MOSQUITO OCCURRENCE IN A SEASONALLY FLOODED WATERFOWL AREA, MERCED COUNTY, CALIFORNIA

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INTRODUCTION. Each autumn in the Sacramento and San Joaquin Valleys of California approximately 150,000 acres of basin lands (classified as seasonally flooded basins and saline flats) are flooded to produce waterfowl habitats (United States Department of Interior, 1954). The recreational and waterfowl conservational benefits derived from these flooded lands are of great value to the state. However, under certain circumstances wetland areas can be prolific sources of mosquitoes.

The purpose of this study was to obtain quantitative information on mosquito production, seasonal prevalence of species, and the environmental factors associated with mosquito production in waterfowl areas which are subjected to fall flooding. A study area was selected in the southern portion of the Grasslands Water District three miles southwest of Dos Palos in Merced County, California. Before being developed into a waterfowl habitat the Grasslands Water District west of the San Joaquin River consisted of arid, alkaline, low-lying basin land. Leach (1960) reported that this area contained 297 private duck clubs comprising 58,178 acres. Most of the area remains dry from about April until the ponds are flooded in the early fall. This study included 20 of these clubs ranging in size from 60 to 460 acres, totaling 4,000 acres. Some of the land has been partially leveled, the major part having been allowed to remain in the natural condition. Levees about 3 feet in height enclose each duck pond.

The predominant vegetation in the duck ponds and on the levees is saltgrass *(Distichlis spicata)*, wire rush *(Juncus balticus)*, cattail *(Typha latifolia)*, bulrush *(Scirpus robustus)*, and iodine bush *(Allenvolfea* sp.)

Flooding begins the latter part of September and is continued into October. Water is diverted from main supply canals of the Central California Irrigation District into lateral ditches, thence to the duck club areas. Lands not adjacent to the supply ditches are flooded by overflow water from ponded areas proximal to the supply ditches. The water depth varies from 1 to 10 inches with an average of about 6 inches over most of the area.

METHODS. A preliminary survey was made to determine the overall pattern of standing water. Nineteen larval sampling stations were then selected in situations that appeared favorable for mosquito production. Sampling stations fell into three basic habitat types: (1) along shorelines (12 stations); (2) pond interiors (6 stations); and (3) an overflow area between a pond levee and the roadway (1 station).

A pint dipper was used to collect aquatic forms. Ten dips were made at about 10-foot intervals at each station. From these a composite sample of larvae was taken for determination of species and growth stage. For the first set of observations, each station was sampled weekly from September through November 1955, when adverse weather conditions made the area inaccessible.

In 1959–60 the same stations were sampled twice weekly in September and October and, because the road system had been improved, it was possible to make weekly collections from November 1959 until the water disappeared in April 1960.

To obtain information on newly emerged adults, four red boxes 1 cubic foot in volume were distributed throughout the study area. Sweeping collections were also made adjacent to the sampling stations. Techniques developed by Rosay (1960) were used to evaluate the age composition of the mosquito population.

Observations were recorded on water levels and types of vegetation associated with the sampling stations. Temperature data were obtained from the U. S. Weather

Bureau at Los Banos, 7 miles from the study area.

RESULTS AND DISCUSSION. Mosquito larvae were first noted on September 21 in both 1955 and 1959. Five days prior to this date the general area was still dry. Due to limitations of the water supply and distribution system, not all sampling stations were flooded at the same time; therefore, the number of stations flooded varied each week. *Aedes melanimon* Dyar was the first species to appear after flooding (Table 1) and continued to appear as additional ponds were inundated during September and October. The highest average number of *A. melanimon* larvae per dip for a single station was 49.0 in 1955 and 41.9 in 1959, both from shoreline habitats.

The total number of *A. melanimon* larvae for all stations holding water at a particular date is also indicated in Table 1. The peak larval density for *A. melanimon* in both years occurred during the 4th week of September. In 1959 all sampling stations were negative by the first of November; however, six stations were reflooded the last week in November providing conditions for another hatch of *A. melanimon*. The increased numbers of *A. melanimon* larvae collected each year, after the maximum density in September, were results of reflooding (Fig. 1).

