OBSERVATIONS ON AN OVERWINTERING POPULATION OF *CULEX TARSALIS* WITH NOTES ON OTHER SPECIES

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Much interest has been shown in the biology of *Culex tarsalis* ever since Hammon *et al.* (1942) established that this mosquito is an important vector of the viruses of western equine encephalomyelitis and St. Louis encephalitis. Since it was postulated that the viruses might be carried through the winter in the vector, the hibernation habits of the species have received attention. However, little information has been presented on its wintertime bionomics in northern regions. Keener (1952), Blackmore and Winn (1956), and Dow *et al.* (1956) all report finding *C. tarsalis* in winter man-made shelters in which temperatures were higher than would be expected under natural conditions. Hammon *et al.* (1945) found a few hibernating individuals in unspecified sites in the state of Washington, and Bennington *et al.* (1958) reported capture of 2 specimens which had overwintered in wild animal burrows. Rush *et al.* (1958) found *C. tarsalis* hibernating in natural rocky sites but their observations on the habitat were limited. None of these reports gives information on biological characteristics of the specimens found. This article reports results of an additional study of an overwintering population: one which was found in natural sites in eastern Oregon in the winter of 1960–61.

MATERIALS, METHODS AND LOCALE. The study was centered at hibernation sites which are located in Malheur County, Oregon, about 11 miles northwest of the town of Vale in Bully Creek Canyon. The area is dry and hilly, but there is a narrow strip of irrigated land along the creek, and this opens at its lower end upon more level irrigated agricultural land near Vale. At the upper end of the irrigated strip the canyon narrows to form a rocky gorge. Here, volcanic rock has become exposed and has crumbled to form slides. These are the overwintering sites which were studied. Figure 1 shows typical hibernation habitat in a side gulch which enters upon Bully Creek at the study area. Observations were made on both mosquitoes and habitat at overwintering sites visited in October, November, and December, 1960, and January, March, April, and May, 1961. As long as quiescent mosquitoes could be found they were collected by manually moving rocks and capturing specimens by aspirator. A view of this operation is shown in Figure 2. In spring, collections were made by baited trap. Most of the mosquitoes were identified and frozen in the field, but some were kept alive and brought to this laboratory for study.

Depth of rock in slides was up to 3½ feet. It was usually impractical to work at depths of over 3 feet because of the danger of falling rock, and most of the work was done at 2 feet or less. Temperature observations in slides were made by means of a Telethermometer (Yellow Springs Instrument Co.) with a stiff wire attached to the probe to facilitate passing the apparatus down among the rocks. Even with this arrangement it was possible to reach depths of only a foot or so. Therefore, when making observations at greater depths, it was necessary to remove rock to form a depression, and from the bottom of this to extend the probe farther. That such readings were not appreciably influenced by free air temperature is indicated by the fact that a buried probe did not give a changed reading as it was approached by excavation at the time of its recovery.

In studies on resistance to low temperature, mosquitoes were placed in screw-capped vials containing ice, and these were placed upon insulating material in the

