STUDIES ON THE BIOECOLOGICAL ASPECTS OF ADULT MOSQUITOES IN THE PRADO BASIN OF SOUTHERN CALIFORNIA

LAL S. MIAN[1], MIR S. MULLA, HAROLD AXELROD, JOHN D. CHANEY AND MAJOR S. DHILLON[2]

Department of Entomology, University of California, Riverside, CA 92521

ABSTRACT. Studies on the bionomics of adult mosquitoes were carried out in the Prado Basin of southern California during 1985–86. The faunal composition of mosquitoes caught by species was (in descending order) *Culex quinquefasciatus, Cx. tarsalis, Cx. erythrothorax, Cx. stigmatosoma* (formerly *Culex peus*) followed by *Anopheles freeborni, Culiseta particeps, Cs. inornata* and *Cs. incidens*. The number of mosquitoes per trap night was the lowest during December through February, and the highest during August through October. Depending on both intrinsic and extrinsic factors, adult mosquitoes were active at dusk and dawn. In spatial distribution studies, both adult and larval collections showed that *Cx. quinquefasciatus* and *Cx. stigmatosoma* were associated with dairy lagoons and *Cx. erythrothorax* with duck ponds and a nearby wooded area. *Culex tarsalis* was found in greater number at all habitats. *Anopheles freeborni* and *Culiseta* spp. were found around the wooded area. In vertical distribution studies, more mosquitoes were captured at the highest (6 m) level than at lower (0.6 and 3 m) levels which was probably due to the large percentage of parous females present at this site.

INTRODUCTION

Information on the bioecological parameters of disease vector mosquitoes can be useful in understanding the epidemiology of mosquito-borne diseases such as encephalitis, malaria, filariasis and others. Pertinent data on various ecological aspects and behavioral patterns such as spatial-horizontal and vertical distribution, seasonal abundance, diel activity rhythms, physiological age profiles, host-seeking and autogeny, of various mosquito species have been documented in the literature (Chapman 1962, Corbet 1962, Burdick and Kardos 1963, Nelson and Spadoni 1972, Barnard and Mulla 1977, Snow and Wilkes 1977, Tyndale-Biscoe 1984, Bidlingmayer 1985, Russell 1985, Cope et al. 1986, Mulla et al. 1987, Schreiber et al. 1988). Among mosquito-borne diseases in California, both St. Louis encephalitis (SLE) and western equine encephalitis (WEE) have received a great deal of attention in disease surveillance programs on a statewide basis. Since the first encephalitis report in California about half a century ago, Californians have experienced several epidemics of these diseases; the most noteworthy of these have been in 1950, 1952 and 1954, resulting in 157, 420 and 121 total human cases, respectively (Anonymous 1983).

In southern California, a SLE outbreak in 1984 resulted in 26 human cases in the metropolitan counties of Los Angeles, Orange and Riverside. This outbreak prompted disease surveillance coupled with field research aimed at understanding the behavioral and ecological characteristics of local populations of principal and potential vector mosquitoes. As a part of this renewed research interest, studies were carried out in the Prado Basin, near the city of Norco, during the 1985 and 1986 mosquito seasons. Results here are presented on the faunal composition, temporal or seasonal abundance, diel host-seeking activity, spatial (horizontal and vertical) distribution and physiological age grouping of various mosquito species found in the study area.

MATERIALS AND METHODS

A study area was selected in the Prado Basin near the city of Norco. This area, not far from the Los Angeles County line, abuts 3 other counties, Orange, Riverside and San Bernardino. It is surrounded by fast-growing metropolitan areas and commercial establishments. The Prado Basin itself is a large fresh-water marsh supplied with wastewater from the Santa Ana River and a network of flood control systems. As a result, the area provides a variety of habitats, namely lotic, lentic, benthic, seeps, sloughs, ground pools, duck ponds, clear and wooded areas with indigenous wildlife fauna, nearby dairies, field crops and recreation parks—all very suitable for the breeding and proliferation of mosquitoes. A schematic description of the study area is given in Fig. 1. Mosquito breeding sources in the area included duck ponds, many seepage and ground pools with wastewater, and dairy lagoons in the adjoining areas. Four habitats selected for our studies included: 1) a site next to dairy lagoons, 2) a duck pond, 3) a tree line—an interface of duck pond and wooded area and 4) a wooded area consisting of mostly willow

[1] Current address: San Bernardino County Vector Control Program, 2355 East 5th Street, San Bernardino, CA 92410.

