COMPARISON OF ARTIFICIAL SHELTERS AND LIGHT TRAPS FOR MEASUREMENT OF *CULEX TARSALIS* AND *ANOPHELES FREEBORNI* POPULATIONS

EDMOND C. LOOMIS AND EUGENE J. SHERMAN
Bureau of Vector Control, California State Department of Public Health

Various types of shelters have been used for collecting adult mosquitoes. The term "artificial resting unit" (A.R.U.) was used by Loomis and Aarons (1953) to designate a man-made shelter used only for attracting and collecting mosquitoes. This is in contrast to an artificial resting place which is a man-made shelter used primarily for purposes other than attracting or collecting mosquitoes.

Artificial resting units have been used by many investigators since their introduction by Ross (1910). Numerous workers found that small wooden frames covered with mosquito netting (James, 1914) or earthlined boxes or kegs (Russell and Santiago, 1934; Smith, 1942) were suitable for collecting anophelines. Goodwin (1942) found that a red, cubical, wooden box of one cubic foot capacity was satisfactory for collecting *Anopheles quadrimaculatus* Say. Schoof (1944) described a 3′ x 3′ x 6′ box used in malaria control programs during World War II.

In California, several types of artificial resting units have been used to follow seasonal changes in size of adult mosquito populations. Portable "privy-type" shelters (6′-6″ x 4′ x 4′) (Snow, 1949) were tested for the collection of *Culex* species. The red box designed by Goodwin was first used in California at the Bakersfield Encephalitis Laboratory for collecting *Culex tarsalis* Coquillett. Loomis and Aarons (1953) reported that the red box was more practical than other types tested because of its durability, portability, and ease of inspection. Hayes *et al.* (1958), however, indicated that any of their sampling methods (red boxes, carbon dioxide bait trap, light trap, natural shelters) was adequate for measuring *C. tarsalis* populations and the method of choice was dependent upon the objective of the study. Loomis and Green (1959) found that counting *Culex* mosquitoes in cardboard boxes placed on the walls inside poultry houses was easier and required less time than counting or collecting in the houses.

The objectives of the present study were to determine the reliability of red boxes for measuring population trends of *C. tarsalis* and *Anopheles freeborni* Aitken and to compare these results with those based on light traps.

METHODS. The study was conducted in a 70-square-mile agricultural area of the Sacramento Valley. The area was bordered by the Feather River to the east and the Sutter Buttes (elevation, 2680 feet) to the west. The principal crops in the area were rice, peaches, prunes, almonds, and permanent pastures.

The A.R.U. used in this study was the red box described by Goodwin (*op. cit.*). The boxes were cubical, of one cubic foot volume, and made of quarter inch, exterior plywood painted on all sides with red enamel. A box was utilized in each of six locations in 1955. In 1956 boxes were placed at five of the six locations used in 1955 and at four additional ones. For comparative purposes extra boxes were placed in three of the nine locations studied in 1956. In both years all but two of the locations used were rural.

The boxes were placed on the ground in continuously shaded areas with the openings to the lee of prevailing winds. Mosquitoes were counted and identified with the aid of a flashlight. The counts were made clockwise starting on the left

wall of the box and the back wall was counted last. The total number of each species was recorded in 1955 but in 1956 the total count was followed by a count of the males of each species. *C. tarsalis* was identified by its banded legs and unspotted wings and *A. freeborni* by its unbanded legs and spotted wings. In 1956 the accuracy of counting was checked by chloroforming all mosquitoes in the box and recounting them in the laboratory.

Cracken, *Aedes nigromaculis* (Ludlow), *Culiseta incidens* (Thomson), *Culex erythrothorax* Dyar, *Aedes sierrensis* (Ludlow), *Anopheles punctipennis* (Say), and *Orthopodomyia californica* R. Bohart.

A comparison of field and laboratory counts of *C. tarsalis* in boxes is shown in Table 1. For *C. tarsalis* the difference in counts was greatest when more than 200 specimens were present, but the proportional error was greatest when there were

TABLE 1.—Actual and visual mean weekly counts of *C. tarsalis* and *A. freeborni* (both sexes) in Red Boxes, Sacramento Valley, California, 1956

C. tarsalis			*A. freeborni*		
Actual count	Visual estimate	Count minus estimate	Actual count	Visual estimate	Count minus estimate
288	271	+17	28	31	−3
181	181	0	25	26	−1
95	99	− 4	19	19	0
85	86	− 1	18	18	0
65	69	− 4	12	11	+1
37	45	− 8	9	10	−1
25	25	0	7	7	0
21	23	− 2	6	5	+1
15	17	− 2	4	4	0

Source: State of California, Department of Public Health, Bureau of Vector Control Records.

