

PRELIMINARY FIELD OBSERVATIONS ON THE BEHAVIOR OF THE ADULTS OF *ANOPHELES FRANCISCANUS* McCRACKEN IN SOUTHERN CALIFORNIA

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INTRODUCTION. *Anopheles franciscanus* McCracken 1904 is an extremely common mosquito in Southern California, especially during late summer and early autumn. It utilizes almost any type of available water for breeding but reaches its highest larval densities in drying pools with dense algal growth. Favorable breeding places are frequently available for this species in heavily populated areas. At the present time no effort is made to control *A. franciscanus*, largely on the assumption that this species is not anthropophilic. Actually practically nothing is known about the habits of the adults except for their occurrence in such artificial diurnal shelters as culverts and bridges (Freeborn 1949).

Because of the high larval densities attained by this species in proximity to concentrations of human population, it appeared desirable to obtain some information on the habits of the adults, particularly since on June 10, 1950, one of us (J.N.B.) was bitten by four *A. franciscanus* at Imperial Dam, Imperial County, Calif., in an area where larval densities of this species were apparently very low. A check with field men engaged in mosquito control in Los Angeles for a number of years revealed that the attraction of *A. franciscanus* to humans had been noted by them but no definite records or controlled observations had been made to determine the importance of this species. Such unorthodox behavior on the part of a mosquito generally believed to be innocuous throughout its range also pointed to the possibility that the species in Southern California might be a different member of the *pseudopunctipennis* complex, some of which are strongly anthropophilic

and serious malaria vectors. Previous investigations had indicated, as summarized by Aitken (1945), that *A. franciscanus* exhibits remarkable variability in the egg stage as well as in the male genitalia, but no correlation had been established between these characters or with the habits of the different forms.

In the course of routine mosquito control activities of the Los Angeles City Health Department, an artificial lake supporting a very high population of *A. franciscanus* was located within the city limits and presented us with an opportunity to observe some phases of the behavior of this species for a period of four weeks, from July 20 to August 16, 1950. Since the lake and surrounding park area were used for the filming of motion pictures our observations were interrupted and finally discontinued before the completion of the projected plans, which we hope to realize in subsequent seasons. Nevertheless we are presenting these preliminary observations at this time as they may be of interest to workers engaged on mosquito control in this area.

ACKNOWLEDGMENTS. We are indebted to Mr. R. V. Lee, the owner of the lake where our observations were made, for gracious permission to use the area. We also wish to thank the officers of the Pierce School of Agriculture for the loan and the transportation of animals. To the mosquito control personnel of the Los Angeles City Health Department we are grateful for volunteer help with the landing and biting records.

LOCALITY AND BREEDING. The artificial lake, known locally as Lee's Lake, is situated in a natural draw southwest of and downstream from Chatsworth Reservoir in the San Fernando Valley in the City of Los Angeles (Fig. 1). It has a

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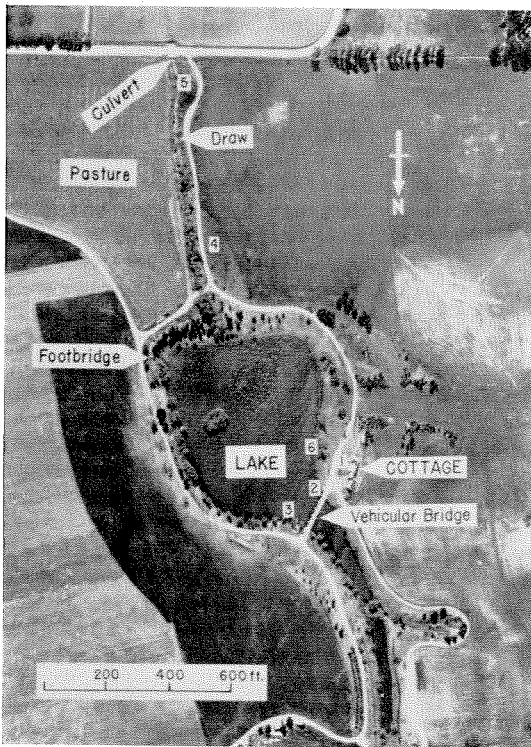