[2] Northwest Mosquito Abatement District, 6851 Granite Hill Drive, Riverside, CA 92509.

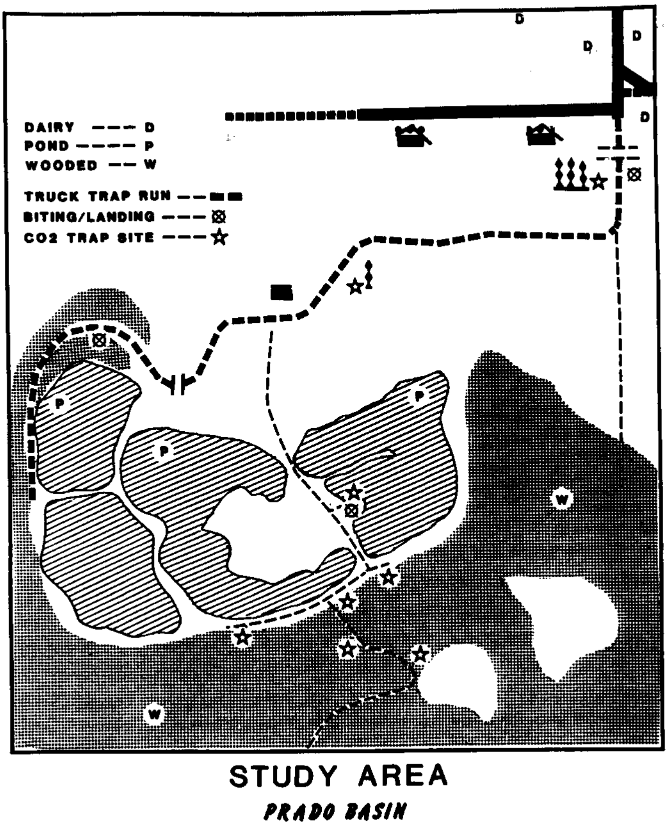

Fig. 1. A schematic view of the study area, Prado Basin, southern California.

trees. At each habitat, one or more sites were selected to assess host-seeking adult female mosquitoes on a weekly or biweekly basis during the study period of August 1985 through November 1986. During the spring and summer of 1986, besides sampling of adult mosquitoes, larval sampling (standard dipping method) was also carried out in 3 habitats, namely tail water of a dairy lagoon, duck pond tributaries with tule growth and ground pools at the interface of duck pond and wooded area.

Data generated on adult mosquitoes caught in overnight dry ice (CO_2)-baited traps during the entire study period were used in studying various parameters such as percent faunal composition and both temporal and spatial distribution of resident mosquito species.

During these investigations, several all-night-long studies were carried out to determine the activity peaks of adult mosquitoes, using dry ice (CO_2)-baited traps as well as human baits (authors) for the 10-min landing and biting counts. At the same time a vehicle-mounted trap was also driven to collect flying mosquitoes. The trap was driven about 1.6 km in the open and 0.8 km in the wooded area along duck ponds. These all-night-long studies were carried out at various time intervals during the scotophase, starting about 30 min prior to sunset and ending about 30 min after the sunrise. Weather data such as temperature, RH, light and wind velocity during the studies were recorded by using a Hygrothermograph (Model No. 160, Bendix Aviation Corp., Baltimore, MD), Sling Psychrometer (Taylor Instrument, Rochester, NY), Luna-Pro Electronic System Exposure Meter (Gossen GMBH, Erlagen, W. Germany) and Anemometer (Casella, London), respectively.

In order to study the vertical distribution pattern of host-seeking female mosquitoes, 3 trees, each over 15 m tall, were selected in a eucalyptus plantation near a dairy lagoon and about 1.6 km from a duck pond in our study area. These trees were about 30 m apart in a north-south-east triangular fashion. A loop of nylon rope on each tree held dry ice (CO_2)-baited traps at ground (0.6 m), 3, and 6 m levels. Mosquitoes caught overnight at each level were counted and identified according to species.

For physiological age determination studies, female mosquitoes, mostly *Culex* spp., trapped in overnight dry ice baited traps in the field, were killed in dry ice and dissected the same day under a stereomicroscope. The ovaries of dissected specimens were carefully examined for ovarial dilatation and tracheal coilation according to the methods of Detinova (1962) and Burdick and Kardos (1963). Mosquitoes were considered parous if the ovariole(s) had one or more dilatations and stretched or extended tracheation without curly endings. Nulliparous females showed their ovarial tracheation tightly set with distinct curly endings and no dilatations.