The boxes were inspected from one to four times each week in 1955 and three to five times each week in 1956. The inspections were usually made in the morning.

An American Model light trap was used to study the mosquito population at one urban location. The trap was suspended five feet above the ground and operated 9 to 12 hours a night on Monday through Wednesday of each week.

RESULTS. The results deal only with the two most common species collected, *C. tarsalis* and *A. freeborni;* other species constituted less than five percent of the total mosquitoes counted or collected. These species were, in decreasing order of abundance: *Culex peus* Speiser (= *stigmatosoma*), *Culex pipiens* Linnaeus, *Aedes melanimon* Dyar, *Culiseta inornata* (Williston), *Anopheles franciscanus* Mc-

fewer than 50 in a box. There was little difference between the counts of *A. freeborni* and the proportional error was about the same as with *C. tarsalis*. Although not shown in Table 1, the inspector was prone to underestimate the number of male *C. tarsalis*. This phenomenon did not occur with visual estimates of *A. freeborni*. Also, collections from boxes during the latter part of August and through September showed that males of *C. tarsalis* gradually outnumbered the females. The sex ratio of *A. freeborni* remained the same during the entire study period.

The difference in population indices between *C. tarsalis* and *A. freeborni* determined from visual estimates is shown in Table 2. These data show that the nine stations in 1956 demonstrated similar population trends over the period of study.

TABLE 2.—Visual mean weekly counts of *C. tarsalis* and *A. freeborni* (both sexes) in Red Boxes, Sacramento Valley, California, 1956

Station	Mean number mosquitoes per inspection by week											
	July					August				September		
	C. tarsalis											
A	30	44	54	52	57	*106*	*123*	88	43	29	36	21	21
B	14	20	*31*	18	23	*41*	26	23	15	8	10	11	9
C	23	*46*	*46*	43	31	*44*	23	NI	*41*	33	28	20	13
D	78	56	*356*	62	*334*	*407*	252	*538*	158	277	25	150	76
E	16	28	89	*104*	*107*	*117*	64	NI	44	77	32	18	7
F	76	53	*323*	*377*	218	167	77	71	49	60	38	26	26
G	52	92	114	101	154	*301*	216	148	89	64	57	18	14
H	49	114	192	167	179	249	149	111	91	96	44	29	25
I	49	43	99	144	257	*327*	125	215	41	129	41	66	30
	A. freeborni											
A	[a]	0	[a]	1	1	6	3	3	1	2	5	*44*	4
B	1	2	1	1	4	3	5	8	4	8	48	*64*	29
C	2	4	1	1	3	4	4	NI	16	24	31	*63*	49
D	8	7	12	3	17	25	21	28	32	40	32	99	78
E	1	3	1	4	3	1	3	NI	11	34	*68*	*73*	74
F	[a]	1	1	2	4	3	7	5	6	2	20	35	50
G	2	4	2	5	4	13	14	12	3	19	*50*	*45*	24
H	2	8	6	9	*18*	*16*	8	5	2	4	5	10	7
I	2	2	3	2	13	16	13	11	18	38	23	*53*	16

NI No inspection.
[a] Less than one.
Source: State of California, Department of Public Health, Bureau of Vector Control Records.

Maximum counts of *A. freeborni* occurred at approximately the same time in boxes placed throughout the study area. With *C. tarsalis*, however, there was greater variability in the time that maximum counts occurred in the same boxes. The degree of agreement among the various boxes was tested by Kendall's (1955) coefficient of concordance which varies from zero to plus one. The coefficients found, 0.726 for *C. tarsalis* and 0.652 for *A. freeborni*, are significant at a probability of .001 and indicate general agreement among the boxes. Similar population trends were obtained from the data on five stations in 1955 but are not included for the sake of brevity. In both years the highest density of *C. tarsalis* generally was in the first part of August, while that for *A. freeborni* was more sharply defined and occurred during the latter part of September.