FIG. 1.—Aerial photograph of Lee's Lake, showing the location of observation points. The density of the park area is not apparent as the photograph was taken in March. (Photo by Fairchild Aerial Surveys, Inc.)

surface area of slightly under six acres and a general depth of three or four feet. It is kept at almost a constant level throughout the year through a balance between inflow and evaporation. The banks of the lake are periodically mowed but abundant marginal vegetation is present throughout the warmer months. The dominant marginal vegetation consists of several grasses, *Juncus* sp., *Scirpus* sp., and restricted areas of *Jussiaea californica*. During the summer months, beds of *Potamogeton pectinatus* cover almost the entire surface of the lake. At this time a dense growth of filamentous algae, largely *Oedogonium*, is produced in the *Potamogeton* beds as well as in the marginal vegetation, forming a mat over the lake.

Blue green algae, desmids and colonial green algae are extremely numerous in these mats. At the time of these observations over 100,000 square feet of the lake surface afforded ideal breeding for *A. franciscanus*. Larval densities varied from 20 to over 100 per square foot and an average of 10 pupae per square foot were found. Since the pupal stage of this species lasts about 36 hours, a conservative estimate of the number of adults emerging daily during this time would be 500,000.

For a width varying from a few feet to over 100 yards, the area surrounding the lake is planted as an open landscaped park, which is periodically watered by sprinklers. At the south end there is a continuation of the natural draw occupied by the lake.

This draw is densely wooded and overgrown with weeds and during the period of observation was entirely dry. To the east of the draw is an irrigated pasture harboring cattle at night. At the south end of the lake is a 12' x 12' footbridge over a ditch from a small overflow dam. At the narrowed northern part of the lake is a vehicular wooden bridge with a "stone" papier-maché facing. To the west of this bridge is a movie-set cottage and stable also faced with papier-maché "stone."

DIURNAL SHELTERS. Almost every protected, shaded situation within 300 yards of the lake revealed resting *A. franciscanus* during the day. They were noted on tree trunks, under fallen logs, in stumps, brush, clumps of grasses, in depressions and excavations in the ground and in various artificial situations such as under the two bridges, in a concrete culvert, in metal tanks and in wooden crates. The largest number were found in the movie-set cottage which offered a multitude of protected nooks and crannies on its face as well as in the scaffoldings. It is noteworthy that numerous specimens were seen in somewhat exposed situations such as the shaded sides of the vehicular bridge, on tree trunks and in the doorways of the cottage, resembling in this respect *Anopheles crucians* Wiedemann.

No attempt was made to count or even estimate the number of adults present around the lake because of the difficulties in sampling. Males appeared to outnumber females in the ratio of 2 to 1 in the majority of resting places. We were surprised at the small number of gravid females and the almost complete absence of recently blooded females resting near the lake. Unengorged and non-gravid females outnumbered them approximately ten to one. Since this indicated that, in all probability, blooded females rested for one or more days in the vicinity of the area where they secured their blood meal, a survey was made of farm buildings and houses within a mile radius of the lake. No *A. franciscanus* were found beyond

one-half mile from the lake, but within this radius small numbers of freshly blooded females were found in various buildings. We are aware that these observations do not agree with the usual finding of large numbers of gravid and blooded females in proximity to breeding sites in other areas of Los Angeles as well as elsewhere in California. With the very heavy population produced in this lake and the readily available cattle blood in the nearby pasture, we had expected to find large numbers of blooded females at least in the shaded draw. It appears that at least in this case, freshly blooded females either utilized a different type of diurnal shelter which we were unable to locate, or secured their blood meals beyond the area checked.