All data collected were statistically analyzed and comparison of means was made by using the chi-square test or Duncan's new multiple range test (DMRT).

RESULTS AND DISCUSSION

Of the total number of adult female mosquitoes (53,211) collected in dry ice (CO_2)-baited traps during the study period, the 3 most predominant species were *Culex quinquefasciatus* Say, *Culex tarsalis* Coquillett and *Culex erythrothorax* Dyar (Table 1). Other species that were found in the study area included *Culex stigmatosoma* Dyar (6.3%), *Anopheles freeborni* Aitken (4.1%), *Culiseta particeps* (Adams) (1.5%), *Culiseta inornata* (Williston) (0.8%) and *Culiseta incidens* (Thomson) (0.1%). Schreiber et al. (1988) drew almost similar conclusions regarding the relative abundance of adult mosquitoes associated with dairies in southern California. From the standpoint of encephalitis disease transmission, however, the prevalence of the main encephalitis vector, *Cx. tarsalis*, and potential vector(s), *Cx. quinquefasciatus*, and possibly other species, is epidemiologically of great significance.

In studying the seasonal abundance of these species, the number of mosquitoes per trap night, as expected, was the lowest during the coldest months, December through February (Table 2). This number was significantly higher, 484–650, during August through October; the highest index of 650 was in August. Epidemiologically, this observation is quite important because traditionally most St. Louis encephalitis (SLE) human cases are reported in the month of September, preceded by August, with higher mosquito populations. For example, the 2 most recent human cases of SLE in San Bernardino, California, were reported in September 1987 and 1988 (Anonymous 1988, Emmons et al. 1988). The seasonal distribution of different mosquito species (Table 2) shows that except for *Culiseta* spp., which were found from October to the following July, the relative abundance of the other species varied from month to month depending on local conditions such as temperature, humidity, etc. The data in Table 2 also indicate that *An. freeborni, Cx. quinquefasciatus, Cx. tarsalis* were less abundant than *Cx. erythrothorax* and *Cx. stigmatosoma* during the colder months.

Like seasonal changes affecting adult mosquito populations, diel changes on a 24-h basis also regulated the activity of adult mosquitoes for swarming, mating, host-seeking and feeding. Based on 5 whole-night-long observations using 3 different sampling methods such as CO_2-dry ice traps at 4–8 sites, 10-min landing and biting counts on human subjects near dairy lagoon, duck pond and wooded areas, and a truck-mounted trap driven in both open and wooded areas, the adult mosquitoes, *Cx. erythrothorax, Cx. quinquefasciatus, Cx. stigmatosoma* and *Cx. tarsalis*, showed a definite activity peak occurring about 30 min after sunset. Depending on weather conditions, especially temperature, the host-seeking activity of adult mosquitoes may sporadically occur at one or more times during the night until about 30 min before sunrise. For example, on a warm night (33–16°C) in August 1985, with full moon, there was, along with the typical evening peak and two small activity peaks around midnight, a morning peak of activity occurring about 30 min before sunrise (Fig.

Table 1. Faunal composition of mosquitoes collected in dry ice (CO_2)-baited traps in the Prado Basin in 1985–86.

Species	Number caught	Number/trap night[a]	% of total caught
Anopheles freeborni	2,182	12.8	4.1
Culex erythrothorax	14,739	86.7	27.7
Culex quinquefasciatus	16,123	94.9	30.3
Culex stigmatosoma[b]	3,352	19.7	6.3
Culex tarsalis	15,538	91.4	29.2
Culiseta incidens	53	0.3	0.1
Culiseta inornata	426	2.5	0.8
Culiseta particeps	798	4.7	1.5
Total	53,211	313.0	100.0

[a] Based on 170 trap nights.
[b] Formerly *Culex peus* revised by Strickman (1988).

Table 2. Seasonal distribution of various species of mosquitoes in the Prado Basin in 1985–86.