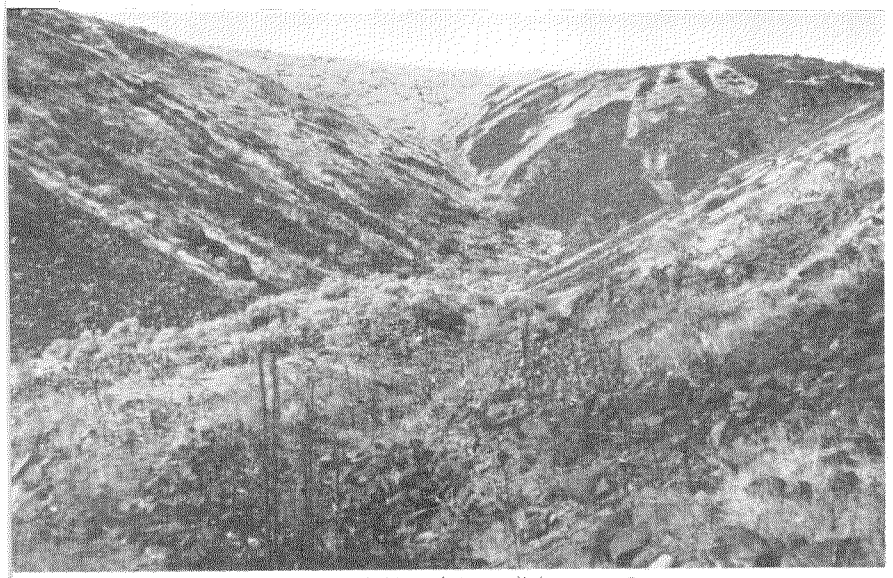

FIG. 1.—Winter habitat of *C. tarsalis* in eastern Oregon

eezing compartment of a kitchen re-igerator. When vials were removed, a uick reading would be made of a mer-ry thermometer lying besides the vials, nd its value would be taken as represent-g the temperature for the entire period exposure. Mosquitoes for this study ere collected in rock slides during winter nd were kept until used in an insulated ox containing ice.

OBSERVATIONS. *Temperatures in Slides.* emperatures within rock slides were und to vary between 25° F. and 38° F. pending upon depth, season, weather, nd direction of face of slope. Since the inter of 1960–61 was a mild one in Mal-ur County, it is believed that tempera-res below 25° F. would ordinarily be ex-cted. The variation with depth was arked. The usual pattern was a de-ease with increasing depth down to a oint a few inches above the soil, then the mperature at the bottom, right against e soil, would be higher again. Some amples are given in Table 1. That in-

TABLE 1.—Temperatures (degrees F.) within rock slides

Depth (feet)	N.E. facing slope Nov. 30	S.E. facing slope Jan. 15	N. facing slope Jan. 11
Surface	43	39	31
1	26	34	29
1½	38½ (near soil)	..	..
2	..	..	27
3	..	32½	24½
3½	..	..	27 (against soil)
4	..	34 (near soil)	..

ternal temperatures are influenced within a period of hours by outside air temperatures is shown by the observations on two side-by-side excavations which were made on a single day, in morning and afternoon respectively. It will be seen (Table 2) that temperature next to the soil remained constant (29°), while an inversion occurred in the shallower parts.

