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MARK–RECAPTURE OF *CULEX ERYTHROTHORAX* IN SANTA CRUZ COUNTY, CALIFORNIA

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ABSTRACT. The dispersal of the tule mosquito, *Culex erythrothorax,* was studied in the proximity of Lake Tynan in the city of Watsonville, CA. From July 18 to 20, 2000, approximately 43,000 female *Cx. erythrothorax* were marked with luminous powder and released, using a distinct color each day. Recaptures were sampled by using 21 carbon dioxide–baited traps ranging in distance from zero to 2.8 km from the release site. During the 5 days of postrelease sampling, 319 marked mosquitoes were recaptured. The percentage of the marked mosquitoes that were recaptured was 0.46, 0.50, and 0.55% based on the 3 releases, respectively. Overall, the mosquitoes dispersed 0.57 km/day; the mean distance traveled increased during the 5-day sampling period from 0.42 km/day to 0.89 km/day from day 1 to day 5, respectively. Based on the Lincoln index, the estimated total population size for *Cx. erythrothorax* in the study area ranged from 3.8 to 9.4 million mosquitoes. This species was found to constitute a nuisance to local residents because of the abundance of this species and its capability to disperse into proximal communities.

KEY WORDS Mark–recapture, *Culex erythrothorax,* dispersal

INTRODUCTION

Adults of *Culex erythrothorax* Dyar are vicious biters that attack humans in the sunshine as well as on cloudy days and in the shade (Carpenter and LaCasse 1955). However, host preference of this species was found to vary between mammals in southeastern California to birds in Utah (Tempelis 1975). Potential for disease transmission also exists because isolations of western equine encephalomyelitis virus, St. Louis encephalitis virus (SLE), and Turlock virus have been found in California, and California serogroup viruses were found in Utah (summarized in Bohart and Washino [1978]). Reisen (1992) found that although *Cx. erythrothorax* fed on humans in a marsh habitat, it infrequently fed on birds and was refractory to SLE infection in vector-competence experiments and thus was not a good vector of SLE.

Larval *Cx. erythrothorax* are found in shallow ponds containing heavy growths of vegetation (Carpenter and LaCasse 1955) such as tule swamps or tule margins of lakes (Bohart and Washino 1978). In Santa Cruz County, large numbers of this species were recovered emerging from lakes containing the nonnative aquatic macrophyte *Myriophyllum aquaticum* Vell. (Verdc.), which commonly is known as parrot feather. This plant gets its name from its featherlike leaves that are arranged around the stem in 4 whorls of 4–6. Originally introduced as an attractive aquarium and ornamental pond plant, it eventually invaded Californian irrigation and drainage canals, ponds, and lakes, sometimes growing up to 30.5 cm above the water surface (Sutton 1985). Orr and Resh (1989) found that parrot feather enhanced the survival of larval *Anopheles* by providing both a favorable microhabitat and a refuge from fish predation.

Culex erythrothorax was found to be the numerically dominant species recovered when using carbon dioxide–baited traps (Walters and Smith 1980), but dispersal was reported as minimal. A more recent study in a constructed wetland (Walton et al. 1999) found this species to disperse at an average of 0.5 km/day and mosquitoes were not recaptured more than 2 km from the release site.

This study investigated the nuisance potential of *Cx. erythrothorax* to residential communities proximal to lakes in Santa Cruz County by assessing this species' dispersal pattern, distance traveled, and relative abundance by utilizing mark–recapture techniques.

MATERIALS AND METHODS

Lake Tynan in Watsonville, CA, was selected as the study site based on the abundance of *Cx. erythrothorax* recovered during previous years and because of proximity to residential neighborhoods. Repeated attempts to manage mosquitoes at Lake Tynan (Table 1) were deemed partially or completely unsuccessful. The private lake is about 1.6 km long and 0.2 km wide and is extensively invaded by parrot feather, particularly along its edges and other shallow areas. A riparian zone immediately surrounding the lake is composed of willows, poison oak, and blackberries. The entire lake is surrounded by agricultural operations utilizing organic farming. Residential communities are to the west and southwest of the lake. The release site was selected to be the southern end of the lake, which is roughly equidistant to 2 residential neighborhoods (Table 2).

To collect specimens for the initial mark and release, 12 carbon dioxide–baited Centers for Disease Control-type traps were placed on the eastern side of Lake Tynan on July 17, 2000. On the following

[1] Santa Clara County Vector Control District, 976 Lenzen Avenue, San Jose, CA 95126.

[2] Santa Cruz County Mosquito and Vector Control District, 640 Capitola Road, Santa Cruz, CA 95062.

