four broods studied and as early a one hour in September; group develo ment to mature larvae was as early as 7 hours in September, with some fourth noted as early as 54 hours. Pupation wa general at 120 hours in September, but i dividuals were noted in the pupal stage early as 100 hours in the July brood. Adu emergence was earliest at 130 hours in th September brood, but a cool spell delaye blood feeding this month so that th earliest record is 152 hours in August. *confinnis* showed a tendency toward rapi development to fourth stage larvae fo lowed by a lag allowing *Ae. vexans* "catch up."

Psorophora cyanescens (Fig. 4)

Hatching occurred in from one to tw hours in the three broods studied. Th earliest mature larvae appeared at only hours in July, but the earliest group reach this stage was at 78 hours in Se tember. Pupae were noted as early as hours, followed by group pupation at 1 hours. The earliest adult emergence individuals was at 118 hours in July, an the earliest group emergence was at 1 hours in September. Here, as in *P. co finnis,* blood feeding was delayed by a co spell, so that the earliest blood feeding b longed to July and August at 144 hou This was noticeably the most rapidly d veloping species of the group, quite willi to bite shortly after emergence, day night.

Psorophora ciliata (Fig. 5)

Hatching ocurred within two hours both broods studied. The first matu larvae occurred at 60 hours in July, wi group populations at 90 hours in July a August. Pupae were noted as early as hours in August, but the July brood p pated first as a group at 120 hours. Adu emergence was general at 144 hours f both broods with the earliest individua

