MAMMALIAN BURROWS AND VEGETATION AS SUMMER RESTING SITES OF THE MOSQUITOES *CULEX TARSALIS* AND *ANOPHELES FREEBORNI*

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Adults of the mosquito *Culex tarsalis* Coq. are frequently absent in man-made shelters (beneath bridges, in sheds) that serve as satisfactory resting sites for other mosquitoes. Considering the widespread distribution of this mosquito and the lack of man-made structures in some areas where it is abundant, there is no doubt that natural resting sites must be present. Because of the aridity and lack of vegetation of much typical *tarsalis* territory, it seemed that rock crevices and animal burrows could provide adequate shelter from conditions of high temperature and low humidity characteristic of the period when the mosquito is inactive. A study of burrows, rock fissures, and vegetation as resting sites for *Culex tarsalis* is recounted here, along with similar findings for *Anopheles freeborni* Aitken, the other principal mosquito present.

The sampling of rodent burrows and other natural resting sites of limited size by enclosing the area with a cage of netting and spraying chloroform into the site to drive out the mosquitoes, has been reported by Mortensen (1953), Loomis and Green (1959). Stuntz (1952, original not seen) collected *tarsalis* from rodent burrows in fall and winter, and Ryckman and Arakawa (1952) made winter collections of this and other mosquitoes by careful examination of the nest of wood rats. All such methods appear to be time-consuming, and subject to error through lack of visibility by the investigator.

To overcome these difficulties, a trap was developed to capture mosquitoes resting in burrows. The trapping chamber was constructed from a two-pound coffee can with an entrance cone in the bottom and a screen replacing the solid metal in the center of the cover (Fig. 1). The can was seated in a flange soldered to a half-inch mesh hardware cloth base. When set over a burrow or fissure, the hardware cloth permitted mosquitoes to enter the trap but prevented the access of small rodents. The hardware cloth served also

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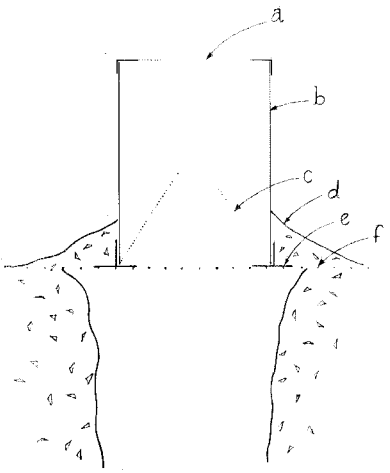

FIG. 1.—Diagram of burrow trap on burrow. a. fine mesh screen top. b. trap chamber from two pound coffee can. c. fine mesh screen entrance cone. d. earth seal. e. metal flange for seating trap chamber. f. hardware cloth base.

as a base for fastening the trap down with pegs or rocks. When placed on a site, light was prevented from entering the burrow outside of the trap chamber by placing soil around the base. A trap, similar in principle, was constructed with the flange attached to a canvas tarpaulin which could then be placed over foliage or other sizable resting sites. Metal tripod legs one foot in length were attached to the flange base of the tarpaulin trap to ensure that light was admitted from the highest point. The burrow and tarpaulin traps were placed on a suspected site in mid-afternoon, when mosquitoes were resting, and picked up at mid-morning or later the following day.

The present investigation was carried out in the Columbia Wildlife Refuge near Othello, Washington, during the summer of 1959. The mosquito population during this period was abnormally low, possibly because temperatures were lower than normal. Summer in the area is characterized by sunny, hot days and cool nights. The vegetation is primarily shrubby (sage brush, *Artemisia tridentata* Nutt.; rabbit brush, *Chrysothamnis* spp.), with willows (*Salix* spp.) confined to the drainage of Crab Creek and other minor watercourses. Since the refuge lies below the large O'Sullivan dam water impoundment and has a large irrigation canal along the eastern boundary, fluctuating water table causes temporary small ponds in which large numbers of mosquitoes may develop.

The vertebrate population of the refuge consists of both domestic and wild animals. Cattle and horses are found on two ranches, but the majority of the area is inhabited by rodents, lagomorphs, and birds. The rodents and rabbits are especially abundant in the broken rock scrabble lying at the base of basalt outcroppings (Fig. 2) and much of the study related here was concentrated in such environments.