At one station two additional boxes were inspected in 1956 to check the precision of the first box. The three boxes were placed on the north side of a home and the box openings faced west. The visual estimates for these three boxes are shown in Table 3. In general, the closeness of the three counts for each species illustrates the reliability of red boxes as sampling devices. On only a few days did the count from one box differ widely from those of the other two boxes. Similarly, for any individual box the daily counts were fairly uniform throughout the week. Similar results were observed with extra boxes placed at each of two other stations.

A comparison of light trap and box counts is shown in Figure 1. For *C. tarsalis*, there were greater fluctuations in light trap collections than in numbers of mosquitoes resting in boxes. Population levels of both species throughout the two years were, however, generally similar regardless of the type of measuring device used. The mean weekly counts of *C. tarsalis* in light traps and in red boxes

TABLE 3.—Daily visual counts of *C. tarsalis* and *A. freeborni* (both sexes) from three red boxes at one location, Sacramento Valley, California, 1956

C. tarsalis				*A. freeborni*			
	Station				Station		
Date	A-1	A-2	A-3	Date	A-1	A-2	A-3
July 30	42	53	39	September 3	2	2	1
31	42	40	73	4	3	1	1
August 1	91	58	54	5	1	1	2
2	71	86	49	6	2	2	2
3	41	51	32	Weekly Mean	2	2	2
Weekly Mean	57	58	49	10	9	11	2
6	138	172	89	11	3	13	6
7	90	96	85	12	4	13	5
8	113	128	163	13	5	14	11
9	112	116	160	Weekly Mean	5	13	6
10	78	105	74	17	7	12	8
Weekly Mean	106	123	114	18	76	5	15
13	119	157	143	19	61	16	4
14	89	102	46	20	26	41	19
15	135	152	109	21	6	10	3
16	139	188	141	Weekly Mean	44	17	10
17	134	149	133	24	1	7	7
Weekly Mean	123	150	114	25	3	7	3
20	103	97	87	26	8	17	6
21	84	59	75	27	3	19	4
24	77	144	76	28	6	12	4
Weekly Mean	88	100	79	Weekly Mean	4	10	5
27	30	119	38				
28	48	43	71				
29	60	78	43				
30	41	41	43				
31	38	62	53				
Weekly Mean	43	68	49				

Source: State of California, Department of Public Health, Bureau of Vector Control Records.

were approximately equal but in general many more *A. freeborni* were counted in red boxes than were collected by light traps. Variations in population trends of the two species were apparent regardless of the type of measuring device used.

DISCUSSION. Fluctuations in *A. freeborni* populations determined from red box counts showed a high degree of correlation among all stations. Light trap collections, although of lesser magnitude, were in like manner consistent. The fact that higher counts were made from boxes than from light trap collections parallels similar findings for *A. quadrimaculatus* reported by Bradley (1943). Although both devices are useful, the box is especially valuable in areas where operation of a light trap is not possible. Also, the box is a more sensitive device than the light trap in terms of *A. freeborni* response.

The relative numbers of *C. tarsalis* and *A. freeborni* varied considerably from one box to another during both years. The greatest variation occurred during the periods of greatest *C. tarsalis* density.

