DISPERSAL OF *CULEX QUINQUEFASCIATUS* FROM A DAIRY IN SOUTHERN CALIFORNIA

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ABSTRACT. The dispersal of *Culex quinquefasciatus* was studied near Norco, California in a periurban situation of southern California. Concurrent studies indicated that host-seeking females were most active up to one hour after sunset. A mark-release-recapture technique was used to document a mean distance traveled of 0.91 km in 12 hr (the first flight period) and a cumulative distance of 1.27 km after 36 hr (following the second flight period). Nearly 0.32% of 47,750 marked females were recaptured. A majority of the population moved with the prevailing wind. Unmarked females were captured at all trapping locations in the study.

INTRODUCTION

The dairy industry in Riverside County, California constitutes a major agricultural commodity and economy with a value in excess of $220 million dollars (Anonymous 1986). Wastewater impoundments from dairies in this region provide ideal habitats for oviposition and larval development of mosquitoes. The most prominent species are *Culex quinquefasciatus* Say and *Cx. peus* Speiser (Bohart and Washino 1978, Mulla et al. 1987) and they have been implicated as vectors of St. Louis encephalitis and western equine encephalitis (Bohart and Washino 1978). Additionally, *Cx. quinquefasciatus* could serve as a vector of *Plasmodium relictum* and *Wuchereria bancrofti* respectively, should these become common in California (Bohart and Washino 1978). The dairy industry in southern California is increasingly being encroached upon by urbanization, thus allowing greater human contact with these two mosquito species. Consequently, we undertook a study to examine the characteristics of dispersal in populations of *Cx. quinquefasciatus* to assess risk to the human population in nearby communities.

MATERIALS AND METHODS

The study area was located in a dairy and truck crop operation 1 km north of the city of Norco, with an approximate population of 25,000, in Riverside county. The prevailing mosquitoes in this area were: *Cx. erythrothorax* Dyar, *Cx. peus*, *Cx. tarsalis* Coquillett and *Cx. quinquefasciatus*. They were produced primarily in a series of three 0.58 ha. wastewater lagoons, woodland ponds, tailwater and backwater from the Santa Ana River 0.5 km from the dairy proper. The dairy had approximately 500 to 800 head depending on the time of year.

During this study the activity and dispersal of *Cx. quinquefasciatus* females were studied by using unlit miniature surveillance traps baited with dry ice as described by Brenner et al. (1984). Concurrent studies at this site with *Cx. quinquefasciatus* collected in this trap generally produced unfed nulliparous females (number dissected = 918, parous = 799, nulliparous = 119). We referred to the females collected in these traps as "host-seeking." The traps were placed between 1 and 2 m above ground level during this study.

The dispersal of *Cx. quinquefasciatus* was studied using a mark-release-recapture technique. Host-seeking females were trapped utilizing dry ice traps in a treeline 1.0 km from the release site from 1900 to 0800 hr and were transported to the laboratory where they were anesthetized briefly with CO_2. Species composition was determined from 10 randomly selected bags from the dry ice traps containing a few hundred adults. The majority of the species collected were *Cx. quinquefasciatus* with a small number of *Cx. tarsalis*. The remaining mosquitoes were counted volumetrically (50 mosquitoes/ml ± 7 mosquitoes) and placed in a 0.97 liter cardboard container and "puffed" with 0.2 gm of fluorescent powder[2]. The mosquitoes were placed in 2 m^3 screen cages, supplied with a 10% aqueous sugar solution *ad lib* and were held until release one-half hour after sunset. At 24 hr postrelease the cages were recovered, the number of dead mosquitoes was determined and subtracted from the estimated number marked. Three experiments were conducted on August 28–29, September 17–19, and September 28–29, 1987.

Preliminary tests assessed the effects of the

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[2] Radiant Pigment Corporation.

dye on mortality, the persistence of dye on mosquitoes and the likelihood of the dye transferring from marked to unmarked mosquitoes in the traps.

In preparation for the placement of traps, we drew concentric rings on a topographic map with radii of 0.25, 0.5, 1.0 and 1.5 km. We selected 20 points on the rings as desirable locations coupled with easy access for the placement of the traps. All 20 traps were fairly evenly spread on each ring. A continuously-recording weather station measured wind speed/direction and temperature at the release site in the center of the rings.