CREPUSCULAR AND NOCTURNAL ACTIVITIES. On the evening and night of July 25-26, one of us (J.N.B.) spent a 12 hour period, from 6 P.M. to 6 A.M., at the foot bridge near the outlet of the lake observing the activities of the adults of *A. franciscanus*. At 6 P.M. an estimated 500 females and 1,000 males were resting under this bridge. At 8 P.M. they first began to show restlessness and gradually moved out. At this time two females landed on the arm but did not attempt to bite, although given the opportunity. The flashing of a light induced a pseudo-swarming of the males. At 8:15 all but a few individuals had disappeared from the bridge. A gasoline lantern was set up some 75 feet from the bridge at 8:30 and was kept burning throughout the night. No mosquitoes came to the light and only a single female landed on the arm without biting at 9 P.M. At 9:15 P.M. the interior of the car used on the trip was checked and was found to contain 25 females and 46 males resting on the upholstery. The underside of the car had a much larger number of mosquitoes, estimated at 350. The mosquitoes remained in and under the car to the end of the observations in the morning. At that time one freshly blooded female was noted within the car. No mosquitoes were noted under the bridge until 5:40 A.M. and by 6 A.M. approxi-

mately the same number were present as on the previous evening. We believe that the activities of the mosquitoes were affected on this particular night by the brilliant moonlight and the particularly low temperature.

On four other occasions we checked the time of the beginning of the evening flight. It appears to start when the light intensity falls to about 50 Weston units. Apparently not all mosquitoes participate in the flight on a given evening since a small number were always found in the diurnal resting places, usually in more exposed situations. As indicated below this species appears to be at least moderately attracted to artificial lights under favorable environmental conditions. In the morning the return to diurnal shelters appears to take place when light intensities rise to about 50 Weston units.

SWARMING AND MATING. On August 4, a swarm of males was noted for the first time over the roof of the cottage at 7:56 P.M. At this time it was fully formed at a height of some thirteen feet above the ground and approximately one foot above the roof of the porch. Another swarm was noted over the roof of the attached stable at a height of over 15 feet above the ground.

On August 7, 8, 10, and 14, swarms were observed in exactly the same locations and in addition a very large swarm was seen over the top of the roof, approximately 25 feet above the ground. Our observations were concentrated on these three large swarms but several smaller

swarms were noted within 100 yards. Table 1 indicates the data we were able to gather on the time, light intensity, and temperature prevalent at the occurrence of the swarm over the porch.

An attempt was made to photograph this swarm. Due to the failure of the synchronization of the flash apparatus the photographs of the entire swarm are not sufficiently clear for reproduction. Fig. 2 shows a close-up of the central part of a swarm. It seems probable that with proper lighting equipment motion pictures may be taken to study the complex movements which take place in swarming.

Since, to our knowledge, the swarming of *A. franciscanus* has not been described before and that of other anophelines seldom seen in nature, it appears worthwhile to describe our observations of the swarm over the porch roof in some detail. Despite our efforts to follow the males from their resting places on the porch walls we were not able at any time to see them actually join the swarm. They could be seen moving through cracks in the roof some ten to fifteen minutes before the swarm formed. The swarm itself became recognizable with only a dozen mosquitoes participating and quickly increased in size until several thousand individuals took part in it within some five to seven minutes. One medium size swarm was incompletely netted and proved to contain 2,341 males and 3 females. We estimated that the larger swarms at their peak numbered at least 5,000 individuals and occupied a space of six feet in vertical

TABLE 1.—Swarming

Date August	Time		Light ¹		Temp. Centigrade
	Start	End	Start	End	
4		8:15			
7	7:28 ²	8:05 ²			25°
8	7:48	8:12	9.5	<0.2	22°
10	7:45	8:10	10.	0.4	20°
14	7:40	8:05	20.	0.8	20°

¹ In Weston units.² Probably in error.