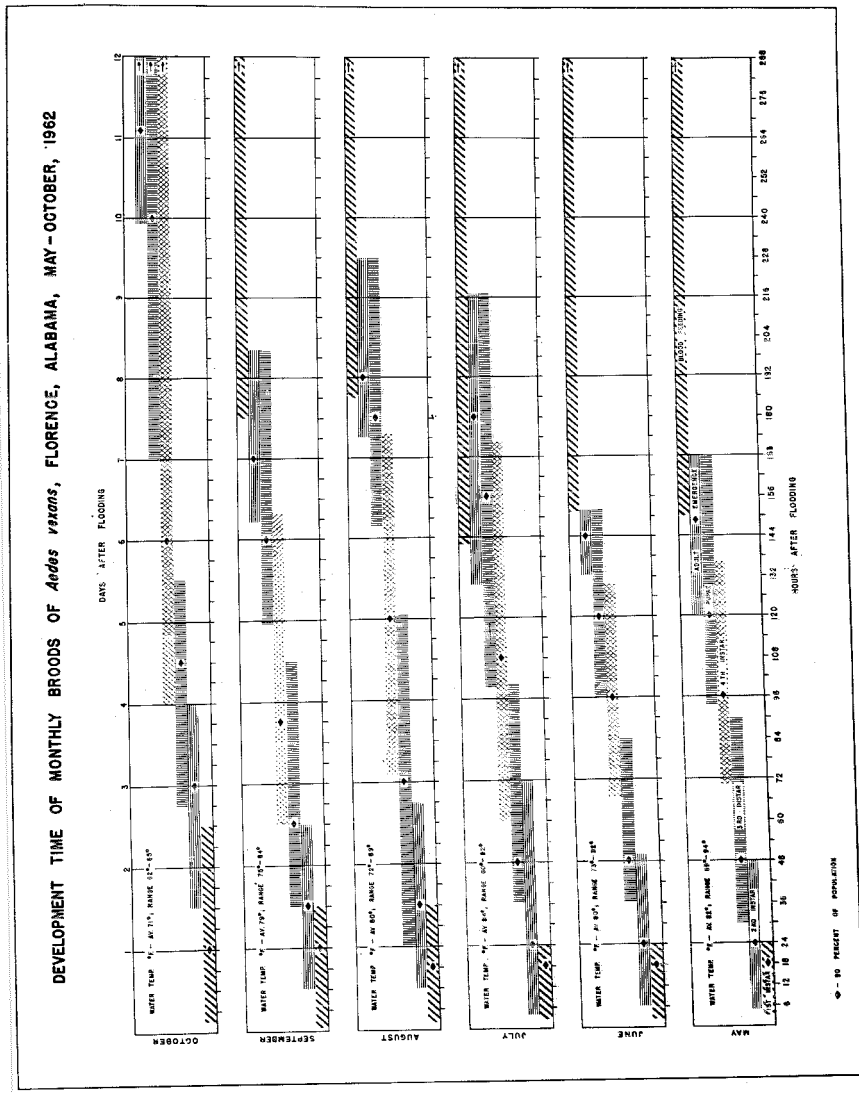
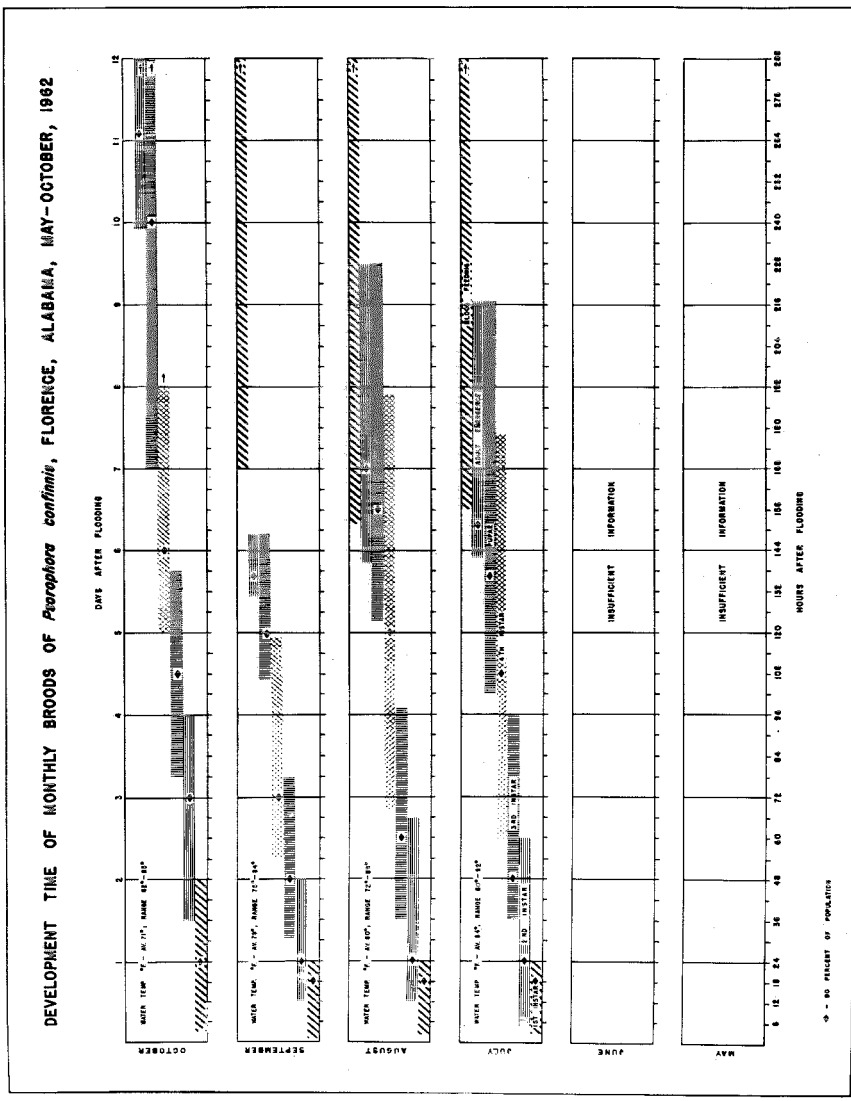

DEVELOPMENT TIME OF MONTHLY BROODS OF *Aedes vexans*, FLORENCE, ALABAMA, MAY – OCTOBER, 1962
DAYS AFTER FLOODING
HOURS AFTER FLOODING
OCTOBER
SEPTEMBER
AUGUST
JULY
JUNE
MAY
◆ – 50 PERCENT OF POPULATION

FIGURE 2


DEVELOPMENT TIME OF MONTHLY BROODS OF Psorophora confinnis, FflorenCE, ALABAMA, MAY–OCTOBER, 1962
DAYS AFTER FLOODING
HOURS AFTER FLOODING
OCTOBER
SEPTEMBER
AUGUST
JULY
JUNE
MAY
INSUFFICIENT INFORMATION
INSUFFICIENT INFORMATION