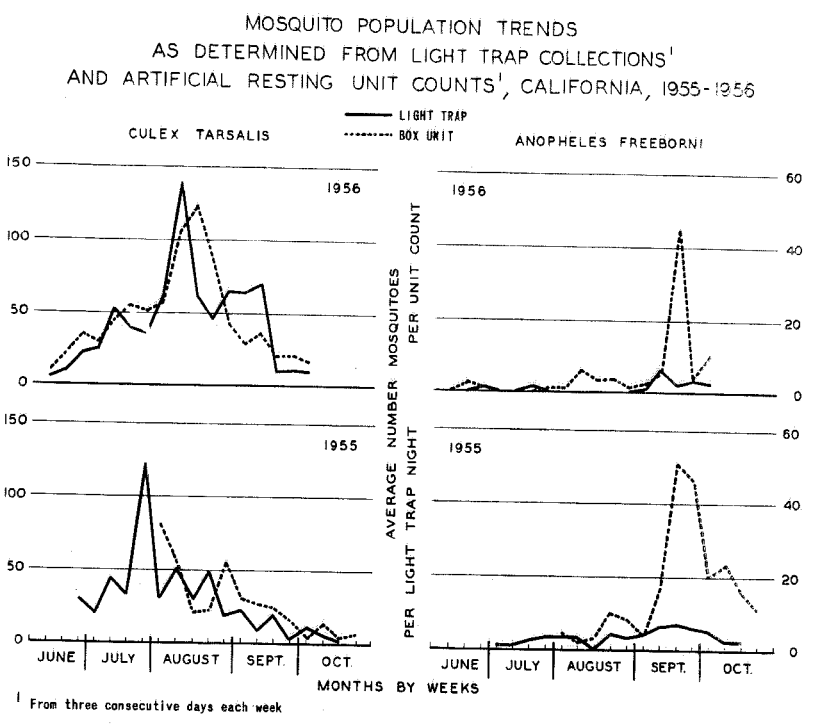

FIG. 1

There was less variation in the periods of maximum density on the basis of box counts in 1956 when they were inspected more frequently.

The larger fluctuations in density of *C. tarsalis* populations as compared with those of *A. freeborni* are not surprising since larvae of the latter species are, in this area, found predominantly in rice fields, a relatively stable habitat. The larvae of *C. tarsalis* are found not only in rice fields but in a wide variety of other types of water accumulations, many of which are of short duration.

The seasonal trend in adult density of each species found in this study agrees with the results of studies of larval populations made in the same general area by Markos and Sherman (1957). Their data showed that the greatest density of *C. tarsalis* larvae occurred during the end of June while maximum numbers of *A. freeborni* larvae were found from the end of August through the first part of September.

The error in distinguishing the sexes of *C. tarsalis* in visual counts was due to the less conspicuous sexual dimorphism of this species and also to the large numbers found in the boxes. The finding of more males than females of *C. tarsalis* in red boxes during autumn months was also observed by Dr. R. E. Bellamy (personal communication) in the Southern Central Valley. Similar results were evident from light trap collections in the present study and those by Hayes *et al.* (1958).

The variations in numbers of mosquitoes in boxes from one day to the next could not be attributed to meteorological conditions or time of day at which the counts were made. It may be necessary to make daily inspections each week to minimize this variation, especially when sampling in an area under mosquito control. Similarly,

it is desirable to place several boxes at one location before selecting one unit as a permanent sampling site. Although the boxes located in the present heterogeneous study area showed pronounced variations in weekly *C. tarsalis* counts, Dr. R. E. Bellamy (personal communication) reported similar results with this species and with *Culex quinquefasciatus* Say found in boxes placed in a homogeneous environment. In his study the boxes were placed at the west base of trees randomly selected in the center of a large olive grove.

Some of the merits of red boxes for studying *C. tarsalis* have already been cited by Hayes *et al.* (1958). Of most importance is their low cost and ease of use. As with other sampling devices, however, the location of the box is extremely important. In general, the present authors found that boxes were satisfactory when located in permanent shade and the box opening placed leeward of prevailing winds. All boxes should be inspected on the same day and visual estimates can be used in areas where there are only a few, easily identifiable species. Representative collections should be made at frequent intervals to confirm identifications and estimates of the number present. This is particularly important when the field work is done by individuals with limited experience. Studies in other regions of the Central Valley of California have shown the boxes to be useful also for studying *C. peus* and *C. pipiens.*

SUMMARY. A red, cubical, wooden box of one cubic foot capacity was successfully used as an artificial resting unit to measure seasonal fluctuations in *A. freeborni* and *C. tarsalis* populations in California during the summer months of 1955 and 1956. A similarity in population trends in all boxes was observed throughout the season with *A. freeborni,* and somewhat less consistently with *C. tarsalis.* In general, fluctuations in population levels of each species as suggested by box counts were consistent with those indicated by light traps. Approximately equal numbers of *C. tarsalis* were taken from the light trap and box, whereas larger numbers of *A. freeborni* were usually taken from the box than from the light trap.

The reliability of the boxes as measuring devices was further substantiated by placing more than one box at a location.

ACKNOWLEDGMENTS. The authors wish to acknowledge the assistance of J. R. Holten and K. M. Grodavent, State Department of Public Health, in construction of the artificial resting units and statistical analysis of the data, respectively.

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