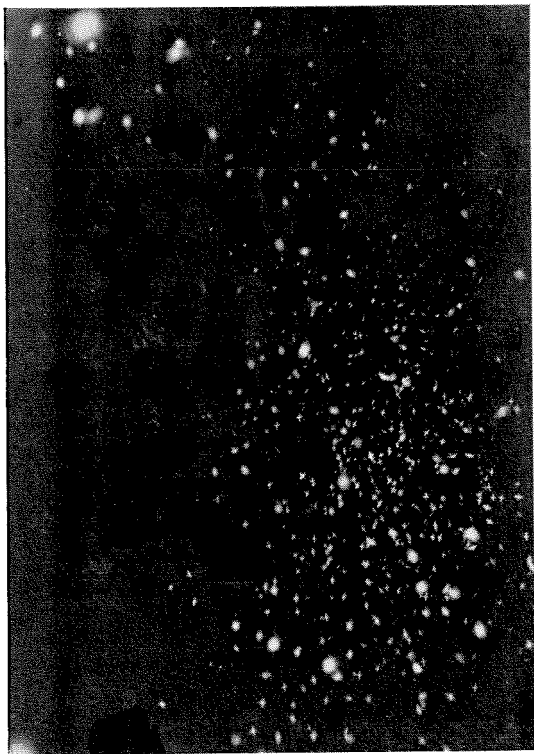


FIG. 2.—Close-up of central portion of a large swarm of *A. franciscanus*.
(Photo by Graham Heid.)

dimension and three feet in diameter in the middle with somewhat tapered ends. A very characteristic, easily perceived humming is produced by the swarm from its inception and becomes audible from a distance of at least 25 feet at the peak of swarming.

Very complex movements are performed by the individuals within the swarm. They are difficult to follow with the eye in detail, but it appears that movement takes place vertically as well as spirally and that individuals change their position in the swarm. From time to time the entire swarm rises *en masse* for a foot or two and then descends to its original position. The most spectacular feature, that distinguishes this mosquito swarm from other nematoceros swarms observed

in this area, is the occurrence of periodic, horizontal (perhaps circular), synchronized sudden rhythmic shifting of individuals back and forth at the peak of swarming. This shifting does not seem to occur at definite intervals but instead sudden rhythmic shifts are concentrated within a short period, usually preceded by one or more vertical movements of the swarm and increased activity. The swarm then loses form almost completely for several seconds, the individuals becoming dispersed and disorganized only to resume the normal swarm-dancing and then build up to the climax again and again. It appears that coupling takes place largely at this time since the majority of paired individuals were seen dropping from the shifting swarm and particularly during the

confused period immediately following it. We were not able to determine whether or not this shifting was initiated by the entrance of females into the swarm.

Once formed the swarm is not easily disturbed, even when part of it was netted, a large percentage of the remaining individuals reformed it. The firing of a flash bulb had no effect on the activity of the swarm, neither did the approach of an individual to within two feet or even less. The remarkable occurrence of swarms in exactly the same location was confirmed by our observations over a period of eleven days. Nothing could be found on the particular spot of the porch roof where the swarms formed that distinguished it to us from the rest of the roof.

The disbanding of the swarm is particularly difficult to follow since the light intensity is very low at this time, but it appears that it takes place gradually and largely within no more than 4 to 5 minutes. Our figures indicate that the entire swarming takes 25 minutes, with most of the activity concentrated in a 15-minute period.

The three large swarms observed over the cottage and the attached stable occurred within 50 feet of each other. The stable roof swarm on several occasions had several foci at the beginning of swarming but usually merged into a single large swarm at the climax. Within 100 feet of the cottage several smaller swarms were observed, one over the roof of a car, and a swarm of some 50 individuals about four feet above the ground and over the railing of the vehicular bridge. The car swarm moved off over the head of an observer and followed him. No mating was observed in any of the smaller swarms.

Comparison of the numbers of resting individuals in the cottage and stable with the numbers in the swarms in their vicinity indicated that only a small fraction took part in these swarms on a given night. Light intensity appears to be one of the principal factors in determining swarming in those individuals that are in the proper state of physiological activity

on a given night. As shown in the table, swarming does not occur until light intensity falls below 20 Weston units, and peak activity takes place when it is between 6.5 and 1.6. As Bates (1949) has indicated, swarming in some mosquitoes exhibits a definite diurnal rhythm. We have observed that in *A. franciscanus* no swarming occurs except in the evening even though the stimulus of proper light intensity is present at other times on cloudy days, and within buildings. No observations were made in the morning hours. Temperature did not seem to play a significant part in the activity of the swarm, although a sharp drop in air temperature was noted about 30 minutes before swarming occurred. On two occasions we were doubtful that swarming would take place because of a rather strong northwest wind but it had no effect on the swarms on the roof slopes, which are on the leeward side, and did not even affect the exposed swarm over the top of the cottage.

