

# BIO-ECOLOGICAL STUDIES OF *CULEX* MOSQUITOES IN A FOCUS OF WESTERN EQUINE AND ST. LOUIS ENCEPHALITIS VIRUS TRANSMISSION (NEW RIVER BASIN, IMPERIAL VALLEY, CALIFORNIA) I. LARVAL ECOLOGY AND TRENDS OF ADULT DISPERSAL

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**ABSTRACT.** The riverine ecology of *Culex tarsalis* Coq., *Cx. pipiens quinquefasciatus* Say and *Cx. erythrorhax* Dyar was compared in a focus of WEE and SLE virus transmission during a study at the New River, Imperial Valley, California in 1978.

*Cx. p. quinquefasciatus* and *Cx. erythrorhax* breeding was widespread in the inundated reed/salt cedar habitat, and larvae were most frequently found alone or associated in shaded, eutrophic sites. Larval *Cx. tarsalis* were less prevalent, occurring solitarily in sites exposed to full sun and commonly cohabitating with *Cx. p. quinquefasciatus*. Larval densities of the 3 species averaged less than 5 per dip during each month of the December to May sampling season.

Adult *Cx. tarsalis* and *Cx. p. quinquefasciatus* exhibited similar tendency to disperse from the breeding area as determined by tropism to CO<sub>2</sub>-baited light traps set in a transect across the river basin. *Cx. erythrorhax* showed minimal dispersion from the breeding habitat.

Bi-modal seasonal peaks of *Cx. tarsalis* density occurred in June and August correlating with maximum WEE and SLE infection rates of 39.5% and 29.1% pools positive, respectively. Infected *Cx. tarsalis* were recovered throughout the basin transect and at rural ranch sites 0.2–1.6 km from the breeding site. WEE and SLE viruses were not isolated from *Cx. p. quinquefasciatus* pools, and abundance was asynchronous with viral activity.

## INTRODUCTION

The Imperial Valley is located in southeastern California, extending from the Salton Sea to the Mexican border. The area is known to be a persistent focus of *Culex tarsalis* Coq. transmitted St. Louis

encephalitis (SLE) and more sporadically, western equine encephalitis (WEE). Recently, Bown & Work (1973) and Work et al. (1977) recovered SLE virus from *Culex pipiens quinquefasciatus* Say<sup>2</sup> mosquitoes collected in rural habitats along the Alamo and New Rivers. Both rivers flow northward from Mexico emptying into the Salton Sea at 75 m below sea level. A potential role for *Cx. p. quinquefasciatus* in the transmission of SLE peridomestically to humans from a riverine *Cx. tarsalis* wild-bird cycle has been postulated (Magy et al. 1976, Work 1977).

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<sup>2</sup> It is the policy of *Mosquito News* to accept names listed in the Knight and Stone Catalog (1977) and the Knight Supplement (1979). In the Supplement *Cx. quinquefasciatus* is considered a valid species, not a subspecies of *pipiens*. There is a considerable body of evidence pro and con. The authors of this paper consider *quinquefasciatus* a subspecies. The editor disagrees but has not interfered with the right of "free speech" in this case.

Although arbovirus recovery from *Culex* spp. mosquitoes in the Imperial Valley has been confirmed since 1967 (Bown & Work 1973; Emmons et al. 1973, 1974, 1975; Madon et al. 1975; Work et al. 1969, 1974, 1977), associated

investigations of vector bionomics in highly endemic areas have been limited to studies by Berlin et al. (1976), Clark et al. (1974) and Nelson (1971).

In late 1977, a study was undertaken to compare the riverine ecology of *Cx. tarsalis* and *Cx. p. quinquefasciatus* in a defined area of the New River basin previously associated with intense arboviral activity (Work et al. 1977). The present paper is limited to aspects of the study concerned with larval habitats, cohabitation and abundance, as well as adult seasonal densities and dispersal correlated with arbovirus recovery. Coincidental aspects of *Culex erythrothorax* Dyar bionomics are also included.

Concurrent investigations of the attraction of these 3 *Culex* species to human and animal bait were reported by Walters et al. (1979). Comparative host preferences of *Cx. tarsalis* and *Cx. p. quinquefasciatus* in both riverine and peridomestic situations and patterns of resting will be discussed in a separate paper of this series.