TABLE 1.—Occurrence of *Aedes melanimon* larvae in dipping stations for 1955 and 1959–60 study periods, Merced County, California.

Week No.	Total no. of stations holding water		Total no. of larvae collected		Average no. of larvae per dip for highest count station	
	1955	1959–60	1955	1959–60	1955	1959–60
Sept.						
2	0	0	0	0	0.0	0.0
3	5	9	237	745	19.0	41.9
4	10	11	669	856	49.0	34.3
Oct.						
1	12	12	253	27	15.0	2.0
2	12	11	29	57	6.0	3.0
3	12	12	152	191	12.8	1.6
4	12	12	58	204	5.4	3.4
Nov.						
1	11	11	104	0	10.3	0.0
2	11	11	125	0	12.5	0.0
3	11	12	64	90	6.4	9.0
4*	9	12	10	204	1.0	9.8
Dec.						
1	..	14	..	376	..	8.3
2	..	13	..	177	..	3.8
3	..	13	..	95	..	5.4
4	..	13	..	99	..	4.3
Jan.						
1	..	13	..	22	..	0.5
2	..	10	..	6	..	0.2
3**	..	9	..	0	..	0.0
4	..	9	..	0	..	0.0

* Observations terminated end of November 1955.
** All stations negative from third week of January, 1960, to end of study period fourth week of April.

Dissected *A. melanimon* adults, taken

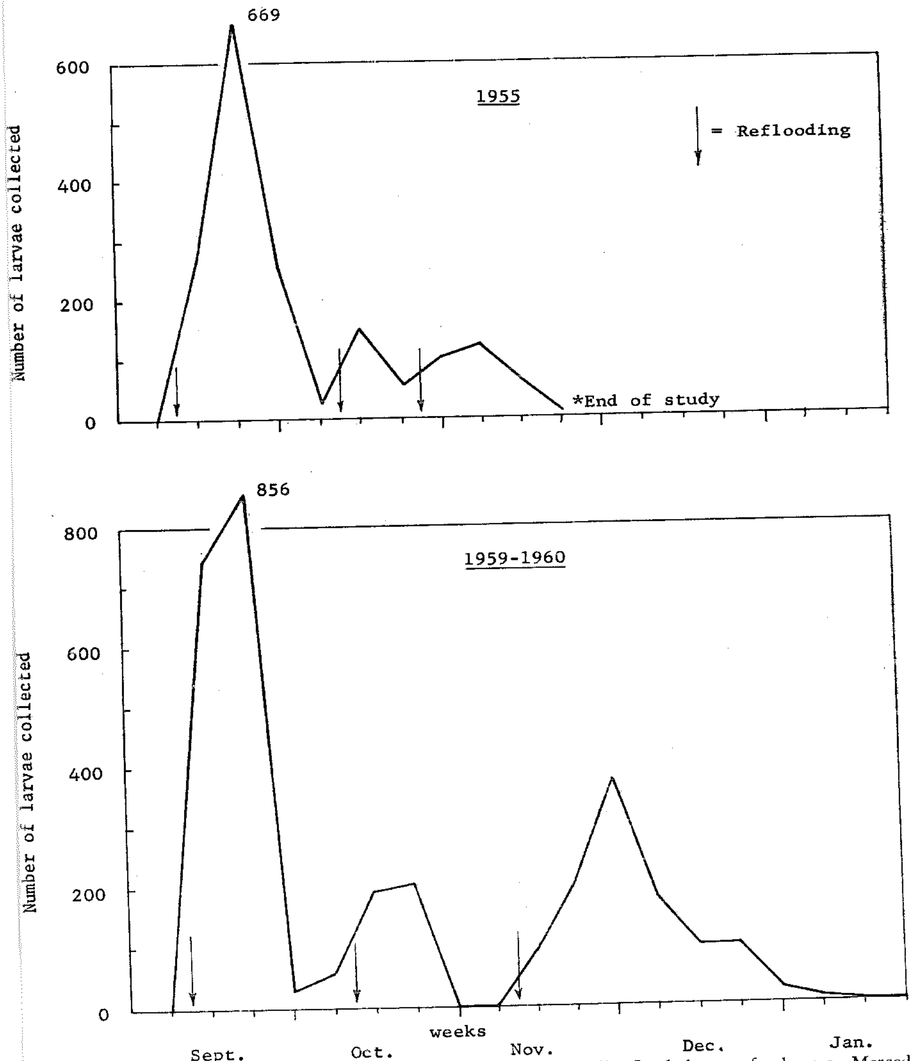

FIG. 1.—Occurrence of *Aedes melanimon* larvae in a seasonally flooded waterfowl area, Merced County, California, 1955 and 1959–1960.