Month/yr	Mosquitoes/trap night[a]	% composition by species[b]					
		A.f.	*C.e.*	*C.q.*	*C.s.*	*C.t.*	*Cs.* spp.
Aug. 85	650.6	2.4	31.9	21.9	3.7	40.1	0
Sep. 85	483.8	1.5	29.0	33.7	4.2	31.6	0
Oct. 85	560.7	1.0	33.9	29.1	9.0	26.9	0.1
Nov. 85	263.2	0.5	63.0	30.0	4.3	1.7	0.5
Dec. 85	54.1	0.7	79.5	15.9	3.2	0	0.7
Jan. 86	33.3	0.2	68.2	15.5	12.7	0.5	2.9
Feb. 86	54.5	1.0	58.6	8.8	16.5	11.3	3.8
Mar. 86	152.7	0	70.7	2.3	15.8	1.3	9.9
Apr. 86	284.2	0.1	52.3	10.3	9.0	20.0	8.3
May 86	187.4	0.9	33.7	15.0	8.9	34.6	6.9
June 86	184.1	0.8	19.8	26.3	4.3	44.7	4.1
July 86	256.0	3.0	8.5	40.5	4.5	41.1	2.4

[a] Based on 170 trap nights.
[b] Species: *A.f.*: *Anopheles freeborni*; *C.e.*: *Culex erythrothorax*; *C.q.*: *Culex quinquefasciatus*; *C.s.*: *Culex stigmatosoma*; *C.t.*: *Culex tarsalis*; *Cs.* spp.: *Culiseta* spp.

2). However, on a relatively cooler night (24–10°C) in September 1985, with 3/4 moonlight, the morning as well as the midnight small peaks of activity were not noticeable (Fig. 3) due to lower temperatures, especially with the early morning temperature dropping to as low as 10°C. The same studies were carried out on 3 separate nights during 1986. Two distinct peaks of adult activity were noticed in the evening and morning hours (Table 3). The fluctuations in mosquito abundance as noticed from night to night could be attributed to a number of factors or conditions, some of which have been included in Table 3.

Depending on physiological rhythms and responses to temperature, humidity and light conditions, the evening and morning peaks of adult feeding activity on human bait have been reported in *Cx. erythrothorax, Cx. quinquefasciatus* and *Cx. tarsalis* in southern California freshwater marsh, Orange County (Cope et al. 1986). The use of the human bait method was as effective as the CO_2-baited trap method in collecting *Cx. quinquefasciatus*, but was less efficient in catching *Anopheles* sp., *Cx. erythrothorax* and *Cx. tarsalis* (Bangs et al. 1986). The effectiveness of various sampling techniques such as CO_2-baited, New Jersey light traps, gravid traps, walk-in red boxes, chicken-, guinea pig- and rabbit-baited traps, landing/biting counts on human baits and truck-mounted traps of adult mosquitoes have been reported in several studies (Bidlingmayer 1985, Russell 1985, Bangs et al. 1986, Cope et al. 1986, Reisen and Pfuntner 1987). Of all these methods, CO_2-baited traps were the most effective in capturing anopheline and culicine mosquitoes.

Besides CO_2-baited traps and landing/biting counts on human baits to collect host-sucking female mosquitoes in our study, the use of a truck-mounted trap was intended to collect flying male and female mosquitoes. During our August 30 and September 12, 1985, nightly studies, data from the truck-mounted trap showed evening activity of male *An. freeborni, Cx. erythrothorax, Cx. stigmatosoma* and *Cx. tarsalis*, with swarming in *Cx. quinquefasciatus* (65 males, 28 females) on August 30 and in *An. freeborni* (122 males) and *Cx. tarsalis* (11 males, 70 females) on September 12. A swarming activity in *Cx. quinquefasciatus* (207 males and 42 females) was also noticed in the 1800 h collection on August 31, 1985.

Studies on the spatial distribution of adult mosquitoes (Table 4) show that near the dairy at habitat I, *Cx. quinquefasciatus* and *Cx. tarsalis* were the most abundant mosquitoes caught, followed by *Cx. stigmatosoma, Cx. erythrothorax* and *An. freeborni*. As expected at habitat II, by the duck pond with tule growth, *Cx. erythrothorax* constituted 51.3% of the mosquitoes trapped, followed by *Cx. tarsalis* (25.5%) and *Cx. quinquefasciatus* (19.7%). The predominant species at habitat III (tree line), interface between duck pond and wooded area, were *Cx. quinquefasciatus* (39.2%), *Cx. erythrothorax* (29.5%) and *Cx. tarsalis* (21.7%). At habitat IV, wooded area, *Cx. tarsalis* was the most prevalent species (40.1%), followed by *Cx. erythrothorax* (22.1%), *An. freeborni* (15.1%), *Cx. quinquefasciatus* (9.8%), *Cx. stigmatosoma* (7.4) and *Culiseta* spp. (5.5%). In comparison with the data at other habitats, *Cx. tarsalis, An. freeborni* and *Culiseta* spp. were found in higher numbers in the wooded area.