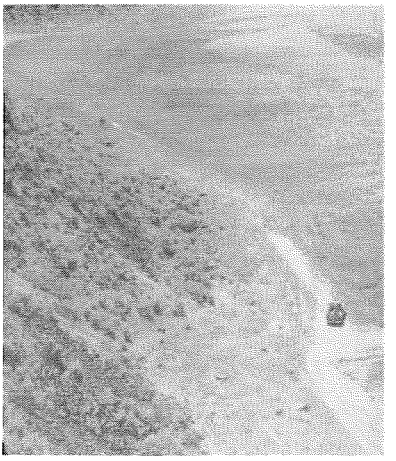

FIG. 2.—Basalt cliff outcropping typical of the study area. Fissures are present in such cliffs, and animal burrows are dug into their bases. The loose basalt lying below cliffs also contains large numbers of animal burrows.

RESULTS. Using the tarpaulin trap modification, it was possible to capture considerable numbers of both sexes of *C. tarsalis* in vegetation during early summer, and an occasional *A. freeborni*. Suitable resting sites were often some distance from water in which larvae could have developed, and these held fewer spiders than were

TABLE 1.—Mosquitoes collected from rock fissures and animal burrows, Columbia Wildlife Refuge, Othello, Washington, 1959

Date	No. traps	*C. tarsalis* ♀	*C. tarsalis* ♂	*A. freeborni* ♀	*A. freeborni* ♂	*Culis. inornata* ♀	*Culis. inornata* ♂
July 1	4	19	47	6	4	—	—
7	10	16	70	2	3	1	—
9	2	21	13	13	16	—	—
13	4	3	11	47	6	—	—
21	8	46	26	36	47	—	—
23	4	7	4	0	0	—	—
28	15	4	2	226	58	—	—
30	2	0	0	0	0	—	—
Aug. 4	19	52	85	425	141	—	9
6	8	0	1	1	0	—	—
11	16	52	74	268	90	1	—
13	6	4	6	132	283	2	—
17	20	30	17	348	321	1	1
Total	118	246	356	1504	971	5	10
Mean	—	2.0	3.0	12.7	8.2	—	—

trapped in unsuitable vegetational cover. For example, in one area investigated on June 25, sedges at water's edge yielded no mosquitoes but large numbers of spiders. At the same time, 16 male and 2 female *C. tarsalis* (and no spiders) were captured in one trap placed in a wheat field some one hundred yards distant. Capture of *C. tarsalis* in vegetation dropped off in mid-July. From then on it was only possible to capture insignificant numbers in dense vegetation, such as clumps of sweet-clover, along stream banks.

Mammalian burrows and fissures in rocks that were habitations, or were often visited by mammals as evidenced by abundant droppings, proved to be adequate resting sites for mosquitoes. Principal animals were the bushy-tailed woodrat *Neotoma cinerea occidentalis* Baird, the yellow-bellied marmot *Marmota flaviventris avara* (Bangs), and the pygmy rabbit *Sylvilagus idahoensis* (Merriam). Promising sites were sampled at intervals of one week or longer, receiving particular attention if they consistently produced mosquitoes. Between July 1 and August 19, 118 burrow trap collections were made (Table 1). Each trap yielded a mean of 2.0 female and 3.0 male *Culex tarsalis* and 12.7 female and 8.2 male *Anopheles freeborni* per night. During this same period 5 female and 10 male *Culiseta inornata* were captured in these burrows.

It was obvious that some burrows consistently yielded more *C. tarsalis* than were found in the total mean catch. One such site consisted of a deep fissure at the base of an east-facing basalt cliff. The abundance of droppings here indicated continuous or frequent use by woodrats. In eight collections from July 4 through August 17, this site yielded a mean of 9.0 female and 13.1 male *C. tarsalis* per night, and 8.7 female and 11.0 male *A. freeborni* per night of trapping (Table 2).

TABLE 2.—Mosquitoes collected from a "woodrat burrow," Columbia Wildlife Refuge, Othello, Washington, 1959

Date	*C. tarsalis* ♀	*C. tarsalis* ♂	*A. freeborni* ♀	*A. freeborni* ♂
July 4	18	44	6	4
9	21	12	13	16
13	3	7	15	3
21	18	14	15	21
28	1	1	10	12
Aug. 4	1	20	3	13
11	6	1	2	5
17	4	6	6	14
Total	72	105	70	88
Mean	9.0	13.1	8.7	11.0

Marmot burrows were particularly attractive to *Anopheles freeborni*. In four collections from a burrow occupied by an adult marmot, a mean of 4.5 female and 7.0 male *C. tarsalis* and 210 female and 46.5 male *A. freeborni* were captured per night of trapping (Table 3).