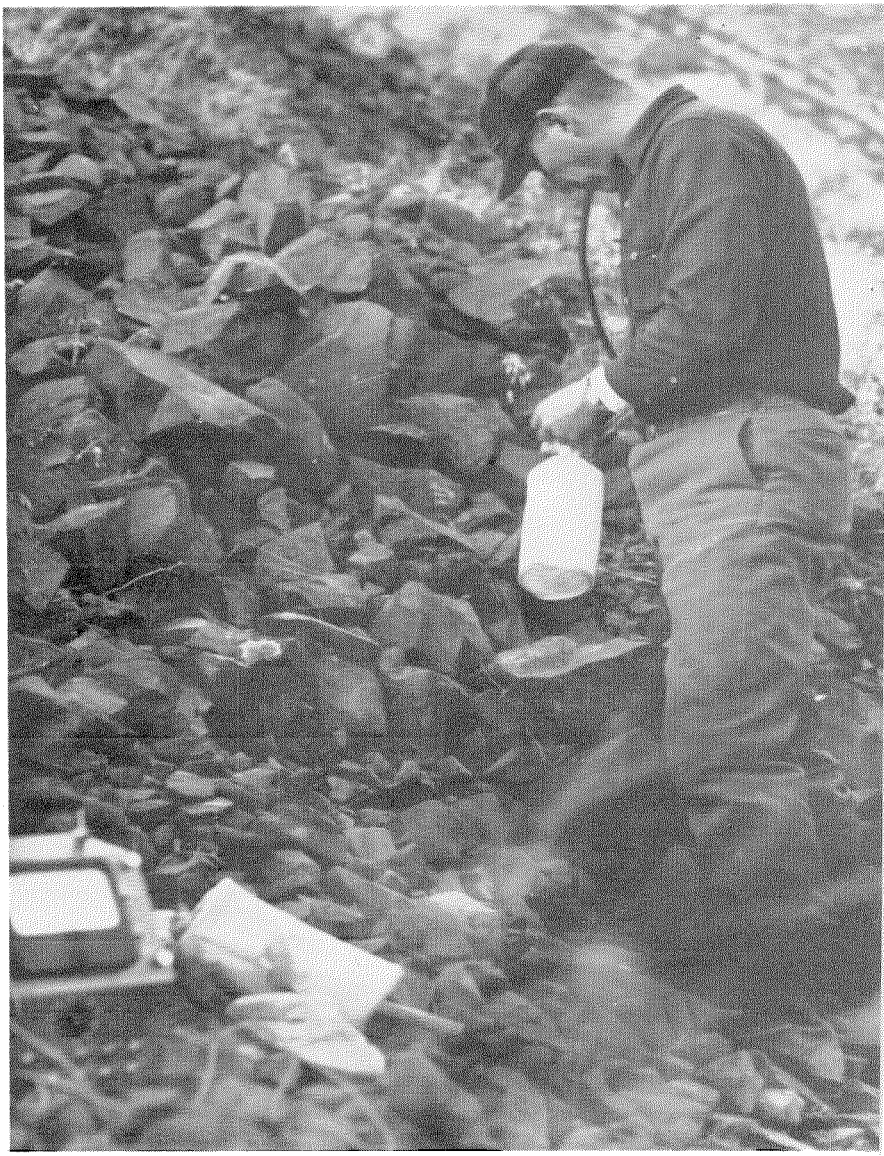

FIG. 2.—Collection of *C. tarsalis* in January

TABLE 2.—Comparison of temperatures (degrees F.) within a rockslide on morning and afternoon of a single day

	Morning	Afternoon
Depth (feet)	Temperature (degrees F.)	
Surface	24	37
	26	..
½	..	30
	..	30
½	27	..
	..	30
½ (near soil)	29	29

Incidence of Mosquitoes. When observations were begun in October, mosquitoes were already in the overwintering sites. They continued to be found there until spring. The average man-hour collection rate of *C. tarsalis* in October, November, December, and January was about five, and the incidence was similar for the four times. *Anopheles freeborni* was found as well, and both species were unevenly distributed through the rocks. It was not unusual to move dozens of rocks without finding a mosquito, and then to find two or more on a single rock. An example of a high concentration was a 120-cubic-foot excavation which yielded 14 *C. tarsalis*. A low concentration was represented by a 30-cubic-foot excavation which yielded two. Temperature conditions below the freezing point of water did not preclude presence of mosquitoes, and an occasional specimen was found resting directly upon a deposit of frost. Environmental factors relating to distribution were not determined, but they are thought to be subtle.

During the fall and winter months 672 female and about 50 male *C. tarsalis* were collected. Also captured were 145 *A. freeborni* females, 4 *Culiseta incidens* females, and 1 *Culiseta inornata* female. The *C. tarsalis* males and the *C. inornata* were taken in October, the *C. incidens* in November and January, and the *A. freeborni* at all times. One other specimen of *C. incidens* was captured in the rocks in March. Larvae of *C. inornata* were found beneath ice in November and January, but not in March. The first springtime observation of adult *C. tarsalis* outside hibernation sites was on March 9, when a female was captured in a baited trap. *C. tarsalis* larvae were found near the hibernation sites in late April and pupae on May 12. An adult male was captured on May 17.

Low Temperature Studies. Some of the mosquitoes captured in January were brought into the laboratory for study, and limited observations were made on their ability to withstand low temperatures. Results shown in Table 3 indicate that some overwintering *C. tarsalis* can withstand temperatures far below the freezing point of water for at least 24 hours. Unfortunately, longer exposures were not made. Field observations were also made in January of minimum temperatures for mosquito activity, and it was observed that both *C. tarsalis* and *A. freeborni* performed coordinated locomotor activity at temperatures below freezing. The results are summarized in Table 4.

TABLE 3.—Resistance to experimental exposure to cold of overwintering *Culex tarsalis*

Temperature (degrees F.)	Time period (hrs.)	No. of mosquitoes	No. surviving
13	24	16	0
14	24	13	5
16	24	12	5
23	24	12	3
26	6	24	24
19–26 (average 22)	48	24	8

Feeding. Of the mosquitoes which were brought to the laboratory in January, an estimated 60 were placed at room temperature and were offered chickens regularly as a source of blood. Twenty-five fed during the next 15 days, at the end of which time no mosquitoes remained alive. On some days there was no blood feeding at all. One day a number of specimens were seen feeding on chicken manure while only one mosquito attacked the chicken.