Data based on larval populations at various habitats (Table 5) indicate 3 main species—*Cx. quinquefasciatus* (32.4%), *Cx. stigmatosoma* (49.1%) and *Cx. tarsalis* (18.5%)—at habitat I near the dairy. Except for *Cx. stigmatosoma*,

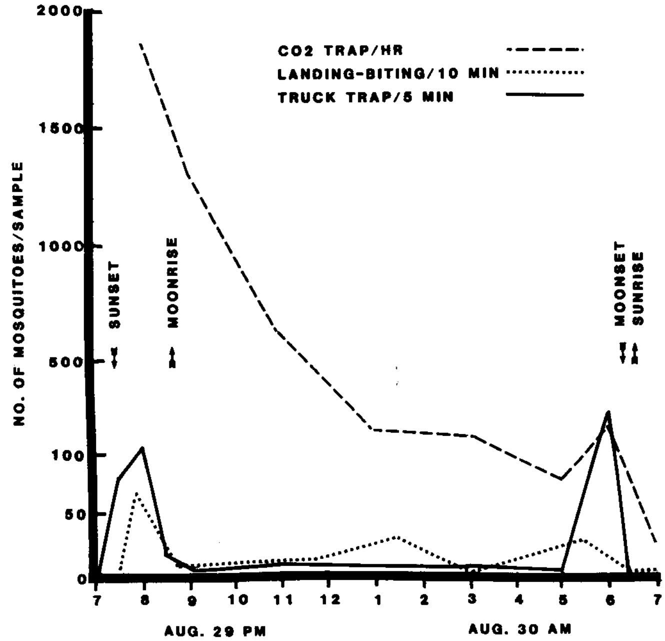

Fig. 2. Diel activity patterns of adult mosquitoes in the Prado Basin area—August 1985.

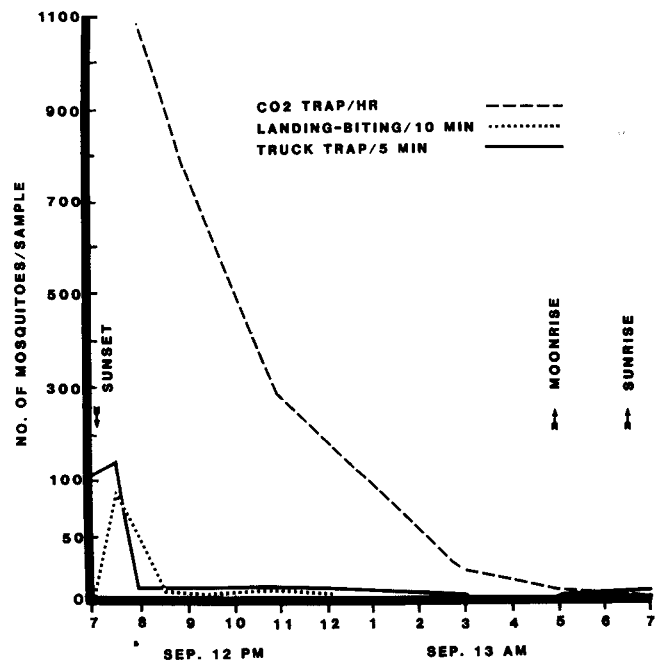

Fig. 3. Diel activity patterns of adult mosquitoes in the Prado Basin area—September 1985.

which accounted for 9.2% of adult collections, the larval data of *Cx. quinquefasciatus* and *Cx. tarsalis* were in agreement with the adult data (see Table 4). The lower percentage of adult females of *Cx. stigmatosoma* in CO_2-baited traps hung at eye level, 150–180 cm above ground level, could be due to the arboreal preference and probably high-flying activity of this species searching for passeriform avian hosts (Tempelis and Washino 1967). Larval collections at habitat II did not yield high numbers, but did show more species. *Culex tarsalis* was 67.7%, followed by

Table 3. Diel activity peaks of adult mosquitoes on 3 separate nights during 1986 in the Prado Basin area.

