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SPATIAL AND CIRCADIAN OVIPOSITION PATTERNS IN AN URBAN POPULATION OF *CULEX QUINQUEFASCIATUS*

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ABSTRACT. A transect of infusion-baited oviposition tubs was used at the Orange County (CA) Vector Control District facility to determine the circadian periodicity and the influence of urban habitat factors, such as buildings, ornamental plantings, and mercury vapor lights on *Culex quinquefasciatus* oviposition activity. The peak oviposition activity occurred during the first 2 h after sunset. Nearly 80% of egg rafts deposited were laid within the first 4 h after sunset and no morning ovipositional peak was detected. Urban and physical habitat factors considered had no effect on tub selection by ovipositing females. Linear analysis indicated that eggs were laid randomly among tubs. Eighty-eight percent of the rafts collected were *Cx. quinquefasciatus*. The remaining egg rafts were laid by *Culex tarsalis*, *Culex stigmatosoma*, and *Culieseta incidens*.

INTRODUCTION

Culex quinquefasciatus Say is a common urban mosquito species in southern California. The larvae are found in poorly maintained swimming pools, ornamental ponds, reclaimed water storage ponds, catch basins, gutters, and storm drains. Dhillon et al. (unpublished data) showed that *Cx. quinquefasciatus* readily moved through the drainage system in storm drains and catch basins, emerging through manhole covers and catch basin openings into urban communities. In the Los Angeles Basin of California, *Cx. quinquefasciatus* was found to be the most abundant mosquito species in the urban setting and it composed more than 85% of CO_2 trap catches (Webb et al. 1990, Reisen et al. 1992).

The status of *Cx. quinquefasciatus* as a vector of St. Louis encephalitis virus (SLE) in southern California has not been well established. Species in the *pipiens* complex are important vectors of SLE in urban areas in the eastern United States (Monath 1980), and *Cx. quinquefasciatus* is naturally infected at lower levels than *Culex tarsalis* Coq. and *Culex stigmatosoma* Dyar in California (Reeves 1990). Webb and Myers (1986) noted that the incidence of SLE in humans was positively correlated with the seasonal abundance of both *Cx. quinquefasciatus* and *Cx. tarsalis*.

One of the most effective arbovirus surveillance tools is the infusion-baited mosquito oviposition trap developed by Reiter (1983, 1986). This trap enables collection of parous (gravid) mosquitoes, which are the most likely to have ingested a virus or other pathogen. This selective trapping of gravid females is an efficient source of information concerning the prevalence of viruses of public health importance in mosquito populations.

In the United States, most studies concerning the bionomics, ecology, and behavior of *Cx. quinquefasciatus* have been carried out in rural or semirural areas, even though *Cx. quinquefasciatus* is a common urban mosquito. In 2 urban residential areas in the Los Angeles basin, Schreiber et al. (1989) studied host-seeking and resting behavior of urban mosquitoes. Schreiber et al. (1988) also carried out studies on this species in a number of southern California dairies that are located near urbanized areas.

As most *Cx. quinquefasciatus* breeding in southern California occurs in urban areas, we investigated the oviposition behavior of this species in this habitat. Our objectives were to determine the circadian periodicity of oviposition in an urban *Cx. quinquefasciatus* population and to quantify the effect of urban habitat factors on oviposition site selection by *Cx. quinquefasciatus*.

MATERIALS AND METHODS

Field studies were conducted from June through October in 1991 and from April through June 1992 at the Orange County Vector Control District in Garden Grove, CA. Experiments could not continue beyond late June 1992 due to construction activity at the site. The district is located in a commercial area surrounded by residential properties.

Twice each month black plastic tubs (50 × 40 × 18 cm) were placed along a 200-m transect that incorporated a variety of environmental and physical factors, including proximity to vegetation, water, intense mercury vapor lights, and buildings (Table 1). The tubs each contained 300 ml of Bermuda grass infusion (Millar et al. 1992), 750 ml alfalfa hay infusion (Reiter 1986), and 8 liters of tap water (making a total volume of 9.05 liters) and were positioned 2 h before sunset. On one night each month, *Culex* egg rafts deposited were counted and removed every 2 h throughout the night. On the other night, tubs were placed

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Table 1. Location of oviposition tubs in relation to physical and environmental factors considered in spatial analysis.