with a net on October 1, 1959 adjacent to three dipping stations, exhibited teneral features indicating very recent emergence. Nine days before the adults were collected these stations contained first instar *A. melanimon* larvae.

The aquatic habitat most favorable for *A. melanimon* was along the shoreline of the ponds with emerging saltgrass and dense stands of wire rush (Fig. 2). An equally favorable habitat occurred where hummocks protruded from the central areas of the ponds, between shallow water and shoreline, as in upper left portion of Figure 2.

number of *C. tarsalis* per dip in 1955 for a single station was 18.5. This occurred the second week in November. In 1959 the highest average for a single station was 37.8, occurring the third week in October. The highest numbers of *C. tarsalis* larvae were collected the last week in September and the first three weeks in October in both 1955 and 1959. In 1959 first and second instar *C. tarsalis* were taken on September 28 in eight stations 4 days after these stations were negative for this species. *C. tarsalis* adults were collected in a red box near one of the eight dipping stations 10 days after the first collection of

FIG. 2.—Pond favorable for breeding of *Aedes melanimon* and *Culex tarsalis* near shoreline in foreground, and hummock area upper left.

Culex tarsalis Coq. was the other most prevalent mosquito collected during the study. The three stations containing *A. melanimon* larvae on September 21, 1955 were sampled again on September 27 and at this time contained *C. tarsalis* larvae. Table 2 shows that the highest average

larvae. These adults were dissected and exhibited teneral characteristics.

Figure 3 shows the total number of *C. tarsalis* larvae from weekly collections for both study periods. Maximum numbers of larvae were present during the last week of September and the first three

TABLE 2.—Occurrence of *Culex tarsalis* larvae in dipping stations for 1955 and 1959–60 study periods, Merced County, California.

Week No.	Total no. of stations holding water		Total no. of larvae collected		Average no. of larvae per dip for highest count station	
	1955	1959–60	1955	1959–60	1955	1959–60
Sept.						
2	0	0	0	0	0.0	0.0
3	5	10	0	0	0.0	0.0
4	9	13	316	829	17.2	70.2
Oct.						
1	14	14	620	897	13.7	19.2
2	13	14	404	785	8.3	21.9
3	13	14	243	747	17.9	37.8
4	13	13	98	272	4.3	14.4
Nov.						
1	14	12	303	153	18.5	4.0
2	10	11	77	182	3.2	5.0
3	9	15	72	70	3.7	3.2
4	8*	15	64	48	2.5	2.3
Dec.						
1	..	16	..	40	..	1.5
2	..	15	..	23	..	1.0
3	..	15	..	50	..	1.8
4	..	15	..	24	..	0.5
Jan.						
1	..	15	..	7	..	0.4
2	..	13	..	3	..	0.3
3	..	12	..	2	..	0.2
4	..	11	..	0	..	0.0
Feb.						
1	..	11	..	0	..	0.0
2	..	11	..	0	..	0.0
3	..	11	..	0	..	0.0
4	..	11	..	0	..	0.0
Mar.						
1	..	10	..	0	..	0.0
2	..	6	..	10	..	0.9
3	..	6	..	334	..	16.9
4	..	6	..	62	..	2.9
April						
1	..	6	..	40	..	1.5
2	..	6	..	81	..	5.7
3	..	5	..	58	..	5.5
4	..	0	..	0	..	0.0

* Observations terminated end of November, 1955.

weeks of October. A steady decrease occurred through November and December until no aquatic forms were collected the last week in January 1960. When the average weekly temperature fell below 60° F. there was a marked reduction in aquatic forms. (A similar relationship existed in 1955 when the average weekly temperature dropped below 60° F. the first week of November). This suggests that the decrease in number of larvae was probably due to decreased oviposition activity of the adult females.