	June 9–10			July 15–16			July 29–30		
Method	CO_2[a]	BC[b]	TT[c]	CO_2	BC	TT	CO_2	BC	TT
Mosquito number									
Evening[d]	340	49	—[e]	141	9	110	480	24	39
Morning[f]	49	6	—	16	4	46	120	2	5
Sunset time		1943			1952			1946	
Sunrise time		0548			0557			0612	
Moon condition		¼ full			½ full			½ full	
Moon-rise time		—			—			2201	
Moon-set time		2215			0300			—	
Temperature (°C)									
Evening		20.0			20.8			22.3	
Morning		19.6			13.9			8.7	
Nightly min-max		16.2–21.8			13.6–22.8			8.2–27.0	
Relative Humidity (%)									
Evening		65			68.8			49.8	
Morning		75			96.7			87.0	
Nightly min-max		65–89			60–<95			41–90	
Wind velocity (km/h)									
Evening		7.2			12.0			4.8	
Morning		11.2			4.0			<1.0	

[a] CO_2-baited (dry ice) traps stationed at 4 sites: by a dairy lagoon, duck pond, tree line and wooded area.
[b] 10-min landing and biting counts made at 3 sites: by a dairy lagoon, duck pond and wooded area.
[c] Truck-mounted trap, run at 1.6 km in the open area and 0.8 km in the wooded area.
[d] Evening data were taken within 1 h after sunset.
[e] No data were taken.
[f] Morning data were taken within 1 h before sunrise.

Table 4. Distribution of adult female mosquitoes caught in dry ice baited traps at different sites in the Prado Basin in 1985–86.

		% composition at habitat[b]			
Species	Mosquitoes/ trap night[a]	I	II	III	IV
An. freeborni	12.8	0.5 a[c]	0.4 a	0.4 a	15.1 b
Cx. erythrothorax	86.7	7.8 b	51.3 c	29.5 b	22.1 b
Cx. quinquefasciatus	94.8	52.6 d	19.7 b	39.2 c	9.8 a
Cx. stigmatosoma	19.7	9.2 b	1.7 a	7.0 a	7.4 a
Cx. tarsalis	91.4	29.7 c	25.5 b	21.7 b	40.1 c
Culiseta spp.	8.5	0.2 a	1.4 a	2.2 a	5.5 a

[a] Mean of 170 trap nights.
[b] Habitats included: I: site near dairy lagoon; II: duck pond; III: tree line; and IV: wooded area.
[c] Means followed by the same letter in a column are not significantly different from each other (DMRT, $P = 0.05$).

Cx. erythrothorax (10.4%), *Cx. stigmatosoma* (10.4%), *An. freeborni* (9.4%) and *Cx. quinquefasciatus* (2.1%). The lower percentage of larval turnout (10.4%), as opposed to the higher incidence (51.3%) of adults of *Cx. erythrothorax* near duck pond sites, was due to the difficulty of dipping for the fast-moving larvae of this species. At habitat III, *Cx. tarsalis* was the predominant species, constituting 97.2%, with the rest being *Cx. stigmatosoma* and *Cx. quinquefasciatus*. The high incidence of *Cx. tarsalis* larvae at habitat III accounts for the large number of adults captured in neighboring areas (see Table 4).

Data on the vertical distribution of host-seeking mosquitoes showed a distinct pattern with significantly greater numbers of mosquitoes being trapped at the highest (6 m) level (Table 6). Mosquito numbers caught at near ground level (0.6 m) were significantly higher than those at the 3 m level. Further analysis of these data showed that both *Cx. quinquefasciatus* and *Cx. tarsalis* were the most predominant species at this site which contributed to the bimodal peak numbers at near ground and 6 m levels. In the physiologic age determination tests on mosquitoes from the same site, the parity rate of the above species was 60% or higher in favor of parous females (Table 7). In an earlier report by Snow and Wilkes (1977) on *Culex thalassius*

Table 5. Distribution of larval mosquito populations in various habitats in the Prado Basin.[a]

Species	% larval composition at habitat[b]		
	I	II	III
An. freeborni	0	9.4 b[c]	0
Cx. erythrothorax	0	10.4 b	0
Cx. quinquefasciatus	32.4 b	2.1 a	0.9 a
Cx. stigmatosoma	49.1 c	10.4 b	1.9 a
Cx. tarsalis	18.5 a	67.7 c	97.2 b
Total number	9,808	96	1,523

[a] Based on a total of 11,427 larvae collected at 12 biweekly intervals during March through July 1986 at 3 habitats, each with 3 sites and a mean of 5 dips per site.

