DAILY SURVIVORSHIP OF ADULT *AEDES COMMUNIS* IN A HIGH MOUNTAIN ENVIRONMENT IN CALIFORNIA

BRUCE F. ELDRIDGE[1] AND WILLIAM C. REEVES[2]

ABSTRACT. Using mark-release-recapture methods and linear regression analysis, daily survivorship for 3 groups of *Aedes communis* in a high mountain environment in the Sierra Nevada of California were estimated to be 0.90, 0.91 and 0.88, respectively. Multiple recaptures of marked females were made for up to 33 days after release. Precise estimates were not made of gonotrophic cycle lengths. However, parity data, based on dissections of samples of marked and unmarked females, suggest the length of gonotrophic cycles was between 1 and 2 weeks.

INTRODUCTION

The isolation of viruses belonging to the California (CAL) serogroup from mosquitoes of the *Aedes communis* group of species (=Group G of Edwards 1932) collected in a number of sites in North America and elsewhere suggests they are vectors of these agents (Eldridge 1990). Recently, six strains of Jamestown Canyon (JC) virus were isolated from mosquitoes in the Faith Valley area of Alpine County, CA, including 4 from *Aedes communis* (De Geer) females and one from *Ae. hexodontus* Dyar females captured in light traps, and one from *Ae. cataphylla* Dyar males reared from field-collected larvae and pupae (Campbell et al. 1990). There have been few ecological studies of these mosquitoes that would establish other aspects of their vectorial capacity for these viruses. Studies are needed to determine adult longevity, dispersal, vertebrate host preference and phenology. In our studies, linear regression analysis of mark-release-recapture data was used to determine adult survivorship of a population of *Ae. communis* in Faith Valley. Although mark-release-recapture methods have been used to study mosquito species inhabiting lower elevations, they have not been used previously to study high mountain mosquito species. Eldridge et al. (1985), in a mark-release-recapture study of *Ae. nevadensis* Chapman and Barr (a member of the *Ae. communis* complex of sibling species) in the Cascade Range in Oregon, demonstrated that this species could disperse for up to 1.5 km.

MATERIALS AND METHODS

A study site was selected along Blue Lakes Road in Alpine County at an elevation of 2,256 m. The site consisted of a series of granite depressions which are flooded each spring by melted snow. The resulting 3 pools were heavily shaded by ponderosa pine trees (*Pinus ponderosa* Douglas ex Loud.). The bottoms of the pools were lined with a thick layer of pine needles. The series of depressions was approximately 0.1 km by 0.2 km in size. Three isolations of JC virus had been made from adult female *Ae. communis* (*sens. lat.*) captured in light traps at this same location in 1988, and one isolate of JC virus was made from a pool of *Ae. hexodontus* captured in a light trap in 1989 (Campbell et al. 1990). Material for the present study came from 3 collections of larvae and pupae made at the northern end of the pools. The first collection of larvae and pupae, made on May 17, 1989, was transported to the University of California at Davis for adult emergence. The adults were provided with sugar water and raisins and held at approximately 27°C. On May 24, the adults were transported back to the study site. The second and third collections of larvae and pupae were made on May 24 and May 26, respectively. These collections were transported to a temporary field laboratory in a cabin in Hope Valley, about 6 km from the study site and otherwise were handled in the same manner as the May 17 collection. About 20 larvae, and after emergence about 20 females, were removed from each collection and identified to species. When emergence was nearly complete, females were transferred to gallon (3.8 liter) cardboard containers and the number of females present was estimated (Dow et al. 1965). Females were transported back to the study site and dusted with a fluorescent marker by inserting the tip of a small bulb-type atomizer containing the marker into an opening of the carton and depressing the bulb 2 or 3 times. Each collection was dusted with a different color. After marking, female mosquitoes were released in the center of the study area at site 1 (Fig. 1). A summary of the marker colors used, and the dates of collection, marking, and release are shown (Table 1).