Early instars of *C. tarsalis* larvae were again recovered beginning on March 14, 1960 in ponds that held water throughout the winter. The average weekly temperature during February and March rose above 50° F. The daily maximum temperatures for the second and third weeks of February and first week of March were above 60° F. for 28 days, providing a

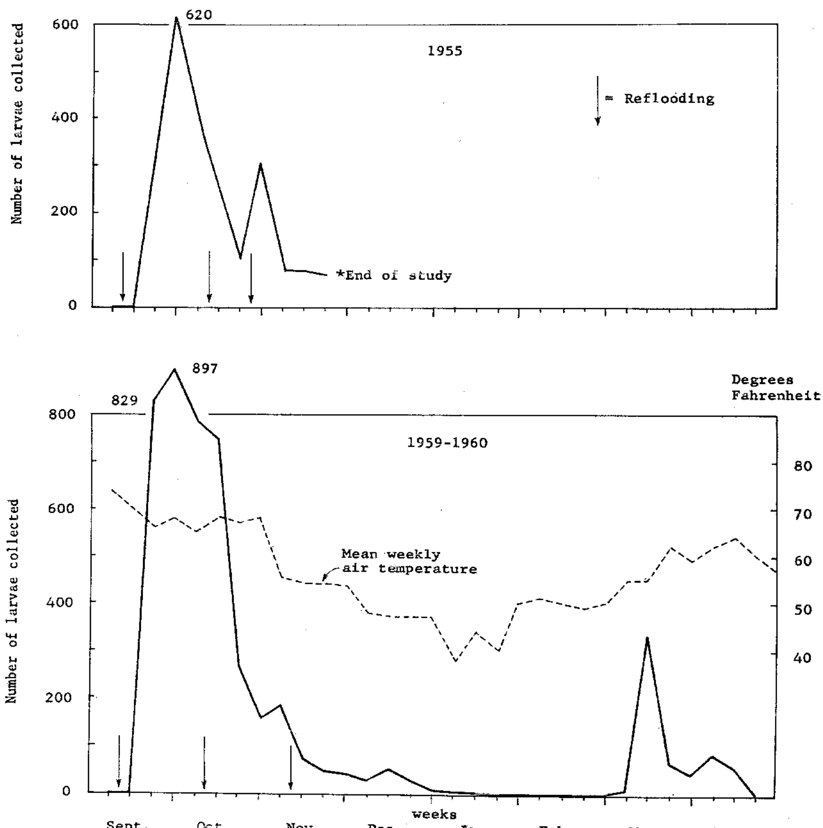

FIG. 3.—Occurrence of *Culex tarsalis* larvae in a seasonally flooded waterfowl area in Merced County, California, 1955 and 1959–1960.

temperature increase suitable for overwintering *C. tarsalis* to oviposit.

C. tarsalis larvae were most abundant in shallow water habitats with emerging saltgrass. This condition often existed in the interior of the pond as well as along the levee shoreline. Shallow water (under 6 inches) with dense stands of emerging wire rush was the second most productive habitat for *C. tarsalis.*

There was no major difference in the occurrence of *C. tarsalis* from the shoreline into the body of the pond. Samples were taken at 10-foot intervals and extended 100 feet into the pond. The average numbers of larvae per dip for 4 stations during the eleven-week study period in 1955 were 2.4, 2.0, 3.6, 2.1, 2.3, 3.8, 2.4, 2.3, 2.8 and 2.9 for each respective ten-foot interval from shoreline to 100 feet.

Seepage and overflow of water from the ponds into borrow areas between the road and pond levees provided additional sources of *A. melanimon* and *C. tarsalis.* In the one dipping station of this type the highest average number of *C. tarsalis* larvae per dip was 17.9, on October 17, 1955.