Table 1. Larvicidal applications against *Culex erythrothorax* at Lake Tynan, Watsonville, CA, from May to July 2000.

Date	Material	Area treated (ha)	Amount (kg)	Application method	Location
May 18	Vectolex® CG	2.25	31.7	HE[1]	Last arm at Turkey Ranch
May 18	Vectolex CG	0.82	9.1	HE	West arm
May 18	Vectolex CG	4.50	63.5	HE	North end
June 28	Vectolex CG	4.09	45.3	BL[2]	South end
June 29	Vectolex CG	0.71	7.9	BL	North end
June 29	Vectolex CG	0.09	1.1	BL	East arm at Turkey Ranch
June 29	Vectolex CG	0.65	7.2	BL	South end
July 18	Vectolex WDG	4.09	4.5	HE	North end
July 18	Vectolex WDG	1.63	1.8	HE	East arm at Turkey Ranch
July 18	Vectolex WDG	3.68	4.1	HE	South end

[1] HE, application method was via helicopter.
[2] BL, application was via Maruyama blower from boat.

morning, the traps were recovered, the mosquitoes were anesthetized with carbon dioxide, abundance was visually assessed, and the mosquitoes then were transferred to a standard 18.9-liter bucket and covered with window screen, where they were allowed to recover. The bucket was immediately placed on its side to purge out the carbon dioxide. Upon recovery, the mosquitoes were dusted with luminous powder (Shannon Luminous Materials, Inc., Santa Ana, CA) applied with a small bulb duster (Target Specialty Products, San Jose, CA). After a thorough dusting, the mosquitoes were released into the riparian zone by removing the screen from the bucket. The above marking process was repeated on the 2 following days, using a different color of powder each day. Red, yellow, and blue luminous powders were applied on July 18, 19, and 20, respectively.

In the afternoon of July 18, 21 carbon dioxide–baited traps were placed at permanent sampling stations, where they were run for 5 successive nights. Sampling sites consisted of residential, riparian, and agricultural areas (Table 2). On the mornings of July 19 through 23, each trap was examined for marked mosquitoes by using an ultraviolet light source (Blak-Ray Longwave Ultra Violet Lamp, 366 nm, model ML-49, UVP, San Gabriel, CA), abundance was visually assessed, and the mosquitoes were either collected for secondary or tertiary marking or released immediately.

Weather data consisting of minimum and maximum air temperature and daily average wind direction and speed were downloaded from the University of California Statewide Integrated Pest Management California Weather Database (http://www.ipm.ucdavis.edu/calludt.cgi/WXSTATIONDATA?STN=WTSNVILE.C) by using the Watsonville Waterworks Station (NCDC 9473) latitude of 36°56′N and longitude of 121°46′W, and an elevation of 29 m.

Site maps and thematic maps were generated by using MapInfo Professional 5.5 (MapInfo Corporation, Troy, NY) by utilizing geographic information system techniques. Maps were generated for each day of the study that showed recapture locations and graphically depicted frequency and percent contribution of each color marker. MapInfo also was used to determine distances from each trap site to the site of release.

Percent recovery was calculated per trap night by dividing the number of recaptures by total mosquito abundance of the trap. Mean distance traveled was averaged for each trap day based on distance from the site of release. Mosquito population size was estimated for each trap day by using the Lincoln index (Lincoln et al. 1982).

RESULTS AND DISCUSSION

Approximately 43,000 female *Cx. erythrothorax* were captured, marked, and released; about 30,000,

Table 2. Recapture sites in proximity to Lake Tynan, Watsonville, CA.

Site no.	Distance[1]	Location type
1	2.41	Suburban
2	2.80	Suburban
3	2.45	Suburban
4	2.18	Bike/walking trail
5	1.98	Apple orchard
6	2.10	Suburban
7	2.51	Suburban
8	1.84	Riparian
9	1.43	Farm house
10	1.06	Riparian
11	1.02	Farm house
12	1.20	Agricultural
13	1.31	Agricultural
14	1.23	Agricultural
15	0.76	Agricultural
16	1.37	Riparian
17	0.29	Riparian
18	0.00	Riparian
19	0.65	Riparian
20	2.14	Riparian
21	0.71	Riparian

[1] Distance (km) from the release site (site 18).

Table 3. Recapture frequency of *Culex erythrothorax* marked with red luminous powder in proximity to Lake Tynan, Watsonville, CA.