Beginning the day after the first release, and for 10 days thereafter, a grid of 6 battery-operated CDC miniature light traps, supplemented by dry ice, was operated daily from approximately 1600 h until 0700 h the following day (Fig. 1). Thereafter, light traps were operated at

[1] Department of Entomology, University of California, Davis, CA 95616.
[2] School of Public Health, University of California, Berkeley, CA 94720.

least weekly until June 30. Four additional light trap collections were made between July 5 and August 4. Trapped females were processed either at the temporary field laboratory in Hope Valley or at the Davis laboratory. Collections were screened under a stereoscopic microscope using illumination from an ultraviolet lamp (Blak-Ray® Model B-100A, UVP, Inc., San Gabriel, CA). All marked females were identified to species, placed in screw-capped freezer tubes and stored at −20°C for later dissection. All unmarked adult mosquitoes in small collections (<100) were identified and frozen for later dissection. From large collections, a random sample of 100 unmarked females was identified and frozen from each day's collection. Occasional collections of females and males were made with sweep nets in the margin of the study site and kept separated from trap collections.

All marked females were subsequently thawed and dissected to determine their parity status. At least 20 unmarked females also were dissected from each day's collection. Dissections were made in physiological saline under a stereoscopic microscope using sharpened number 1 insect pins. Both ovaries of each dissected female were removed; one was left intact, ovarioles of the other were separated with the needles. The preparation was then covered with additional saline and a cover slip and examined under a compound microscope. Ovaries were scored as "parous" or "nulliparous" based on the degree of coiling of tracheae of the intact ovary (Detinova 1962). Separated ovarioles were then examined and the number of dilatations present on stalks of the individual ovarioles was counted. Survivorship was estimated by regression analysis (Milby and Reisen 1989).

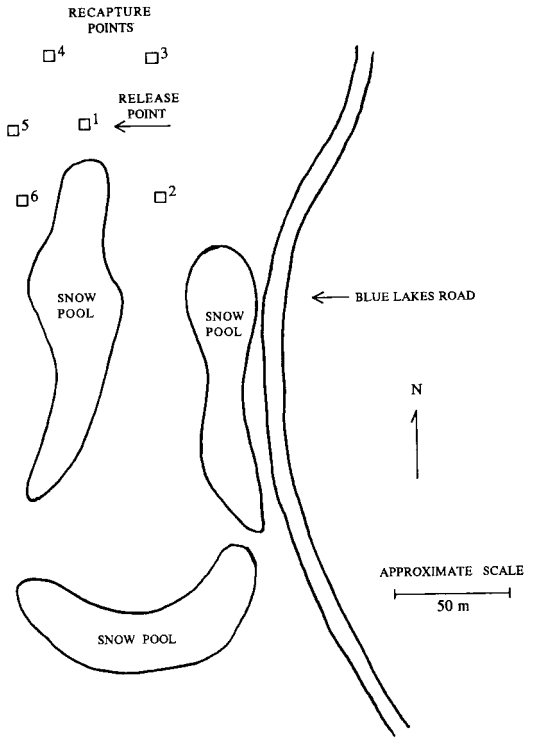

Fig. 1. Diagrammatic representation of study site in Alpine County, CA.

RESULTS

Snow had begun to melt at the study site by April 12. At this time, small numbers of 1st and 2nd-stage larvae of *Ae. communis* were present at the edges of the newly formed pools. By May 17, the snow had melted completely and larvae were present throughout the pools. By May 24, pupae were present but only a few 4th-stage larvae remained. By May 26, larvae were nearly gone but heavy concentrations of pupae were still present. At the southernmost of the 3 pools, small numbers (1–2 per dip) of *Ae. fitchii* (Felt and Young) larvae and pupae appeared. By June 1, the water in the pools had evaporated to about half its former depth and a few pupae were still present. All pupae were gone by June 15 and, by June 24, the pools were completely dry.