Culiseta inornata (Williston) was the third most prevalent species collected in the study. During both years of observation this species first appeared the second week of November. *Culex erythrothorax* Dyar larvae were collected in small numbers during the first week of November 1959, and were present until the study terminated in April 1960. *Culex quinquefasciatus* Say, *Culex peus* Speiser, and *Anopheles freeborni* Aitken larvae were also collected in the dipping stations during October and November but their occurrence was minor.

There were no major differences apparent between 1955 and 1959–1960 observations in the species of mosquitoes present and their seasonal occurrence. However, in 1959 there was an increase in the number of times *C. erythrothorax* larvae occurred in the collections. This was attributed primarily to a change in the character of habitats of two stations with the establishment of dense growths of bulrushes and cattails, thus providing conditions favorable for *C. erythrothorax.* This change took place during the intervening time between the two study periods.

SUMMARY AND CONCLUSIONS. Observations made of a seasonally flooded waterfowl area in Merced County, California, during the fall and winter months of 1955 and 1959–60 revealed the following:

1. A wetland type of waterfowl habitat flooded during September and October provided conditions suitable for substantial mosquito production. The most abundant species collected were *A. melanimon* and *C. tarsalis.* *A. melanimon* appeared at the time of initial flooding followed in 2 to 3 days by *C. tarsalis.* The time for development of *A. melanimon* from 1st instar larvae to the teneral adult stage was 8 to 9 days; *C. tarsalis* required 10 to 12 days. These minimum periods of growth occurred in the last half of September.

2. *A. melanimon* larvae occurred principally in the areas along the shoreline of the levees, in the main body of the pond wherever a raised area provided an interface between water and shoreline, and in overflow or seepage areas in borrow pits between the roadway and levees. *C. tarsalis* larvae were mainly found in areas along the shoreline of the levees and in the main body of the pond where shallow water, emerging vegetation, and plant debris were present. The highest level of occurrence for both species occurred in saltgrass habitats. McHugh (1958) in a study of mosquito occurrence in waterfowl areas of the Great Salt Lake also found that emerging saltgrass in shallow water was the most productive habitat for *Aedes* and *Culex* mosquitoes.

3. Other species of mosquitoes occurring in the duck club area were *C. inornata, C. erythrothorax, C. peus, C. quinquefasciatus* and *A. freeborni.* These species were collected in small numbers and occurred infrequently.

4. The dipping stations holding water throughout the winter and early spring months of March and April again produced *C. tarsalis* as a result of overwinter-

ing females ovipositing in these standing water areas.

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TRANSMISSION OF SEMLIKI FOREST VIRUS BY *ANOPHELES ALBIMANUS* USING MEMBRANE FEEDING TECHNIQUES

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The Semliki Forest virus (SFV) was first isolated from a group of *Aedes abnormalis* mosquitoes from Uganda (Smithburn and Haddow, 1944) and later isolated from *Aedes argenteopunctatus* collected in Portuguese East Africa (McIntosh, *et al.*, 1961). Semliki Forest virus belongs to Group A of the arthropod-borne viruses.

The virus has been shown to be transmitted by *Aedes aegypti* (Davies and Yoshpe Purer, 1954, and Woodall and Bertram, 1959) and by *Aedes togoi* (Nye and Lien, 1960) using suckling mice as the transmission animal.

The infection of mosquitoes by allowing them to feed through membranes onto virus containing mixtures has been reported by a number of workers. *Aedes aegypti* mosquitoes have been infected with dengue virus using a guinea pig skin (St. John, *et al.*, 1930) and with Chikungunya and Makonde viruses using a batwing membrane (Ross, 1956). This mosquito has also been infected with Zika virus (Boorman and Porterfield, 1956), Uganda S virus (Boorman, 1958), and Semliki Forest virus (Nye and Bertram, 1960) using mouse skin as a membrane.

Reported here are the results of studies to infect *Anopheles albimanus* mosquitoes with Semliki Forest virus using an animal derived membrane, and to determine the quantity of virus inoculated during mosquito feeding using this membrane.

Methods and Procedures. The virus was Semliki Forest virus (SFV), strain R-1-1, mouse brain passage 12, obtained through the courtesy of Dr. Telford Work, Communicable Disease Center, Atlanta, Georgia.

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