Coincident with the formation of the swarms, and occasionally preceding it by a few minutes, was the appearance of females of *A. franciscanus* and the beginning of their biting activities. On every occasion the biting increased with the activity of the swarm. We did not determine whether the biting females were those that had recently mated, or were merely attracted to the swarm or to the blood source.

Mating was observed in every swarm over the porch roof. It varied in intensity considerably from day to day. We estimated that on no occasion did more than 500 females mate in a swarm of ten times this number of males. As indicated above coupling occurred at or following the shifting of the swarm. The paired individuals could be easily seen in the swarm and their downward drop followed. Some individuals flew off paired in a horizontal direction. Pairing lasted from a fraction to several seconds. At the height of the swarming as many as fifty pairs could be counted thrashing on the roof. We were surprised to observe fairly

frequently two or even three males apparently coupled with a single female. At the completion of mating the males returned to the swarm while the females flew off.

BLOOD FEEDING. Our first encounter with *A. franciscanus* taking blood from humans was at the site of Imperial Dam on June 10, 1950, when one of us (J.N.B.) was bitten by four females between the hours of 9:20 and 9:30 P.M. Further collecting with the aid of a gasoline lantern in a protected camp area along the Colorado River below the dam disclosed 22 additional females landing during a period of an hour. Because of a strong wind we were not able to continue observations in this area.

The remaining observations and tests were all made at Lee's Lake. As indicated in the section on swarming and mating, females of *A. franciscanus* bit the observers viciously at the time of the swarming. Not uncommonly three or four females attempted to bite at one time. On August 4, 10 females engorged in a 10-minute period and on August 7, 18 engorged females were removed from an observer in 30 minutes with at least an equal number escaping. This biting activity continued after the swarm of males had dispersed.

To determine the extent of the biting activity we made landing records on

August 10, 1950, from 8:00 to 9:00 P.M. The results are indicated in Table 2. It will be noted that mosquitoes were also attracted to a duck, a turkey, a rabbit and a guinea pig. The observers worked in pairs and used a flashlight. No mosquitoes were recorded in the area south of the lake (stations 4 and 5). A possible explanation for this is the fact that south of the lake the evening flight had taken place before we entered the area and cattle were available in the adjacent pasture, whereas in the cottage area the observers had been present since 7 P.M. and had attracted the mosquitoes from the beginning of the flight.

Information on blood preference was desirable but as no freshly blooded females could be found in diurnal resting places around the lake it was impossible to carry out precipitin tests. Instead the most obvious areas where blood could be secured were checked within a mile radius of the lake. On July 25 and 28 no mosquitoes could be found. We believe that the full moon at this period may have affected the behavior of the mosquitoes. On August 4, freshly blooded females were found in practically every building or shelter harboring farm animals within a half mile radius of the lake. From two to not more than 200 blooded *A. franciscanus* were found in rabbit and duck cages, in calf and horse stalls and three specimens in a

TABLE 2.—Landing Records

August 10, 1950

Bait and Station	Time				Total
	8:00-8:15	8:15-8:30	8:30-8:45	8:45-9:00	
2 men—Sta. 1	7	3	2	2	14
2 men—Sta. 2	3	5	3	1	12
2 men—Sta. 3	0	15	7	3	25
2 men—Sta. 4	0	0	0	0	0
2 men—Sta. 5	0	0	0	0	0
2 men—Sta. 6 with birds	5	4	0	0	9
2 men—Sta. 6 with mammals	6	3	1	0	10
Duck and turkey—Sta. 6	4	5	20	3	32
Rabbit and Guinea Pig—Sta. 6	20	5	9	0	34
TOTAL	45	40	42	9	136

play tent used by children. Since the source of blood appeared obvious in each case no precipitin tests were made.

The very small number of blooded females that were located as compared with the enormous numbers produced in the lake indicated the need for further tests to determine the biting propensities of *A. franciscanus*, particularly since the larger animals in the area were left in the pastures at night. Accordingly on August 14, biting records were made using several different hosts as bait in the clump of trees near the cottage. Two gasoline lanterns provided a light of 0.8 Weston units at the animals arranged in a circle around them. Two observers were assigned to each of the larger animals. The results of the test are indicated in Table 3. Unfortunately the night was cool, 19° C. at 9 P.M., and very few mosquitoes were biting. Nevertheless, the records show that humans are attractive to this species even in competition with the horse and the cow. The protective screen over the lanterns showed at the end of the hour 77 dead *A. franciscanus*, 20 females, and 57 males, indicating that they were present in larger numbers than shown by the biting records.