Traps were operated continuously for night 1 (release date) from 1700 to 0800 hr then again from 1700 to 0800 hr on night 2. In addition to nights 1 and 2, one release, September 17–19, traps were run on night 3 from 1700–0600 hr. All collection bags were transported to the laboratory and examined under long-wave ultraviolet light for fluorescence. The number marked, and the total number of *Cx. quinquefasciatus* (determined either directly or volumetrically) were recorded.

Mean distance traveled (MDT) per time interval was calculated according to procedures described by Lillie et al. (1981a). Correction factors were computed for each trap ring to eliminate variations in trap density. This then allowed us to estimate the density and distance of marked mosquitoes per equal trapping area. The formulas for correction factor (CF) and MDT are given in Brenner et al. (1984).

RESULTS

In our preliminary tests on the effects of the dye on mosquitoes, difference in mortality between marked versus unmarked mosquitoes was not apparent. Dye duration on marked mosquitoes was at least 8 days. To detect if dye from marked mosquitoes could be picked up by "clean" mosquitoes, the following test was conducted: 10 marked mosquitoes were placed in a surveillance trap along with 20 unmarked mosquitoes from a colony of *Cx. quinquefasciatus* maintained at our laboratory. The test duration was 12 hr, with two replicates. Despite some dye contamination on the collecting bag, the number of marked mosquitoes did not change. Similar findings were reported by Lillie et al. (1981b) with fluorescent dusts for marking *Culicoides variipennis* (Coquillett) adults.

During the study conducted on the nights of August 28 (night 1) and August 29 (night 2), the weather conditions at peak activity were: winds were west to west northwest at 3.2 kph with gusts between 7–16 kph and the mean air temperature was 21°C.

On the nights of September 16 and 17 winds were from west to west northwest (September 16) and west to west northwest shifting later to the south (September 17). Wind speed and mean temperature on both nights were 8–16 kph and 21°C, respectively. On the nights of September 28th and 29th, wind direction and speed were west to south to east at 3.2 kph, west to south at 6.4 kph, respectively, with a mean air temperature of 18°C both nights at the time of peak activity.

Of the estimated 47,750 marked *Cx. quinquefasciatus* females released, over three different times, we recaptured 163 (0.34%). Many of the traps never collected marked *Cx. quinquefasciatus* females (Figs. 1 and 2). Most of the marked females recaptured were taken in traps south and southeast of the release point. On the first flight period (0–12 hr postrelease), 140 marked females (86%) were recaptured whereas the next period (24–36 hr postrelease) 23 marked females (19%) were recaptured. A third night (36 to 48 hr postrelease), was conducted on September 19, no marked females were collected. The nights of September 28 and 29 collected 5 and 3 marked female mosquitoes, respectively. Trap distribution was the same, as in the two previous releases, and are not presented in the interest of brevity.

The recapture rates by distance and computed MDTs for marked females for all three releases are presented in Table 1. Since we had trap failures on two nights (August 28, only 19 traps and September 17 only 17 traps), two sets of correction factors were needed for the calculations. From 1 to 12 hr postrelease 80.0% of the recaptures were within 0.5 km of the release point; cumulatively, 96.4% were trapped within 1 km. The MDT, based on the corrected data averaged over three releases, was 0.91 km in 12 hr. At the 24-hr to 36-hr postrelease interval, 52.2% of the recaptures were within 0.5 km and 73.9% within 1.0 km. Thus females had dispersed further; MDT in 36 hr averaged over three releases equaled 1.27 km.

DISCUSSION

The movement of insect populations, over short distances, which include behavior such as feeding, are referred to as dispersal (Dingle 1972). Studies on the dispersal of *Cx. quinquefasciatus* have been limited to the Old World (Macdonald et al. 1968, Service 1976). These prior studies revealed maximal flight distances of less than 1 km. Fussell (1964), utilizing radioactive-tagged techniques, studied the dispersal of *Cx. quinquefasciatus* in Florida. He released 275,000 males and females, and recaptured