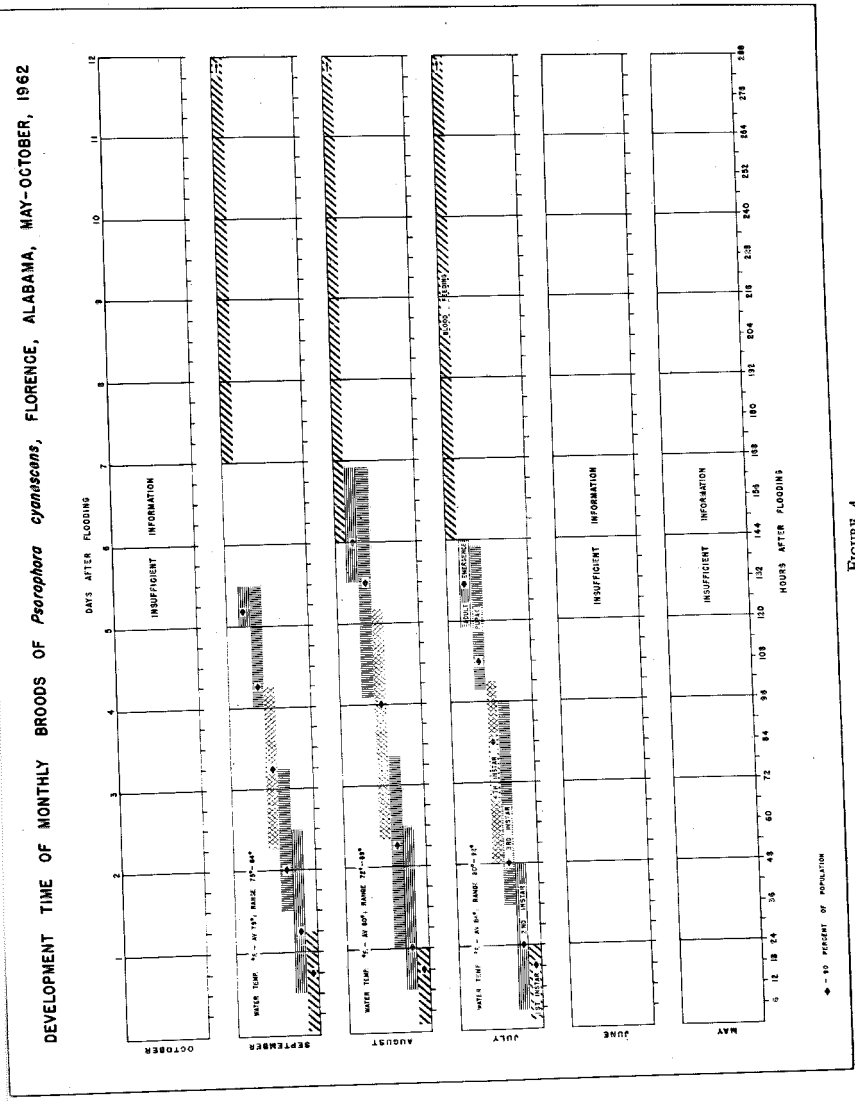

DEVELOPMENT TIME OF MONTHLY BROODS OF Psorophora cyanescens, FLORENCE, ALABAMA, MAY-OCTOBER, 1962
DAYS AFTER FLOODING
HOURS AFTER FLOODING
INSUFFICIENT INFORMATION
OCTOBER
SEPTEMBER
AUGUST
JULY
JUNE
MAY
WATER TEMP.
◆ - 99 PERCENT OF POPULATION