**DESCRIPTION OF STUDY AREA.** The study site, located 7 km southwest of El Centro, California, encompassed a 1 km length of the New River and 1 ha of surrounding basin bordered by 20 m high bluffs to the north and south. The mosquito breeding habitat was north of the river (0.1 ha) and resulted from agricultural tileline drainage and rainwater, impounded from the river channel. Emergent vegetation in the breeding area consisted of dense 10 m high reeds (*Phragmites*), salt cedar (*Tamarix*), and some cattails (*Typha*). Other common riverine vegetation in the basin included arrowweed (*Pluchea*), mesquite (*Prosopis*), and pickleweed (*Salicornia*). Much of the basin south of the river was fallow cropland, overgrown by saltgrass (*Distichlis*). Bordering the area on the north bluff was a 10,000-head feedlot operation; cattle were also held east of the study area in the basin. Alfalfa was grown year-round on the south bluff and in the basin, west of the study site. The study area constituted the primary source of *Culex* production within several km radius.

The Imperial Valley experienced a mild and wet winter (3–28 C, 75 mm rainfall) and a typically hot summer (17–47 C) during late 1977–1978, allowing continuous *Culex* production in the study area. Winds, averaging 8 knots occurred frequently in the valley during this period, a potential factor influencing mosquito dispersal. The prevailing direction was from southwest to west.

## MATERIALS AND METHODS

To expose mosquito breeding sites, two trails were cut: a 540 m trail transecting the river basin from the south(west) to the north(east) bluffs (transect trail) and a 200 m trail, paralleling the river channel, 50 m from the northern bluff (bluff trail).

**LARVAL SURVEILLANCE.** Thirty-five larval sampling sites (ca. 0.5–2.0 m<sup>2</sup>) were selected 5–20 m apart along the north transect and bluff trails, encompassing a variety of habitat types. Sites were established 1–2 m from the trails for minimal habitat disruption. Water levels fluctuated from 5–25 cm along the transect trail and 25–50 cm along the bluff trail. Sampling was done 1–3 times a month from December, 1977 to May, 1978. Sampling was terminated in May because of the drying of accessible sites. A standard 500 ml dipper was used for sampling, taking 2–6 dips dependent on site surface area. The total larval sample from each site was transported to the laboratory where 2nd to 4th instars were identified live or after freeze-thawing.

**ADULT SURVEILLANCE.** Ten miniature light traps (Rohe & Fall 1979) were used to monitor adult densities and dispersal across the basin. Traps were placed 1.5 m high in diverse habitats along the transect trail; 0, 90, 150, 180, 270, 360, 450, and 540 m from the north bluff and at the top of each bluff. Sampling of adults was done 1–2 nights per week for most weeks from January to mid-September, 1978. Traps were set 1–2 hr before sunset and collected soon after sunrise. They utilized ca. 1 kg dry ice as an attractant for host-seeking females, an amount found to last

the entire night. Mosquitoes were collected in 1000 ml cartons (attached to trap nets) to minimize injury during field transport. Samples were kept continuously on dry ice from the field to the laboratory where identifications were made. *Cx. tarsalis* and *Cx. p. quinquefasciatus* were pooled according to trap site and species (1–50 mosquitoes) and shipped frozen to Dr. Telford Work at the University of California, Los Angeles for virus isolations and determination. Limited funding excluded arbovirus testing of *Cx. erythrothorax* mosquitoes in this study.

Augmenting transect collections were light traps set at 3 ranches located 0.2, 0.5, and 1.6 km from the study area. These ranches, housing domestic animals

as well as human populations, were monitored to detect possible dissemination of infected vectors from the basin.

## RESULTS AND DISCUSSION

**LARVAL ECOLOGY.** Larval *Culex* mosquitoes were widespread in the habitat, and were present in 50–80% of sites during each sampling period. Additionally, *Culiseta inornata* Williston inhabited up to 25% of sites from January–March.

*Cx. p. quinquefasciatus* and *Cx. erythrothorax* were the dominant species in the riverine habitat, but extreme fluctuations in larval prevalence were observed from month to month (Fig. 1). Asynchronous