Site no.	July 19	July 20	July 21	July 22	July 23
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	—	0	0
5	0	0	0	1	0
6	0	0	1	0	0
7	0	—	0	0	—
8	0	0	1	2	3
9	0	0	3	5	0
10	0	0	3	3	1
11	0	0	0	0	—
12	0	—	2	0	2
13	3	0	0	0	1
14	3	1	—	0	0
15	3	0	0	0	1
16	1	4	5	8	0
17	17	1	12	25	4
18	29	17	1	19	0
19	2	0	0	17	2
20	—	0	0	2	1
21	6	—	0	0	13
Total	64	23	28	82	28

Table 4. Recapture frequency of *Culex erythrothorax* marked with yellow luminous powder in proximity of Lake Tynan, Watsonville, CA.

Site no.	July 20	July 21	July 22	July 23
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	—	0	0
5	0	0	0	0
6	0	0	1	0
7	—	0	0	—
8	0	0	0	0
9	0	0	0	0
10	0	0	1	0
11	0	0	0	—
12	—	0	2	0
13	0	0	0	0
14	0	—	0	0
15	0	0	0	0
16	0	0	2	1
17	0	2	9	0
18	8	0	6	0
19	0	0	9	0
20	0	0	0	0
21	—	0	0	1
Total	8	2	30	2

5,000, and 8,000 mosquitoes were released on July 18, 19, and 20, respectively. A total of 319 marked mosquitoes was captured during the study. The largest number of recaptures was from the larger initial release. In general, recapture frequency decreased with distance from the release site.

Based on recaptures, dispersal during the 1st 2 days of the study was generally restricted to the southeastern end of Lake Tynan (Tables 3 and 4 and Fig. 1). On the 3rd day (July 21), marked *Cx. erythrothorax* were recovered along the eastern and western sides of Lake Tynan as well as in an apple orchard south of the lake (site 5) and in a residential zone (site 6) (Tables 3–5 and Fig. 1). On the 4th day, this trend was extended further north along the eastern side of the lake (site 20) and again at the same residential site (Tables 3–5 and Fig. 1).

Yellow-marked mosquitoes were not recaptured outside the release site on their 1st day after release (July 20) and were in general more restricted to the southern side of the lake. However, a single yellow-marked mosquito was recaptured 2.1 km from the release site at a residence (site 6) 3 days after release (Table 4). Blue-marked mosquitoes dispersed up to 1.98 km southward after 1 day after release. On July 22, blue recaptures were made in the riparian zones on both sides of the lake (Table 5). Three days after release, blue-marked mosquitoes were also recovered 1.2 km southeast of the release point (site 13) in an agricultural area containing strawberries, zucchini, and yellow squash (Table 5 and Fig. 1).

The initial release using red luminous powder resulted in mean distances of 0.71, 0.30, 0.86, 0.60, and 0.89 km/day during the 5 successive days (July 19–23). The number of mosquitoes in the 2nd release made with yellow powder was much smaller (about 5,000) and averaged mean distances of 0, 0.29, 0.56, and 1.04 km/day on the 4 successive days (July 20–23). The 3rd release of 8,000 mosquitoes was marked blue and had mean distances traveled of 0.56, 0.66, and 0.95 km/day. The overall average dispersal rate in this study was 0.57 km/day, a value that is in accord with that of Walton et al. (1999), who found an average daily dispersal of about 0.5 km/day.

Lincoln index calculations for the total mosquito population size yielded the values 4,248,750, 9,366,451, 9,595,615, 3,831,330, and 3,837,283 for July 19–23, respectively. These estimates are based on the assumption of random mixing, lack of emigration, and no change of behavior caused by marking (Lincoln et al. 1982).

Air temperature and wind speed and direction were fairly consistent each day of the study. Maximum air temperature averaged 21.9 ± 2.2°C (SD); minimum air temperature averaged 10.9 ± 1.6°C. Wind generally averaged 8 km/h from the south but shifted to a southeasterly direction on July 20 and 21. Dispersal trends did not follow average wind direction because recaptures were made south of the release site. Apparently, during the 1st 3 days of the study, site 17, 0.29 km east of the release point, was the initial dispersal direction, based on the large number of recaptures made there.