Trap	Water[1]	Vegetation[2]	Light[3]	Buildings[4]
1	0	0	0	0
2	+	0	+	0
3	+	0	0	0
4	+	0	0	0
5	+	0	0	0
6	0	+	+	0
7	0	+	0	+
8	0	+	0	+
9	0	+	0	0
10	0	0	+	+

[1] Trap placed within 1 m of open water.
[2] Trap placed within 1 m of ornamental vegetation.
[3] Trap illuminated by mercury vapor light.
[4] Trap placed within 1 m of a building.

before sunset and egg rafts were recovered the following morning. Subsamples of the egg rafts collected were returned to the laboratory and hatched individually. Larvae were held until they became 4th instars and were identified.

Data from all egg raft collections were placed in 5 period classes: 1) egg rafts collected 0–2 h postsunset, 2) rafts collected 2–4 h postsunset, 3) rafts collected 4–6 h postsunset, 4) rafts collected 6–8 h postsunset, and 5) rafts collected 8+ h postsunset. Total egg rafts in each class were square-root transformed and classes compared using ANOVA. The square-root transformation is an appropriate transformation with data sets where the mean and variance are proportional (Snedecor and Cochran 1980). Mean numbers of egg rafts per time period were separated by a protected least significant difference test (LSD) (Snedecor and Cochran 1980).

Oviposition data for all nights were analyzed spatially in 2 ways. First, the total egg raft numbers for each tub per night was compared to the other egg raft counts using ANOVA after square root ($\sqrt{x}$) transforming the data. Second, the dispersion pattern was determined using the mean/variance regression method of Taylor (1961). One of the initial regression residuals was determined to be an outlier (Draper and Smith 1981) and the analysis was repeated after its removal.

RESULTS AND DISCUSSION

Egg rafts of 3 *Culex* species were collected during this study. Eighty-eight percent of 253 egg rafts that were taken as subsamples from the oviposition tubs and reared to the L4 stage were identified as *Cx. quinquefasciatus*; 3 other species constituted the remainder. *Culex stigmatosoma* constituted 3%, *Cx. tarsalis* constituted 5%, and *Culiseta incidens* (Thomson) constituted 4%. These samples were representative of egg rafts deposited throughout the night. These results are consistent with those of Schreiber et al. (1989) who collected 98.9 and 95.9%, respectively, of adult female *Cx. quinquefasciatus* using infusion-baited traps at 2 residential sites in the Los Angeles basin.

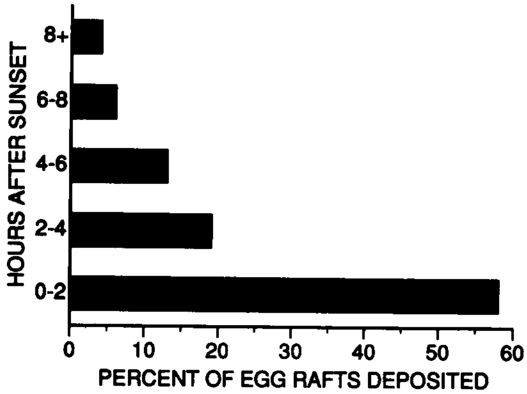

Fig. 1. Circadian periodicity of *Culex quinquefasciatus* oviposition behavior.

Circadian periodicity data are summarized in Fig. 1 as percentages. Fifty-nine percent of the egg rafts were deposited within the 2 h after sunset and nearly 80% were deposited within the first 4 h after sunset. There was no increase in ovipositional activity toward the end of the night. The difference between the time periods in which egg rafts were deposited was significant (ANOVA; $F = 9.2$, df = 4,30, $P = 0.0001$). For the period 0–2 h after sunset, a mean of 42.9 egg rafts/night was deposited. Means of 13.0, 7.6, and 4.0 egg rafts were collected during the next 3 2-h time periods. During the final time period, from midnight to sunrise, 3.3 egg rafts/night were collected. Multiple means testing on the transformed data by a protected least significant difference test showed that significantly more rafts were laid in the first time period, which occurred between 0 and 2 h after sunset, compared to egg rafts deposited in other time periods (LSD = 1.78 on $\sqrt{x}$, $P < 0.05$).