Recapture data are shown (Table 2). During late May, weather conditions changed frequently at the study site. On May 28 and again on May 31, subfreezing temperatures occurred at night and some snow fell. Mosquito captures

Table 1. Adult female mosquitoes marked and released.

Event	Color of marker		
	Yellow	Red	Blue
Larvae and pupae collected	May 17	May 24	May 26
Peak of adult emergence	May 19	May 26	May 28
Adults marked and released	May 24	May 27	May 30
Number released	205	1,700	5,500
Number recaptured*	117	66	200
Percent recaptured	57.1	3.9	3.6

* By light trap; 4 yellow-, 5 red- and 10 blue-marked females also were recaptured by sweep net.

Table 2. Recaptures of marked and unmarked female *Aedes communis*.

Date (1989)	Yellow	Red	Blue	Unmarked
May 24	R[1]			
May 26	25			8
May 27	39	R[1]		172
May 28[2]	5	0		37
May 30	—	—	R[1]	—
May 31[2]	4	0	0	27
June 1	7	1	4	321
June 2	19	10	34	810
June 3	13	36	133	2,890
June 9	1	7	10	492
June 16	0	1	1	510
June 21	2	4	8	1,352
June 22	1	4	2	946
June 23	0	1	6	1,799
June 29	1	2	2	857
July 5	0	0	0	756
July 18	0	0	0	362
August 4	0	0	0	8
Totals	117	66	200	11,347

[1] Release dates.
[2] Cold weather with snow—data disregarded in analyses.

in the cold period were very few and these data were disregarded in analyses. The first marked females were recaptured May 26 (yellow-marked) and the last on June 29 (1 yellow-marked, 1 red-marked, and 2 blue-marked). All marked mosquitoes were identified as *Ae. communis* as were the samples taken at the time of marking. Light traps also were operated on July 5, 18 and August 4, and additional unmarked *Ae. communis* were collected. Other unmarked species captured in light traps included *Ae. cataphylla, Ae. fitchii, Ae. hexodontus, Culiseta incidens* (Thomson), *Cs. inornata* (Williston) and *Culex tarsalis* (Coquillett).

A total of 13,699 female *Ae. communis* were captured. Of these, 653 mosquitoes were dissected (marked and unmarked). Of those dissected, 202 (31%) were scored as parous. Among the parous group, 122 had single follicular relicts, 23 had 2. No mosquitoes were found that had more than 2 relicts. Fifty-seven individuals (28% of those dissected) were scored as parous on the basis of ovarial tracheation but no relicts were observed. In most such instances, some tissue degeneration had occurred after storage, making dissection of individual follicles difficult. In no case were relicts observed in females showing tightly coiled tracheal skeins. Results of dissections of marked females are shown (Fig. 2). Among females recaptured within 15 days of adult emergence, the proportion scored as parous was low (0–50%). Nearly all females recaptured 15 days or more after adult emergence were scored parous.

The regression analyses on data for the 3 groups are shown (Table 3). Adjusted R^2 values ranged from 0.50 to 0.74. The daily survival values, estimated from the slopes of linear regression lines, were 0.90, 0.91 and 0.88 for yellow-, red- and blue-marked females, respectively. All 3 values fell within the 95% confidence limits for the other values.

DISCUSSION

The use of linear regression to estimate adult daily survivorship in connection with the mark-release-recapture method assumes that the survival rate is constant for marked females over the recapture period. This may not be true. The escape of marked females from the recapture zone may produce underestimates of daily survival rates (Wada et al. 1969). The adjusted R^2 values (Table 3) indicate that considerable variation (as much as half) in recapture rates cannot be accounted for on the basis of cumulative natural mortality of marked females. This is not surprising, given the widely fluctuating weather conditions present in the central Sierra Nevada during the spring and summer of 1989. Although data from the periods of extreme weather conditions were not used, weather fluctuations dur-