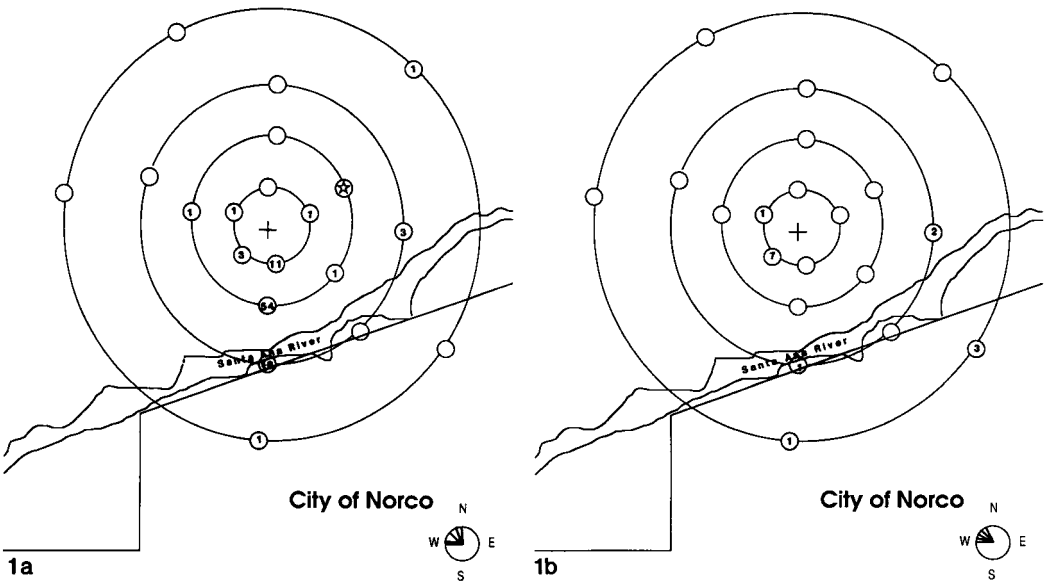

Fig. 1. Number of marked *Culex quinquefasciatus* captured per trap location from (1a) 0 to 12 hr and (1b) 29 hr–36 hr postrelease at Midhill Dairy on August 28–29, 1987. Empty discs indicate that no marked females were captured. Traps represented by a white star in a disc failed. Wind rosettes in right hand corner depict where the prevailing winds originated during the flight period.

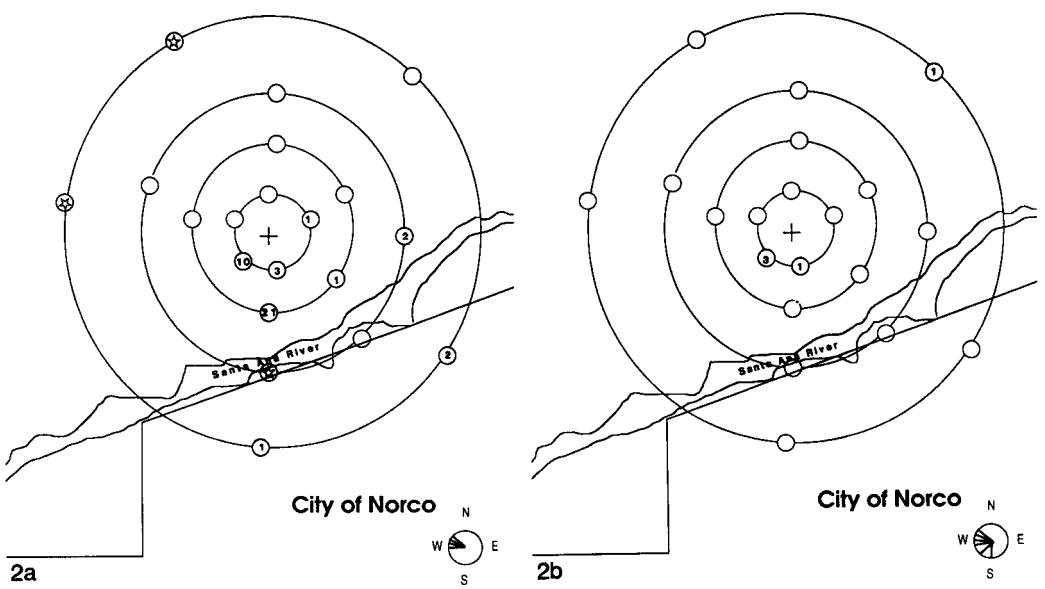

Fig. 2. Number of marked *Culex quinquefasciatus* captured per trap location from (2a) 0 to 12 hr and (2b) 24–36 hr postrelease at Midhill Dairy on September 17–19, 1987. Empty discs indicate that no marked females were captured. Traps represented by a whole star is a disc failed. Wind rosettes in right hand corner depict where the prevailing winds originated during the flight period.

marked adults in light traps. In Fussell's study, 95% of the recaptured marked mosquitoes were within 0.14 km of the release site, whereas the remaining recaptures were equal or greater than 0.80 km; the maximum distance traveled was 2.1 km. The differences in distances traveled by the reported studies probably is due to differences in ecological profiles of the areas and availability of proper hosts. Additionally, the use of light traps (Fussell 1964), may have collected individ-

Table 1. Rates and distances of recaptures during two collection periods following the release of 47,750 *Culex quinquefaciatus* marked with fluorescent dust near Norco, CA during August–September, 1987.