Females of *A. franciscanus* are very quiet in flight and extremely difficult to spot in the field because of their coloration and sudden, wary approach. They are easily disturbed but are persistent in their attack. They appeared to show a preference to bite humans on the neck,

face and arms, but other parts of the body when exposed seemed to be equally attractive. The bite is quite painful to some individuals but to one of us (J.N.B.) it seemed much milder than that of most anophelines. A blood meal is generally secured in one or two minutes, once a favorable spot is located. When undisturbed *A. franciscanus* had a tendency to over-engage and to pass a droplet of clear fluid from the anus when replete.

Our records show that blood feeding never occurs in this species during the day even when cloudy or in shaded situations where light conditions are favorable. Blood feeding appears to begin in the evening at a time when the light intensity falls below 50 Weston units and continues for at least one and a half hours. We have no definite information as to biting activities during the remaining night hours or morning.

SUMMARY

Observations were made from July 20 to August 16, 1950, on the behavior of males and females of *A. franciscanus* McCracken 1904 in the vicinity of a six-acre artificial lake in the City of Los Angeles, producing an estimated 500,000 adults per day. Various types of shaded situations near the lake provided diurnal resting places for large numbers of males and a smaller number of non-gravid and unblooded females, while very small numbers of blooded females were found resting in farm buildings within a half mile

TABLE 3.—Biting Records
August 14, 1950—Station 6

Bait	Time				Total
	8:00-8:15	8:15-8:30	8:30-8:45	8:45-9:00	
10 men	1	0	2	1	4
Horse	1	5	4	1	11
Calf	1	2	1	2	6
Sheep	2	0	0	0	2
Rabbit	0	0	0	0	0
Turkey	0	0	0	0	0
TOTAL	5	7	7	4	23

radius. The activities of the adults proved to be entirely crepuscular and were confined to the period when light intensity was below 50 Weston units. Both males and females are moderately attracted to artificial light. There is indirect evidence that adult behavior is markedly influenced by environmental conditions and particularly by strong moonlight. Swarms numbering as many as 5,000 males were observed regularly in the evening when the light intensity fell below 20 Weston units and lasted for 25 minutes. Rather abundant mating was observed at the peak of swarming. Females started feeding on observers shortly before swarm formation and were particularly active in the vicinity of swarms. The limited comparative landing and biting tests indicate that *A. franciscanus* is moderately anthropophilic, feeding in preference on only the larger mammals (horse, cow, sheep), and in fewer numbers on smaller animals (duck, turkey, rabbit, guinea pig). The numbers biting and landing were extremely

small in comparison with the enormous populations produced in the lake. Despite the difference in anthropophilism the forms investigated proved morphologically indistinguishable in all stages from *A. franciscanus* from Central and Northern California. Further investigations on this species are indicated in view of its anthropophilism and its great abundance in populated areas in Southern California.

Literature Cited

- AITKEN, T. H. G. 1945. Studies on the anopheline complex of Western North America. Univ. Calif. Publ., Ent. 7:273-364.
- BATES, MARSTON. 1949. The natural history of mosquitoes. 379 p. The Macmillan Company, New York.
- FREEBORN, S. B. 1949. Anophelines of the Nearctic region. In Boyd, M. F.: Malariaology 1:379-398. W. B. Saunders Co., Philadelphia.
- HERMS, W. B., AND S. B. FREEBORN. 1920. The egg laying habits of Californian anophelines. *Jour. Parasit.* 7:69-79.
- HERMS, W. B., AND F. M. FROST. 1932. A comparative study of the eggs of Californian anophelines. *Jour. Parasit.* 18:240-244.

H. M. SPEECHLEY

Word has been received of the death of H. M. Speechley of Winnipeg on March 15. A more complete account of his life and activities will be made in a forthcoming issue of the *News*. His genial personality was well known to many A.M.C.A. members.