FIGURE 4

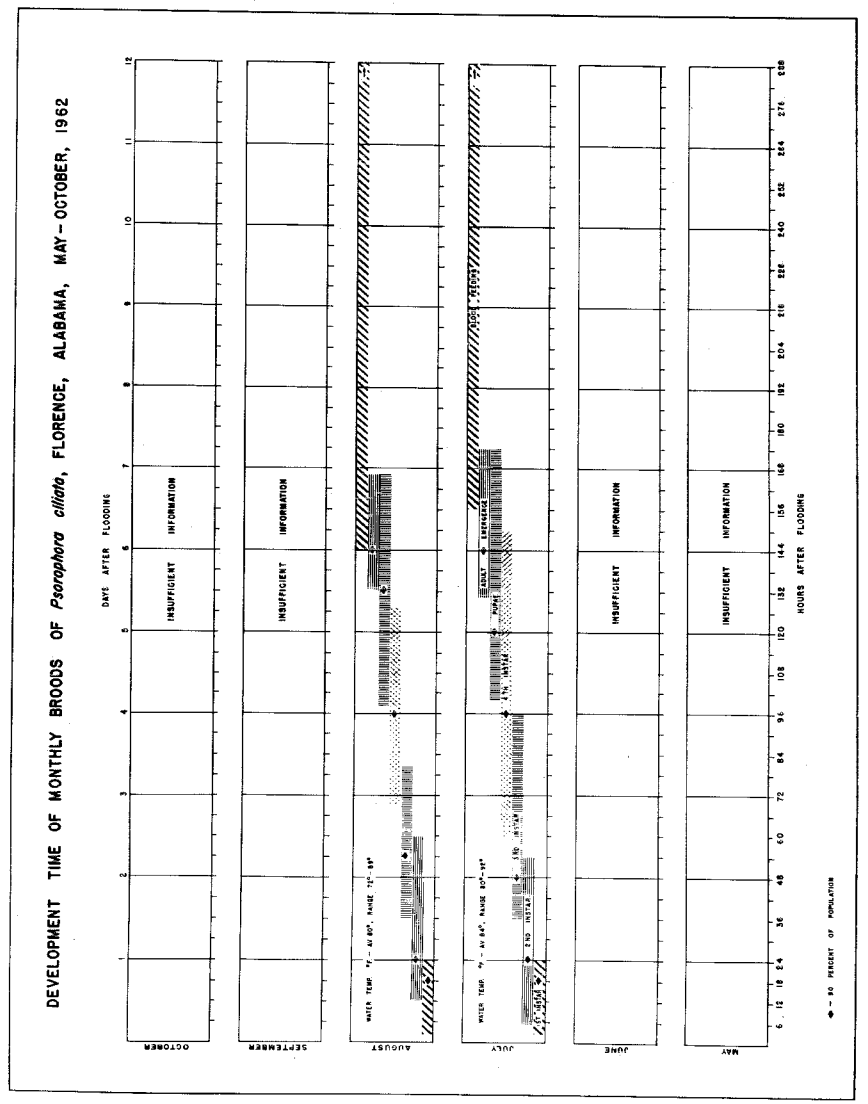

DEVELOPMENT TIME OF MONTHLY BROODS OF Psorophora ciliata, FflorENCE, ALABAMA, MAY-OCTOBER, 1962
DAYS AFTER FLOODING
HOURS AFTER FLOODING
INSUFFICIENT INFORMATION
OCTOBER
SEPTEMBER
AUGUST
JULY
JUNE
MAY
WATER TEMP. 79° - AV 85°, RANGE 72°-99°
WATER TEMP. 79° - AV 84°, RANGE 60°-99°
1ST INSTAR
2ND INSTAR
PUPAE
EARLY EMERGENCE
ROCK PEDDER
● = 50 PERCENT OF POPULATION

FIGURE 5

t 130 hours in July. Blood feeding began t 144 hours in August and 156 hours in uly. This species paralleled that of *Ae. exans* in development.

INSECTARY RESULTS. Table 2 summarzes results obtained on blood feeding nd oviposition habits of 150 isolated feales handled as described under the secion on methods. Experience with these nd other specimens indicates that females aking blood meals in the field, even within the first 24 hours after emergence, re almost sure to have been previously nseminated. This was ascertained from he high percentage of such females depositing viable eggs (column 6), and those having sperm in the spermathecae. Viability was determined by actual hatching and/or dissection, and the presence of sperm by dissection of the spermathecae.

These observations show the three *Psorophora* species to be very easy to handle under isolated conditions, while *Ae. vexans* is more difficult (note columns 2 through 7). The difficulty with *Ae. vexans*, however, was associated with its unwillingness to take blood meals (column 4). Also, it refused to deposit eggs on bare substratum. Eggs were not readily obtained until a shelter of leaf cover was pro-

TABLE 2.—Longevity, oviposition, and blood feeding records of 150 isolated females of several floodwater mosquito species, TVA insectary, Wilson Dam, Alabama, 1962.