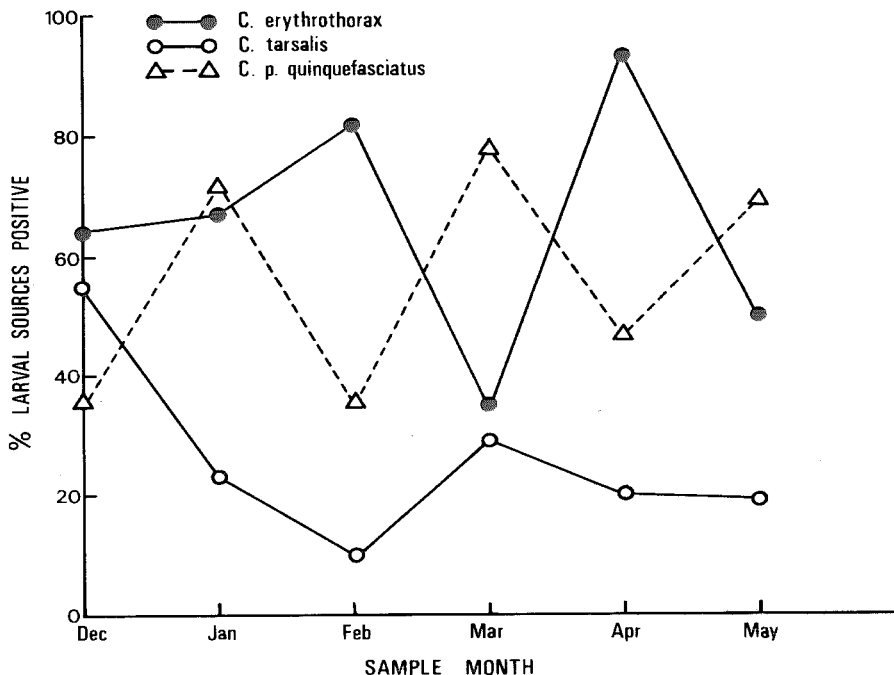


Figure 1.—Seasonal prevalence of larval *Culex* mosquitoes in the New River study area, December, 1977 to May, 1978.

seasonal distribution patterns between these species appeared to represent natural population cycles as well as probable competitive displacement within shared larval habitats. *Cx. tarsalis* was less widespread, present in less than 30% of sites each month. Larval densities of *Cx. p. quinquefasciatus*, *Cx. erythrothorax*, and *Cx. tarsalis* averaged less than 5 per dip each sample period.

Although most accessible trail sites were dry by early summer, local *Cx. tarsalis* production continued through August as evidenced by males (2%) collected in light traps in the breeding area. Males of *Cx. p. quinquefasciatus* and *Cx. erythrothorax* were found in light traps only through June.

Aquatic habitats available within the study area were mostly eutrophic (69%) with several zooplankton groups present; however, insects other than mosquitoes were generally absent. Mosquito larvae were the only macroscopic organisms present in dystrophic waters.

Each *Culex* sp. was found in all available habitat types; however, some differences were apparent between species (Table 1). *Cx. p. quinquefasciatus* and *Cx. erythrothorax* larvae were collected in comparable frequency from each habitat with the highest percent of collections from sites which

were eutrophic and shaded. In contrast, larvae were only rarely found in open, sunny eutrophic habitats. *Cx. tarsalis* larvae, however, were most frequently collected from eutrophic habitats with at least partial sun, and were found in all sites exposed to full sun. Additionally, *Cx. p. quinquefasciatus* and *Cx. erythrothorax* appeared slightly more adaptable to dystrophic habitats than *Cx. tarsalis* (Table 1).

Larval cohabitation of *Culex* species in basin breeding sites reflected these ecological habitat preferences. *Cx. p. quinquefasciatus* and *Cx. erythrothorax* were found alone or in association with each other in 51% and 68% of positive collections for each species, respectively. *Cx. p. quinquefasciatus* was secondarily associated with either *Cs. inornata* (15%) or both *Cx. tarsalis* and *Cx. erythrothorax* (10%). Larval *Cx. erythrothorax* were found an additional 20% of the time in conjunction with *Cx. p. quinquefasciatus* and either *Cx. tarsalis* or *Cs. inornata*. Total association of *Cx. p. quinquefasciatus* and *Cx. erythrothorax* with *Cx. tarsalis* (including all species combinations) was only ca. 20% for each species.

*Cx. tarsalis* was primarily found alone (30% of positive collections) or in combination with both *Cx. p. quinquefasciatus* and *Cx. erythrothorax* (27%). An additional 27% of sources containing *Cx. tarsalis* also

Table 1. Development of larval *Cx. tarsalis*, *Cx. p. quinquefasciatus* and *Cx. erythrothorax* in habitats associated with the New River study area, December, 1977–May, 1978.