[b] Habitats included: I: tail water of dairy lagoon; II: duck pond tributaries with tule growth; III: ground pools adjacent to wooded area.

[c] Means followed by the same letter in a column are not significantly different from one another (DMRT, $P = 0.05$).

Table 6. Vertical distribution of adult mosquitoes in the Prado Basin area.[a]

Height (m)	Number of mosquitoes[b]	% species composition[c]				
		A.f.	*C.e.*	*C.q.*	*C.s.*	*C.t.*
0.6	174 B	1 a	2 a	14 bc	0	16 bc
3.0	69 A	0	1 a	7 ab	1 a	6 a
6.0	282 C	1 a	0	27 d	3 a	21 cd

[a] Mosquitoes were caught overnight (1900–0900 h, Sept. 18, 1986) in dry ice (CO_2) traps hung at different heights by a nylon rope on eucalyptus trees. Means followed by same letter(s)-capital in a column for mosquito number or small in a row for species composition show that they are not significantly different from one another according to the Duncan's multiple range test ($P = 0.05$).

[b] Each figure represents the mean of mosquito counts on 3 trees each carrying 3 traps.

[c] Species composition consisted of: *A.f.*: *Anopheles freeborni*; *C.e.*: *Culex erythrothorax*; *C.q.*: *Culex quinquefasciatus*; *C.s.*: *Culex stigmatosoma*; *C.t.*: *Culex tarsalis.*

Theobald in Gambia, West Africa, it was shown that more parous than nulliparous mosquitoes were caught at the higher (9.15 m) level. Moreover, this species also showed a bimodal distribution with peaks at the highest (9.15 m) and lowest (0–0.91 m) levels. The lower peak was due to a high number of young > 70% nulliparous females; this high number of nulliparous females was attributed to a period of wing maturation and development of flight musculature. Older and parous females capable of flying at higher levels and transported farther by high wind currents, will be epidemiologically more important in disease transmission by increased encounters with avian reservoir hosts of encephalitis viruses.

Table 6 also shows that other species such as *An. freeborni* and *Cx. erythrothorax* were found at the lower levels. *Culex stigmatosoma*, however, was found at the higher levels. It is conceivable that due to the arboreal nature of this species, it preferred higher canopy levels in search of a possible avian blood source.

In assessing the results in Table 7, overall there were more parous than nulliparous female mosquitoes caught in CO_2-baited traps. The lower percentages of parous females may be related to the proximity of breeding sites. The higher number of host-seeking female mosquitoes with one or more previous blood feedings poses a potentially greater risk of encephalitis virus transmission in the area.

In conclusion, the present studies have demonstrated that the Prado Basin provides ideal habitats for a variety of mosquito species, including those capable of transmitting encephalitides in the area. Data on the population dynamics, as influenced by seasonal changes, showed the numbers of mosquitoes per trap night to be much lower during December through February and higher during August through October. Depending on fluctuations in daily temperature, humidity, light, etc., all species exhibited crepuscular peaks of host-seeking

Table 7. Physiological age groupings of female mosquitoes caught in different habitats of Prado Basin.[a]

Species	% parous mosquitoes at habitat[b]				Chi-square value
	I	II	III	IV	
Culex erythrothorax	100.0	73.4	0	100	5.34 ns
Culex quinquefasciatus	61.6	42.6	34.9	51.1	8.27*
Culex stigmatosoma	75.0	—	66.7	100	6.15*
Culex tarsalis	68.9	42.4	60.7	53.8	6.95 ns
Culiseta particeps	—	—	78.3	40.0	12.23*

[a] Means of 4 weekly collections in August 1986.

[b] Based on weekly sample size of 200 mosquitoes/4 weeks. Habitats included: I: site near dairy lagoon; II: duck pond; III: tree line; IV: wooded area.

* Significance at 5% level.

ns: nonsignificant.

and feeding activity. In vertical distribution studies, more mosquitoes were found at the highest level (6 m) than at lower (0.6 and 3 m) levels. Encephalitis vector species, such as *Cx. tarsalis* and *Cx. quinquefasciatus*, showed a bimodal pattern of activity, with peaks at the highest and lowest levels. This bimodal pattern was probably due to the higher number of parous females at the highest level and more nulliparous females at the lowest level. The number of *Cx. stigmatosoma* increased with increasing trap height, showing the arboreal nature of this species. The larger numbers of vector species at the highest level was further explained by the physiological age profile of over 60% parous mosquito populations.