These data agree with those of Schreiber et al. (1989) who noted in a residential area of the Los Angeles Basin that the largest proportion of *Cx. quinquefasciatus* oviposited within several hours after sunset. No morning peak was recorded for *Cx. quinquefasciatus* in this study. Early evening peaks of oviposition activity with no morning oviposition flight are not unusual and have been reported for *Anopheles minimus* Theobald (Muirhead Thomson 1940). Few *Cx. tarsalis* were

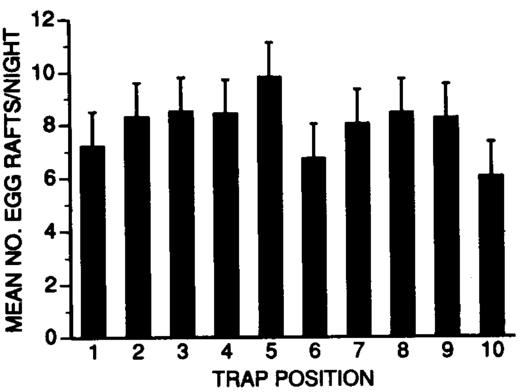

Fig. 2. Mean number of *Culex quiquefasciatus* egg rafts deposited in oviposition tubs placed at the Orange County Vector Control District facility (Garden Grove, Orange Co., CA).

collected in the infusion-baited tubs. Laboratory studies have shown a similar ovipositional response in *Cx. tarsalis* to evening twilight periods, but there is also a distinct morning oviposition peak (Logan and Harwood 1965). These evening and morning peaks also occur in other species including *Culex pipiens Linn.*, *Culex restuans* Theobald, and *Coquillettidia fuscopennata* (Theobald) (Haddow and Gillett 1958, Oda and Kuhlow 1979, MacDonald et al. 1981).

Spatial analysis of egg raft counts from all tubs over all nights yielded interesting results. The mean numbers of egg rafts recovered from each tub along the transect (Fig. 2) were compared to each other using ANOVA. There was no significant difference in the number of egg rafts laid in any of the tubs ($F = 0.65$, df $= 9{,}149$, $P = 0.75$). In other words, no oviposition tub was preferred over any other tub regardless of placement. This strongly suggests that the urban and physical habitat factors considered had no influence on *Cx. quinquefasciatus* oviposition site selection.

Another test of these data was made to determine dispersion using the regression method of Taylor (1961). When the $\log_{10}$ of the sample mean for each night is regressed against the $\log_{10}$ of the sample variance for that night, the resulting slope can be viewed as a dispersion index. If the slope is not significantly different from 1, the individuals are considered to be randomly dispersed. The mean/variance regression yielded the following equation: $y = 0.17 + 1.2x$. The r^2 for the regression was 0.46. A test of the slope showed that it was not significantly different from 1 (t-test, $P > 0.05$), thus again indicating an independent choice of oviposition sites regardless of habitat factors considered. One of the regression residuals was found to be an outlier (Draper and Smith 1981) and after removal the analysis was repeated. The resulting equation ($y = 0.56 + 0.89x$) and an r^2 of 0.44. Again the slope was not found to be significantly different from 1.

Kitron et al. (1989) and Beehler and DeFoliart (1990) found that oviposition trap location was important in collecting eggs of *Aedes triseriatus* (Say). In our study, there were no positional effects related to tub placement. The power or availability of the attractant presented in the urban landscape was more important than any positional effect. Therefore, trap placement is less important than the use of an organic infusion in an urban area. This could greatly simplify surveillance programs.

In summary, the peak ovipositional period for this urban population of *Cx. quinquefasciatus* occurred between 0 and 2 h after sunset. There is strong evidence that oviposition site selection for this species has a strong random component and is dependent on the presence of oviposition attractants rather than the interaction between the site and the surrounding urban environment.

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