Date of release	Number released	Trap ring radius (km)		Correction[1] factor	Mean Number recaptured 0–12 hr	Mean Number recaptured 24–36 hr	Mean Corrected recaptured 0–12 hr	Mean Corrected recaptured 24–36 hr
Aug. 28	30,000	0.2	0.25	0.53–0.56	3.2	1.6	1.7	0.90
		0.6	0.50	1.61–1.69	14.0	0.0	22.5	0.00
		2.3	1.00	6.15–6.47	4.0	0.6	24.6	3.88
		4.0	1.50	10.70–11.26	0.4	0.8	4.3	9.00
Total		7.1			21.6	3.0	53.1	13.78
Mean distance traveled (km)						0.92	1.28	
Sept. 17	10,850	0.25		0.47–0.56	2.6	0.8	1.22	0.45
		0.5		1.43–1.69	4.6	0.0	1.58	0.00
		1.0		5.50–6.47	0.5	0.0	2.75	0.00
		1.5		9.58–11.26	1.0	0.2	9.58	2.25
Total					8.7	1.0	20.13	2.70
Mean distance traveled (km)						1.03	1.29	
Sept. 28	6,900	0.25		0.56	0.6	0.0	0.34	0.0
		0.5		1.64	0.2	0.0	0.33	0.0
		1.0		6.47	0.2	0.4	1.29	2.59
		1.5		11.26	0.0	0.2	0.00	2.25
Total					1.0	0.6	1.96	4.84
Mean distance traveled (km)						0.79	1.23	

[1] August 28 correction factor based on 19 traps; September 17 correction factor based on 17 traps.

uals of physiological states other than strictly the "host seeking" portion of a different marked population.

This study has provided experimental evidence suggesting that the main population of host-seeking *Cx. quinquefasciatus* dispersed approximately 1.5 km or more. Within 36 hr, populations of marked host-seeking females dispersed a mean distance of 1.27 km with the wind.

The apparent movement with the wind observed in our studies is surprising in view of other workers studies on dispersal of haematophagous dipterans where they found that movement was not wind aided; Bidlingmeyer et al. (1985) with Florida mosquitoes, White and Morris, i.e., (1985) with simuliids in the Adirondacks, and Lillie et al. (1985) with a ceratopogonid species. In our studies, wind speeds were high and had strong gusts >0.25 m/s; whereas Bidlingmeyer and his co-workers did observe a slight increase in the percentage of mosquito taken in their downwind traps. Greater wind velocities may have increased our observed downward dispersal. Topographic concerns may have also played a role in our observed dispersal pattern. In White and Morris' black fly study, they noted that the black flies travelled the "route of least resistance." Our mosquitoes may have utilized landscape cues, thus crossing the dairy lagoons directly south of the release site, then across the Santa Ana River, relatively free of hindrances to flight.

A lower mean distance travelled is quite apparent in the first 12 hour flight period for the September 28 release. Two factors may account for this discrepancy: 1) fewer marked individuals released and 2) lower temperatures. In the first release, an estimated 30,000 individuals were released, in the second 10,850, while the third only 6,900 were released. The percent recaptures of marked mosquitoes reflects the lower number of released individuals with 0.36% on the first, 0.42% on the second and only 0.11% on the third. The effect of temperature may have also played a role in a decrease in movement, the two previous releases had a mean temperature of 21°C while the third release had a mean temperature of 18°C.

Our results also revealed a change in the rate of dispersal over time. During the first 12 hr, postrelease females subjected to winds from the west to west northwest, dispersed primarily in direction of the winds (but see above); the mean distance traveled averaged 0.91 km. During the next period of host-seeking activity the MDT increased, but at a lesser rate, to 1.27 km (a gain of only 0.36 km from 24 to 36 hr). Lillie et al.

(1981a) and Brenner et al. (1984) observed similar trends with their ceratopogonid species. It is possible that after the initial flight, secondary flights become less directed or omnidirectional (Service 1976). Another possible explanation in the alternation of the dispersal rate is due to a greater number of behavior stimuli present in the city residential areas, i.e., other hosts (besides the traps) and the presence of city lights.

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