Both proximity to the lake and abundance of mosquitoes contributed to the serious nuisance potential of *Cx. erythrothorax* to Watsonville resi-

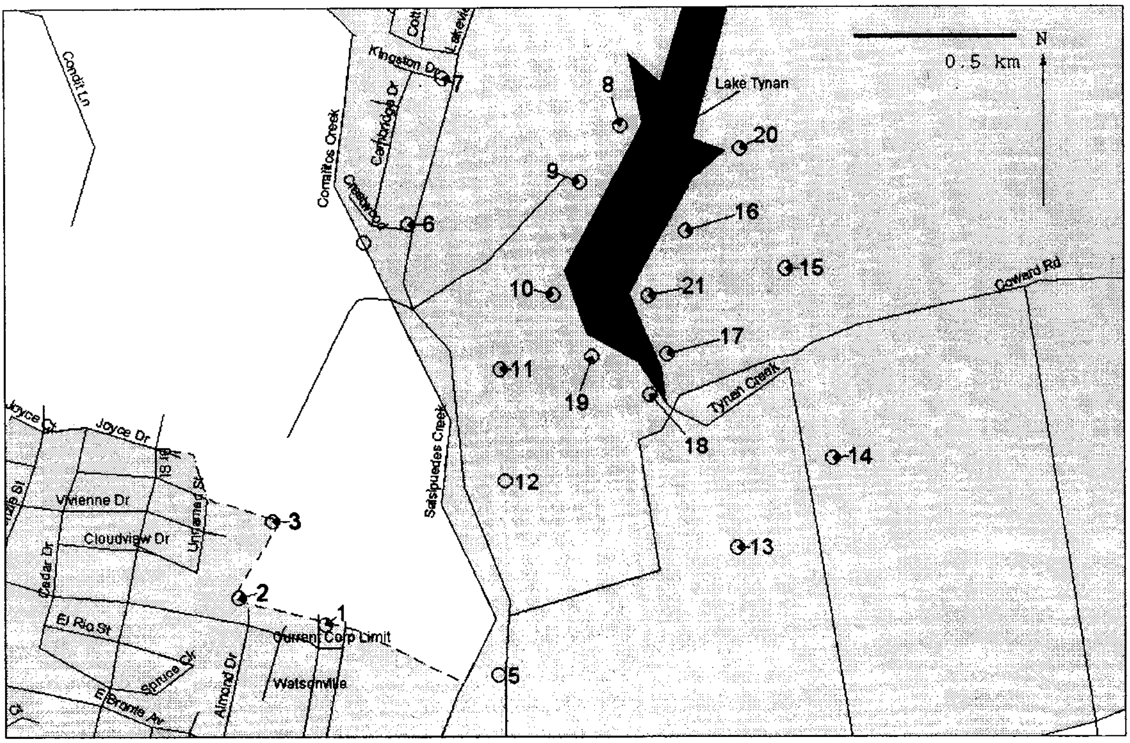

Fig. 1. Map of carbon dioxide–baited Centers for Disease Control–type trap locations around Lake Tynan in Watsonville, CA.

dents. Trap counts for *Cx. erythrothorax* in the suburban areas averaged 24.3 mosquitoes per trap night. The site where the recaptures were found (site 6) averaged 34.4 mosquitoes per trap night. This site was about 2.1 km from the release site, but much closer emergence sites existed about 1 km away. Residents complained about mosquitoes and readily agreed to participate in the study. Agricultural workers and residents at farm houses working or residing close to the lake probably experienced even greater nuisance levels from this species than did outlying communities. Dry ice–baited trap counts of 2,000–10,000 *Cx. erythrothorax* per night were not unusual for riparian zones around Lake Tynan, although average trap counts in the surrounding agricultural zones were 203 ± 88 (± SE).

Our results were contrary to those of Walters and Smith (1980), who reported dispersal of *Cx. erythrothorax* from the breeding habitat to be minimal. At the New River in Imperial Valley in California, Walters and Smith (1980) found little dispersal from the reed–salt cedar breeding habitat and recovered that species at 0, 90, and 150 m from the larval habitat. This was attributed to optimal ovipositional and environmental requirements within the reed habitat. Perhaps warmer temperature and dryer conditions in Imperial Valley were factors in the restricted dispersal as compared to cooler and moister conditions in the current study.

Table 5. Recapture frequency of *Culex erythrothorax* marked with blue luminous powder in proximity of Lake Tynan, Watsonville, CA.

Site no.	July 21	July 22	July 23
1	0	0	0
2	0	0	0
3	0	0	0
4	—	0	0
5	1	0	0
6	0	0	0
7	0	0	—
8	0	1	1
9	0	3	0
10	0	0	0
11	0	0	—
12	3	0	0
13	0	0	4
14	—	0	0
15	0	0	1
16	0	3	2
17	5	7	2
18	0	9	0
19	0	2	4
20	0	2	0
21	0	0	2
Total	9	27	16

The authors noted intense biting activity of *Cx. erythrothorax* that occurred in and near the riparian zone of the lake, especially during the handling of dry ice, placement of traps in the riparian zone, and while assessing trap results inside the vehicle. Initially, no pain was associated with the bite, but an itching sensation was noted that commenced within the next 24 h.

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