Column No.		*Aedes vexans*	*Psorophora confinnis*	*Psorophora cyanescens*	*Psorophora ciliata*
	Number of specimens isolated	20	36	62	32
*	Longevity in days				
	Range:	(6–27)	(10–63)	(6–35)	(11–53)
	Average:	15.8±1.5	31.7±2.7	16.6±0.8	25.8±2.2
	Number taking blood in laboratory	12	33	55	30
	Percent taking blood in laboratory	60.0	91.6	88.7	93.7
**	Number of blood meals				
	Range:	(1–4)	(2–18)	(1–15)	(1–11)
	Average:	1.6±0.3	6.3±0.6	4.7±0.4	4.4±0.5
**	Preoviposition blood meals				
	Range:	(1–3)	(1–5)	(1–8)	(1–6)
	Average:	1.8±0.1	2.8±0.2	3.6±0.3	3.0±0.3
	Number ovipositing viable eggs	12	33	43	26
	Percent ovipositing viable eggs	60.0	91.6	69.4	81.3
	Percent of laboratory blood-fed Specimens ovipositing	75.0	91.6	69.6	83.3
	Number of ovipositions				
	Range:	(1–3)	(1–18)	(1–8)	(1–11)
	Average:	1.7±0.1	5.7±0.8	2.2±0.3	3.4±0.5
*	Preoviposition period in days				
	Range:	(5–19)	(7-19)	(5–22)	(6–39)
	Average:	8.8±1.1	11.5±0.6	12.2±0.7	16.6±1.5
0	Number of eggs per oviposition				
	Range:	(1–226)	(1–181)	(1–99)	(1–91)
	Average:	85.1±21.3	56.2±3.6	30.5±2.9	27.0±0.2
1**	Average number of eggs per blood meal	68.8	46.8	17.7	18.3
2	Lifetime egg deposition				
	Range:	(64–261)	(20–958)	(2–489)	(3–200)
	Average:	149±5.9	326.2±16.1	91.6±14.2	90.6±11.6

* From time of capture.
** Includes field meal at time of capture.

vided, although the eggs were deposited on the sand *under* the leaves. The most cooperative species was *P. confinnis,* followed closely by *P. ciliata* and *P. cyanescens.* This is exemplified by a specimen (No. 112) of *P. confinnis* which lived for 63 days during which time she eagerly took 18 blood meals, oviposited a total of 958 eggs in 18 batches ranging from 3 to 181 per batch, and had 101 mature eggs in her body at death. Feeding time for this specimen ranged (insertion to withdrawal) from 45 seconds to 3 minutes, the usual meal requiring about 2 minutes. The outstanding *P. cyanescens* specimen in the group (No. 12) lived 35 days, deposited 489 eggs in 15 batches ranging from 5 to 98 eggs, and took 15 blood meals. The usual feeding time for *P. cyanescens* was less than 2 minutes, one specimen requiring only 30 seconds. One specimen of *P. ciliata* was outstanding for egg production (No. 168) and a different one (No. 73) for longevity. The former specimen lived only 27 days (about average, column 2), but during that time she took 4 blood meals and deposited a total of 200 eggs in 4 batches ranging in number from 20 to 91 eggs. The latter specimen lived 53 days in confinement, took 9 blood meals (6 before ovipositing any eggs), and deposited only 58 eggs in 5 batches ranging from 1 to 28. *P. ciliata* usually required about 2 minutes for a blood meal, but the range was from 45 seconds to 6 minutes! This species usually required a little more coaxing than either *P. confinnis* or *P. cyanescens* for blood meals; however, on occasion, it was quite aggressive, several specimens escaping from the carton and chasing the donor across the room with "blood in their eyes."

Ae. vexans, even though hard to handle, gave "hints" as to why it is an outstanding pest mosquito. It seems to make greater use of its blood meals (a hazardous event) than the other species as well as a greater utilization of its time.