Habitat Type		Percent of Collections <sup>1</sup>		
		<i>Cx. tarsalis</i>	<i>Cx. p. quinquefasciatus</i>	<i>Cx. erythrothorax</i>
EUTROPHIC				
Full Sun	absent	11	1	1
Partial Shade	reeds	48	32	27
	salt cedar			
	pickleweed			
Full Shade	reeds	23	41	42
	salt cedar			
DYSTROPHIC				
Partial Shade	reeds	2	3	2
Full Shade	reeds	16	24	28
Total		100	100	100

<sup>1</sup> Based on the total number of collections for each species; *Cx. tarsalis* (44), *Cx. p. quinquefasciatus* (117), *Cx. erythrothorax* (107).

contained *Cx. p. quinquefasciatus*, with or without *Cs. inornata*.

**ADULT DISTRIBUTION PATTERNS.** Based on total transect light trap collections, *Cx. erythrothorax* and *Cx. p. quinquefasciatus* populations exhibited a single seasonal peak in density, during April (Fig. 2). *Cx. p. quinquefasciatus* was rarely collected beyond June, whereas *Cx. erythrothorax* continued to appear in small numbers until September. *Cx. tarsalis* showed a bi-modal pattern of abundance with peak densities in June and August. Bi-modal patterns of *Cx. tarsalis* abundance are typically observed in the Imperial Valley, but densi-

ties are usually highest in June and October (Bown & Work 1973, Gordon et al. 1978, Magy et al. 1976, Webb et al. 1977).

*Cx. erythrothorax* was the most numerous mosquito collected in CO<sub>2</sub> light traps, followed by *Cx. tarsalis* (Fig. 2). *Cx. p. quinquefasciatus* was collected in very small numbers even at peak abundance. Based on larval prevalence in the area, adults appeared to be under-represented in light traps. The unresponsiveness of *Cx. p. quinquefasciatus* to light trap stimuli relative to other *Culex* species has also been reported by Magy et al. (1976) and Webb et al. (1977).

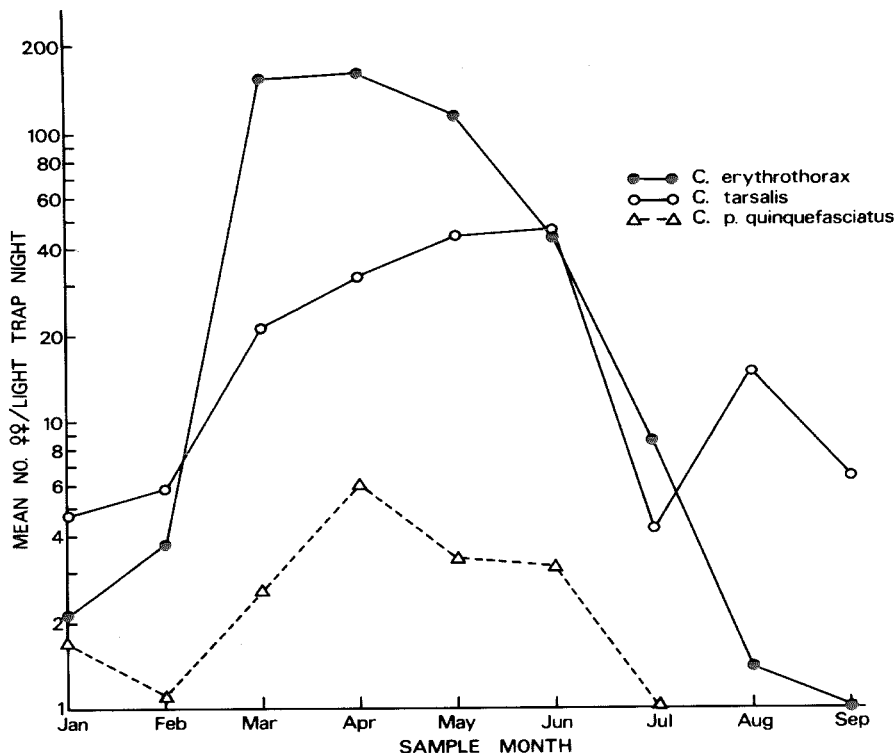


Figure 2.—Seasonal densities of *Culex* mosquitoes attracted to CO<sub>2</sub>-baited light traps set in a transect across the New River basin.

Seasonal patterns as reflected by collections from transect sites within the breeding area and across the river were similar to total transect collections. This suggested that most trapped mosquitoes originated from the local area.