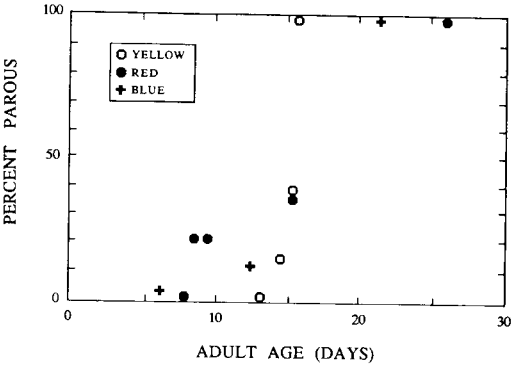

Fig. 2. Parity data for 3 series of marked female *Aedes communis*. Adult age is estimate of time (days) since peak of adult emergence from pupae.

Table 3. Linear regression analysis of recapture data.

Color of marker	−95%	s	+95%	R^2	*P*
Yellow	0.85	0.90	0.95	0.74	<0.01
Red	0.84	0.91	0.99	0.50	0.03
Blue	0.74	0.88	0.97	0.53	0.02

For analysis, X = days since release; Y = $\log_e$ of marked females recaptured daily, s = estimate of daily survival from antilog of slope of regression line; R^2 is adjusted regression coefficient; *P* = significance level.

ing other periods were probably responsible for some variation in recapture rates.

The daily survival rates estimated for the 3 series of marked females are very high in comparison with data derived from observations conducted on multivoltine mosquitoes closer to sea level. Estimates of daily survival in these cases usually have ranged from 0.5 to 0.8 (Service 1974). We know of no previous attempts to estimate daily survival in univoltine mountain *Aedes* using the present techniques.

The recapture rate for the yellow-marked females was extremely high (57%). Presumably, the yellow-marked females stayed very close to the release site during the period of cold weather that occurred at the time of their release.

Estimates of the length of gonotrophic cycles were not attempted from an extension of the survivorship estimates or parity rates (Milby and Reisen 1989, Birley and Rajagopalan 1981). These kinds of estimates require assumptions (e.g., that the ratio of nulliparous to parous females remains relatively stable over a long period of time) that cannot be met with a univoltine species in which development and adult emergence is relatively synchronous and the population represents a single cohort moving through time. However, from inspection of the parity data (Fig. 2), the gonotrophic cycle appears to be between 1 and 2 weeks. The estimates derived in this study using mark-release-recapture methods are in close agreement with the estimates obtained by Carpenter and Nielsen (1965), based on determination of parity status of samples of *Ae. communis* collected over 2 breeding seasons in Utah and Wyoming. They estimated a biting season for this species of 27 days and they also found no females had more than 2 follicular relicts. A gonotrophic cycle length of 1–2 weeks also would be consistent with their data. The results reported here also agree with a study by Rosay and Nielsen (1969). They found 20 of 22 females of *Ae. communis* collected in Salt Lake and Duchesne counties, UT, to be in the third ovarian cycle or less. However, they reported the collection of two females from Mirror Lake (Duchesne County) in late August, one in the fourth cycle, the other in the fifth. *Aedes hexodontus*, *Ae. fitchii* and *Ae. cataphylla* persisted for the duration of the study along with *Ae. communis*, which indicates a long survival period for all 4 species in this ecological setting.

A relatively small number of blood meals and a relatively long gonotrophic cycle may reflect a low density of vertebrate animals available as blood meal sources in this environment. Observations by workers in the project confirmed the general absence of mammals and birds in the daytime in the vicinity of the trapping area. Slow rates of blood digestion and ovarian development also may result from the low temperatures that occur at high mountain sites, especially early in the season. Few blood meals and long gonotrophic cycles tend to decrease vector capacity, but high daily survivorship rates tend to increase it. The occurrence of autogeny would also reduce vector competence. Chapman (1962) reported low rates of autogeny in *Ae. communis* collected in the Sierra Nevada, but Ellis and Brust (1973) observed no autogeny in samples of this species collected at sites located within 25 km of our study site.

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