At the end of March a second group of

TABLE 4.—Activity of mosquitoes at low temperature

Temperature	Maximum activity		
	Culex tarsalis	*Anopheles freeborni*	*Culiseta incide*
26	very slow walking	..	..
27	..	walking	..
32	walking	short "stumbling" flight, not airborne	..
34	vibration of wings for a second or two, no flight	..	..
35	short "stumbling" flight, not airborne	..	..
36	true flight of 4"	..	..
37	strong flight of 2'	..	strong flight of many feet
40	strong flight of 30' or more	..	..

mosquitoes was brought into the laboratory. These had been captured in chicken-baited traps, and all had fed on blood. Twenty-seven of them were placed in a cage with honey solution and water for oviposition, and they were offered chickens regularly. The last one died on April 23, and by that time 6 rafts had been deposited and 2 specimens had taken second blood meals.

Results of spring collections in baited traps are shown in Table 5, as are attack

TABLE 5.—Spring collections of *Culex tarsalis* in baited traps with attack rates and average temperatures

	No. specimens trapped	Attack rate in traps	Temperature * (degrees F.)
March 9–18	130 †	2%	49
March 19–31	1115	31%	50
April 13–27	459	61%	52
May 12–28	152	95%	65

* At Vale.
† Approximately.

rates of trapped specimens and average air temperatures. Mosquitoes entered traps in early March, but only a small percentage of them fed then. It was of interest, however, that these same mosquitoes were avid for water and that they would feed readily on chicken manure. That non-blood feeding does occur naturally in *C. tarsalis* is indicated by an observation which was made on the first spring brood, the progeny of the mosquitoes dealt with in this report. In a series of microscopic examinations an estimated 25 percent of the females, and also some of the males were found to contain clear sticky fluid. This phenomenon was previously reported by Bennington *et al.* (1958), and is not unexpected in view of the observation (Philip, 1943) that this species visits flowers. It will be noted that attack rate in baited traps increased throughout spring —from 2 percent during early March to 95 percent during late May. During this time average temperatures rose from 49 F. to 65° F. It is probable that the collections of late May were composed largely of first-brood individuals.

Flora and Fauna. Each of the following vertebrates was common in or near the hibernation area during at least part of the period from mid-summer 1960 to mid-summer 1961: deer mouse, wood rat, kangaroo rat, cottontail, jackrabbit, mule deer, antelope, coyote, raccoon, bobcat, dog, horse, cow, man, red-winged blackbird, Brewer's blackbird, yellow-headed blackbird, chukar partridge, pheasant, California quail, mallard duck, spoonbill duck, white-crowned sparrow, meadow lark, mourning dove, killdeer, magpie, goldfinch, crow, raven, golden eagle, house sparrow, bank swallow, cliff swallow, violet green swallow, bull snake, racer, and garter snake. At the time of appearance of the spring brood, the most conspicuous blooming plants were of the mustard family, Cruci-

ferae. Several kinds, particularly of the genus *Lepidium,* were found in immediate proximity to breeding areas. Many kinds of Diptera, none of which were mosquitoes, were observed in association with, or actually feeding upon, these flowers.

DISCUSSION. It was of interest that *C. tarsalis* could survive at 18° F. lower than the freezing point of water. The observation was not unexpected, however, in view of the presence of this mosquito in such places as North Dakota, Manitoba, and Saskatchewan. The fact that strong flight occurs at temperatures below 40° F. suggests that feeding might also occur, although the observation was not made.

Mosquitoes collected in mid-winter were short-lived when brought into the laboratory and kept at room temperature. Since spring-caught overwintered individuals showed greater longevity, physiologic characteristics associated with hibernation are thought to be involved.

Of particular interest is the low spring-time biting rate, even by mosquitoes which are entrapped with a suitable host. This is in contrast to the usual concept of the behavior of *C. tarsalis* upon emergence from hibernation. The fact that fluids are taken readily suggests the possibility that blood-feeding is delayed until after ingestion of some other material.

These observations, which have been presented primarily for their interest from the standpoint of ecology and bionomics, may also be pertinent to studies on the epidemiology of human encephalitis.

SUMMARY. The report presents observations on a population of *Culex tarsalis* which was overwintering in rock slides in eastern Oregon. Limited study was also made of the habitat itself. Temperatures in rock slides varied from 25° F. to 38° F. Mosquitoes were active at temperatures as low as 27° F. and could survive at a temperature of 14° F. for 24 hours. Hibernating mosquitoes brought into the laboratory fed on blood at a moderate rate. Mosquitoes entered baited traps in the spring, feeding on the bait first at a low rate (2 percent), and at higher rates as the season progressed. Notes are given on occurrence of *Anopheles freeborni, Culiseta incidens,* and *Culiseta inornata* and of vertebrate species.

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