The transect trapline showed differing trends of *Culex* dispersal and distribution in the river basin. Figure 3 depicts mean *Culex* densities per trap night over the 37 week study period, associated with 1) proximity of light trap sites to the breeding area, 2) site vegetation, and 3) transect topography. Confidence intervals at the 90% level (Student's *t*, Steel & Torrie 1960) define the sample mean in terms of both seasonal and site variability.

*Cx. erythrorhax* dispersed little from the reed/salt cedar breeding habitat. Highest densities in light traps were encountered at sites 0, 90, and 150, in or adjacent to the breeding area; mosquitoes were rarely collected across the river or at bluff sites (Fig. 3). Apparently, host, ovipositional and environmental requisites of this species were optimal within the reed habitat. Dow et al. (1965), in flight range studies, also observed *Cx. erythrorhax* to remain markedly localized (near release points) with recovery of marked females at a maximum distance of only 2.4 km.

*Cx. tarsalis* and *Cx. p. quinquefasciatus* exhibited similar patterns of distribution relative to the breeding area (Fig. 3). *Cx. p. quinquefasciatus*, although collected in very small numbers, appeared more numerous at sites 0 and south bluff. These sites, and also sites 270 and 540 were associated with dense arrowweed vegetation and bluff areas, perhaps providing a favorable riverine microhabitat for resting adults. *Cx. p. quinquefasciatus* was collected at both bluffs, indicating a capacity to disperse from the basin. A predominance of mosquitoes accumulated at the south bluff compared to the north bluff; this was attributed to flight into the prevailing wind.

Adult *Cx. tarsalis* were also collected in abundance at sites 0, south bluff, 270 and 540, but they additionally favored salt cedar sites 150 and 180, adjacent to the river. This may indicate a specific route of dispersal along the river channel. Dispersal to both bluffs was indicated and greater numbers accumulated at the south bluff.

VIRUS INCIDENCE. Transect infection rates of *Cx. tarsalis* with WEE and SLE viruses are shown in Table 2. No viruses were isolated from 343 *Cx. p. quinquefasciatus* (93 pools) tested in the same period. Highest *Cx. tarsalis* infection with WEE

Table 2. Recovery of WEE and SLE viruses from *Cx. tarsalis* in the New River transect, 1978.

Month	No. <i>Cx. tarsalis</i> Tested	No. pools tested (mean pool size)	No. pools Positive		Infection Rates (%)			
			WEE	SLE	WEE		SLE	
					min <sup>1</sup>	max <sup>2</sup>	min	max
Jan.	235	37 (6.4)	0	0				
Feb.	261	39 (6.7)	0	0				
Mar.	545	28 (19.5)	0	0				
Apr.	961	175 (5.5)	0	0				
May	517	16 (32.3)	0	0				
Jun.	1419	43 (33.0)	17	1	1.2	39.5	0.1	2.3
Jul.	62	10 (6.2)	1	0	1.6	10.0	0.0	0.0
Aug.	950	55 (17.3)	1	16	0.1	1.8	1.7	29.1
Sep.	181	22 (8.2)	0	0				
Total	5131	425						

<sup>1</sup> Minimum infection rate (%) =  $\frac{\text{No. pools positive}}{\text{No. } Cx. \text{ tarsalis tested}} \times 100$

<sup>2</sup> Maximum infection rate (%) =  $\frac{\text{No. pools positive}}{\text{No. pools tested}} \times 100$