Note in column 4 that *Ae. vexans* took an average of only 1.6 blood meals as compared to 4.7 and 4.4 for *P. cyanescens* and *P. ciliata,* respectively, but it deposited considerably more eggs in a shorter average lifetime than did either of these species (columns 2 and 12). Furthermore, it began ovipositing earlier in life with fewer preoviposition blood meals (columns 5 and 9) than any of the *Psorophora* species and deposited more eggs per oviposition (columns 8 and 10) as well as more per blood meal (column 11). It is to be noted further that columns 5, 8, 9, 10, and 11 put *Ae. vexans* in a "class by itself" in these important life history items, and columns 4, 5, 9, 10, and 11 essentially form an array paralleling the descending order of importance of these four species in the Tennessee Valley. It is felt that if improved methods can be devised for handling this species in isolation it will show a rather astounding biotic potential.

A surprising observation in this study was the preoviposition period. As many as 39 days (column 9) elapsed before one specimen of *P. ciliata* deposited eggs, but thereafter egg-laying rhythm was good in this specimen. The average period ranged from more than one week for *Ae. vexans* to more than two weeks for *P. ciliata.*

SUMMARY. A river bottom experimental pool harboring large numbers of floodwater mosquito eggs of several species near Wilson Dam, Alabama, subject to intermittent inundation by rainfall and/or river overflow, was artificially flooded by pumping water from the adjacent Tennessee River during each month of the 1962 mosquito breeding season, May through October. The resulting broods of mosquitoes were observed for hatching rates, developmental time, adult emergence, and blood feeding. Additional observations were made on blood meal requirements and oviposition habits with isolated, wild-caught females under insectary conditions.

Field results showed the population to be dominated by *Ae. vexans, P. confinnis, P. cyanescens,* and *P. ciliata,* in that order. Hatching occurred in all species and broods within 1 to 3 hours after inundation. For the composite population, a

irst stage larval population was usual fter 18 hours; a second stage population fter 24 hours; a third after 48 hours; a ourth after 96 hours; pupation reached a eak at 120 hours; adult emergence after 44 hours; with blood feeding beginning everal hours thereafter. A graphic account of development is given for the omposite population and for each of the our species and shows exceptions to the isual.

Eight sandbox-type framed plots, 96 quare feet each, represented habitat and contour differences within the pool. Four of these plots were screened to prevent oviposition. From this it was learned that six successive floodings did not deplete the overwintering egg population of the previous winter.

Insectary results, presented in Table 2, show longevity, blood feeding, and oviposition records of 150 isolated females representing the four dominant species of the study. An interpretation of these results is given in the text, above.

ENTOMOLOGICAL EVALUATION OF A PROPOSED MOSQUITO SOURCE REDUCTION PILOT OPERATION

EMBREE G. MEZGER [1]

During the past decade there has been steady increase in the number of acres nder irrigation in the Solano County Mosquito Abatement District. As a result here has been a gradual change in emhasis within the District from salt-marsh nosquito control to the control of mosquitoes associated with irrigated forage and ow crops. This change in program direction called for greater effort on the part f the District to get farmers to adopt nore efficient land and water management ractices. It soon became apparent that he rate of progress toward this goal was ot keeping pace with the increase in mosquito production potential. In order to neet this need, a carefully-organized and ighly-controlled mosquito source reduction pilot study was undertaken in the Tremont area of Solano County (Pangburn *et al.*, 1961).

This report is concerned with the entomological aspects of the Tremont Township Source Reduction Project, and is an integral part of the information-gathering phase of the study, preliminary to instituting an intensive source reduction program (Dunphy *et al.*, 1962).

Tremont Township is in the Dixon area, which is located in the southwestern part of the Sacramento Valley in California, lying at the eastern base of the Coast Range. This area includes 75,950 acres of irrigated agricultural land; of this, approximately 21,700 acres are in pasture, 13,250 acres in alfalfa, and 41,000 acres in row crops (sugar beets, milo, field corn, tomatoes, and beans).

The climate is characterized by hot, dry summers and cool, moist winters. The greater part of the annual precipitation falls during the winter and early spring, with little or none during the summer and early autumn. Approximately 75 percent of the total annual rainfall occurs between December and March, with less than 2 percent between June and September.

There are three principal soil types in the area under investigation—Zamora

[1] Entomologist, Solano County Mosquito Abatement District, Suisun, California. The kind assistance of Dr. Basil G. Markos and Mr. John R. Walker, California State Department of Public Health, Bureau of Vector Control, in reviewing this manuscript is gratefully acknowledged.