REFERENCES CITED

Anonymous. 1983. Control of communicable diseases in California. Calif. State Dept. Health Services, Sacramento, CA, 594 p.

Anonymous. 1988. Arbovirus Disease Surveillance Bull. 19. Viral and Rickettsial Disease Lab., Calif. State Health Services, Berkeley, CA, 1 p. (mimeo).

Bangs, M. J., A. R. Barr, S. E. Cope, A. C. Morrison and P. Guptavanij. 1986. Assessment of adult mosquito populations in a freshwater marsh in southern California by various trapping methods. Proc. Calif. Mosq. Vector Control Assoc. 54:113–116.

Barnard, D. R. and M. S. Mulla. 1977. Diel periodicity of blood feeding in the mosquito *Culiseta inornata* in the Coachella Valley of southern California. Mosq. News 37:669–673.

Bidlingmayer, W. L. 1985. The measurement of adult mosquito population changes—some considerations. J. Am. Mosq. Control Assoc. 1:328–348.

Burdick, D. J. and E. H. Kardos. 1963. The age structure of fall, winter, and spring populations of *Culex tarsalis* in Kern County, California. Ann. Entomol. Soc. Amer. 56:527–535.

Chapman, H. C. 1962. The bio-ecology of *Culex erythrothorax* Dyar. Mosq. News 22:130–136.

Cope, S. E., A. R. Barr, M. J. Bangs, A. C. Morrison and P. Guptavanij. 1986. Human bait collections of mosquitoes in a southern California freshwater marsh. Proc. Calif. Mosq. Vector Control Assoc. 54:110–112.

Corbet, P. S. 1962. The age composition of biting mosquito populations according to time and level: a further study. Bull. Entomol. Res. 61:125–132.

Detinova, T. S. 1962. Age-grouping methods in Diptera of medical importance with special reference to some vectors of malaria. Monogr. Ser. World Health Organ. 47.

Emmons, R. W., D. V. Dondero, C. S. Chan, M. M. Milby, J. D. Walsh, W. C. Reeves, L. T. Hui, F. Ennik, J. Griffin, E. V. Bayer and R. A. Murray. 1988. Surveillance for arthropod-borne viral activity and disease in California during 1987. Proc. Calif. Mosq. Vector Control Assoc. 56:1–10.

Mulla, M. S., L. S. Mian and N. G. Gratz. 1987. Agricultural management practices—their impacts on production of vector and pest mosquitoes. J. Agric. Entomol. 4:97–131.

Nelson, R. L. and R. D. Spadoni. 1972. Nightly patterns of biting activity and parous rates of some California mosquito species. Proc. Calif. Mosq. Control Assoc. 40:72–76.

Reisen, W. K. and A. R. Pfuntner. 1987. Effectiveness of five methods for sampling adult *Culex* mosquitoes in rural and urban habitats in San Bernardino County, California. J. Am. Mosq. Control Assoc. 3:601–606.

Russell, R. C. 1985. The efficiency of various collection techniques for sampling *Culex annulirostris* in southeastern Australia. J. Am. Mosq. Control Assoc. 1:502–505.

Schreiber, E. T., M. S. Mulla and J. D. Chaney. 1988. Population trends and behavioral attributes of adult mosquitoes associated with dairies in southern California. Bull. Soc. Vector Ecol. 13:235–242.

Snow, W. F. and T. J. Wilkes. 1977. Age composition and vertical distribution of mosquito populations in the Gambia, West Africa. J. Med. Entomol. 13:507–513.

Strickman, D. 1988. Redescription of the holotype of *Culex (Culex) peus* Speiser and taxonomy of *Culex (Culex) stigmatosoma* Dyar and *thriambus* Dyar (Diptera: Culicidae). Proc. Entomol. Soc. Washington 90:484–494.

Tempelis, C. H. and R. K. Washino. 1967. Host feeding patterns of *Culex tarsalis* in the Sacramento Valley, California, with notes on other species. J. Med. Entomol. 4:315–318.

Tyndale-Biscoe, M. 1984. Age grading methods in adult insects: A review. Bull. Entomol. Res. 74:341–377.