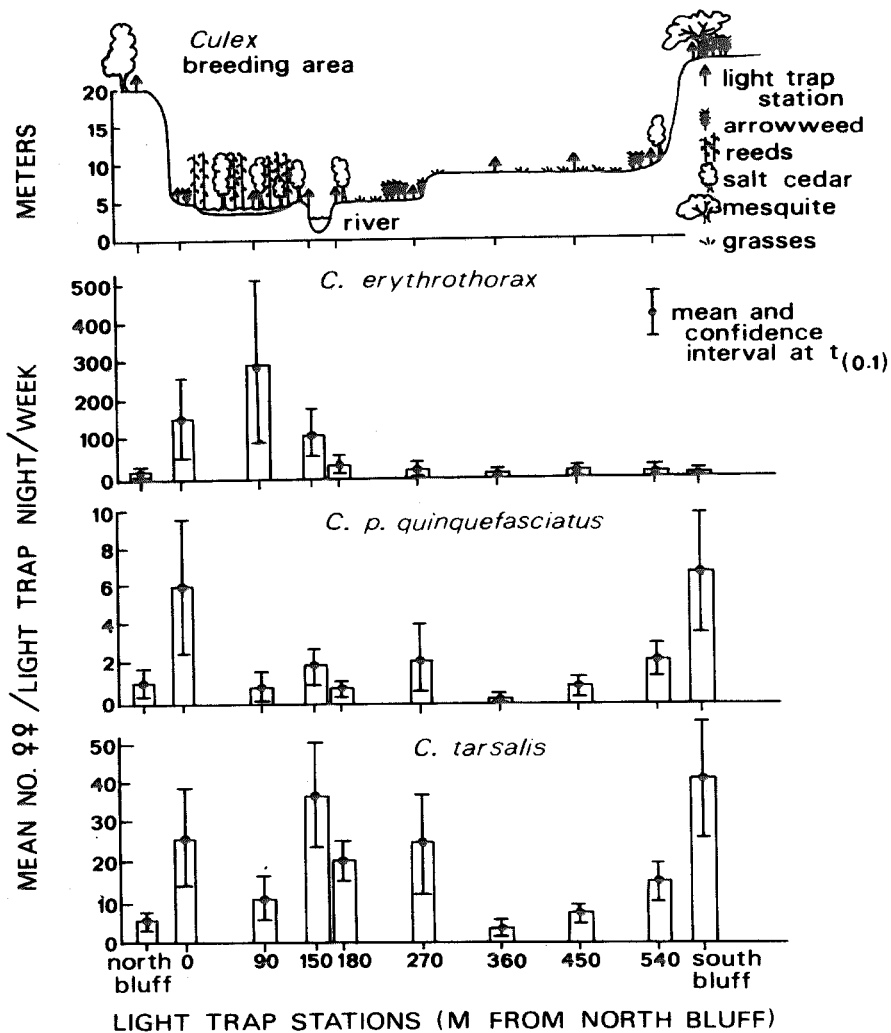


Figure 3.—Distribution of *Culex* mosquitoes in a light trap transect of the New River basin with respect to the breeding area, January to September, 1978.

virus occurred during June and July, with comparable SLE infection observed in August. Actual infection rates were not determinable, but occur between the minimum and maximum rates calculated.

Isolations of WEE and SLE from *Cx. tarsalis* first occurred on June 8. By June 15, pools from most transect sites, and ranches north (0.2 km) and south (1.6 km) were positive for WEE. The single July isolation was significant due to the minimal number of pools tested and pool size. WEE infection rates were much reduced in August and no isolations were made in September. No SLE isolations were successful from pools collected during July or September, however, SLE exploded in *Cx. tarsalis* populations during August. First transect isolations were made from *Cx. tarsalis* collected at sites 90-270; SLE was recovered from a ranch 0.5 km north by late August.

#### EPIDEMIOLOGICAL ANALYSIS

Adult *Cx. tarsalis* infected with WEE and/or SLE viruses were well dispersed within the river basin, and isolations at rural ranch sites indicated probable dissemination of infected vectors from the basin. Close temporal association between *Cx. tarsalis* abundance and high virus activity was observed. WEE virus activity was associated with the first peak of the bi-modal population curve, whereas SLE virus activity was associated with the second peak in August. This sequence of virus occurrence in *Cx. tarsalis* was the same as that reported from the Central Valley of California (Reeves & Hammon 1962), indicating that similar epidemiological mechanisms may be involved in both areas.

*Cx. p. quinquefasciatus* production was highly compatible with riverine habitats, and the distribution of adults across the basin was comparable to that of *Cx. tarsalis*. However, it is doubtful that *Cx. p. quinquefasciatus* contributed to the transmission of SLE within the basin or in adjacent peridomestic situations during

1978 for 2 reasons: First, populations of *Cx. p. quinquefasciatus* were at their lowest when SLE virus activity was highest. This temporal asynchrony would certainly limit successful mosquito infection and transmission to reservoir hosts or humans. Second, although SLE has been previously isolated from *Cx. p. quinquefasciatus* at maximum infection rates of 24% (Work et al. 1977), no virus was detected from pools tested during the present study, even when infection rates in *Cx. tarsalis* were as high as 29%.

*Cx. erythrothorax* was abundant in the river habitat during early summer and might therefore play some role in WEE transmission within the river basin. However, minimal movement from the basin would exclude this species as a mechanism for disseminating arboviral disease from riverine to rural or urban areas. Although *Cx. erythrothorax* were not able to be tested for viruses in this study, both WEE and SLE have been recovered from this species in the Imperial Valley previously (Emmons et al. 1973, 1974).

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