TABLE 3.—Mosquitoes collected from a marmot burrow, Columbia Wildlife Refuge, Othello, Washington, 1959

Date	*C. tarsalis* ♀	*C. tarsalis* ♂	*A. freeborni* ♀	*A. freeborni* ♂
July 28	1	0	158	37
Aug. 4	5	8	249	69
11	10	19	206	28
17	2	1	233	52
Total	18	28	840	186
Mean	4.5	7.0	210.0	46.5

DISCUSSION. Some speculation is possible on what constitutes a suitable resting site for *Culex tarsalis*. Measurements of temperature, humidity, and light were made in resting sites and in adjacent exposed areas in early afternoon when the extremes of these conditions were attained. Temperature and humidity were measured with a psychrometric device that sampled air within a burrow at depths up to three feet from the entrance. Light was measured with a Model 756 Weston illumination meter. There was no great difference between burrows at the depth measured and the external environment with respect to temperature and humidity. For example, the external environment at 14.40 on July 16 was 104° F. and 13 percent R.H. in direct sunlight, whereas at three feet in a very productive marmot burrow the temperature was 103° F. and 17 percent R.H. There is little doubt that temperature was lower and humidity higher at mid-afternoon in burrows at depths greater than were measured (Schmidt-Nielsen & Schmidt-Nielsen, 1950).

Light intensity appears to be of major significance in determining the suitability of resting sites. In the study of a marmot burrow referred to above, the maximum measurable external light was 11,800 foot candles, whereas a similar measurement at three feet inside the burrow indicated a maximum of 10 foot candles. Rather similar light intensities were found in all productive resting sites for *Culex tarsalis*. The best sites had a maximum measurable light intensity of ten foot candles or less in mid-afternoon. This was the case whether these sites were in burrows or in dense vegetation.

Based on observations made during this single summer, a few generalizations can be made concerning which animal burrows constitute the best summer resting sites for *Culex tarsalis*. The best burrow sites were in contact with the soil. Burrows at the base of cliffs, at the ground level, invariably held more *C. tarsalis* than adjacent fissures within such cliffs at some distance from the ground. Burrows in the ground, particularly rabbit dens in the shade of sagebrush, were quite productive, though ground burrows inhabited by marmots appeared more attractive to *A. freeborni*.

There is some question as to whether the occupants of mammalian burrows are of significance with respect to the maintenance of encephalitis viruses. Female *Culex tarsalis* were frequently gravid or replete with blood when captured in burrows. The blood appeared digested to a degree where a good precipitin test for animal source was impossible. The fact that males were also present, frequently in large numbers, should indicate that such sites were not necessarily chosen because of a particular host attractiveness. However, as Hubert *et al.* (1954) have pointed out, *C. tarsalis* readily feeds on any of a large variety of vertebrates in the laboratory. For this reason, any factors providing a close proximity of the mosquito with vertebrates should be viewed with suspicion with respect to the maintenance of encephalitis viruses.

SUMMARY. Vegetation, mammalian burrows, and rock fissures were examined in the Columbia Wildlife Refuge near Othello, Washington, as summer resting sites for mosquitoes. Dense vegetation provided satisfactory resting sites for *C. tar-*

salis through mid-July. Mammalian burrows and rock fissures provided shelter for *C. tarsalis* and *A. freeborni* throughout the period of study. *C. tarsalis* preferred burrows in ground contact for resting, *A. freeborni* showed a preference for marmot burrows. While temperature and humidity within burrows to a depth of three feet varied little from the external environment during mid-afternoon, the maximum light intensity of good resting sites was less than ten foot candles during the same period.

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References Cited

HUBERT, A. A., RUSH, W. A., and BRENNAN, J. M. 1954. Simplified techniques for the continuous rearing of *Culex tarsalis* with additional notes and observations. Mosq. News 14:75–8.

LOOMIS, E. C. and GREEN, D. H. 1959. Ecological observations on *Culex tarsalis* Coquillett and other mosquitoes in the Delta region of the Central Valley of California, 1953–1956 (Diptera: Culicidae). Ann. Ent. Soc. Amer. 52:524–33.

MORTENSEN, E. W. 1953. Observations on the overwintering habits of *Culex tarsalis* Coquillett in nature. Proc. and Papers 21st Ann. Conf. Calif. Mosq. Control Assoc., pp. 59–60.

RYCKMAN, R. E. and ARAKAWA, K. Y. 1952. Additional collections of mosquitoes from wood rat's nests. Pan-Pac. Ent. 28:105–6.

SCHMIDT-NIELSON, B. and SCHMIDT-NIELSON, K. 1950. Evaporative water loss in desert rodents in their natural habitat. Ecology 31:75–85.

STUNTZ, J. R. 1952. Observations of the distribution and overwintering behavior of adult *Culex tarsalis* and *C. stigmatosoma* during 1951. Report (unpublished) of Rice Field Mosq. Research Proj., Calif. Mosq. Control Assoc., pp. 1–17.