but the quotation of a more accurate estimate must await the accumulation of further observations.

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ON THE HIBERNATION OF *CULEX TARSALIS* COQUILLETT, *CULISETA INORNATA* WILLISTON, AND *ANOPHELES EARLEI* VARGAS, (DIPTERA: CULICIDAE) IN ALBERTA

J. A. SHEMANCHUK [1]

INTRODUCTION. *Culex tarsalis, Culiseta inornata,* and *Anopheles earlei* are common mosquitoes in Alberta. It is generally accepted that these species overwinter in the adult stage, but little is known about the natural hibernation sites of the adults. More detailed knowledge of the winter behaviour is necessary to relate the spring density of the vectors to the ocurrence and spread of diseases in man and livestock.

MATERIALS AND METHODS. During the winter 1961–62, root cellars, abandoned mine shafts, man-made rock piles, and mammalian burrows in the irrigated areas of Alberta were searched periodically for hibernating adults. At this stage the interest was in establishing the most likely hibernating sites rather than numbers of adults.

In early September, 1962, the area south of Brooks within Alberta was surveyed for mammalian burrows. Burrows that could be visited and checked under adverse winter conditions were selected and marked. In September, 1962, traps similar to those described by Harwood and Halfhill (1960) were placed over the mammalian burrows and were then checked at least once a month. Traps containing insects were replaced by fresh traps and were brought to the laboratory where their contents were identified and recorded.

In September, 1963, 176 burrows were selected and the study area was extended northward (Fig. 1). All the burrows selected were checked periodically during the fall to determine if adult mosquitoes were entering the burrows. After the first heavy snowfall (December 3–4, 1963) the traps were set over the burrows and were left undisturbed until March 1964, at which time all the traps were checked for contents and state of repair. Damaged traps or those containing insects were replaced by fresh ones. Thereafter the traps were checked and the contents identified and recorded every two weeks. In

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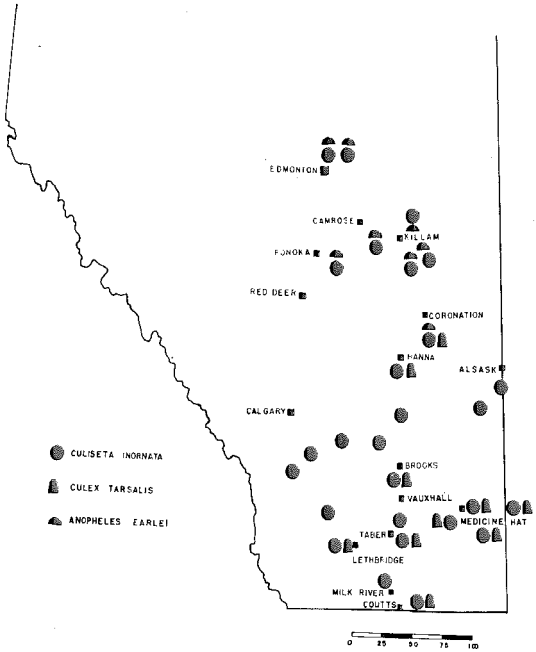

FIG. 1.—Locations in Alberta where mosquitoes were found to overwinter in mammalian burrows.

the southern part of the study area during the winter of 1962–63, air temperatures in the burrows were recorded once a month, usually after a cold spell with a Telethermometer.[1] A continuous record of the air temperature in one burrow near Lethbridge was taken from November 14, 1963 to March 16, 1964.

Continuous soil temperature records from the Canada Department of Agriculture Substation at Vauxhall, Alberta (21 miles north of Taber) at depths of 2 cm., 50 cm., and 100 cm. were used.

RESULTS AND DISCUSSION. The scarcity of root cellars, mine shafts, and rock piles in the study area was sufficient alone to discount these as major overwintering sites. In fact, no adults of *C. tarsalis* and *C. inornata* were found in such places in the irrigated areas of Alberta, even though high numbers of these species are known to be present in the area every year (Shemanchuk, 1959). However, mosquitoes were found in mammalian burrows, which are common in the open prairie and are natural subterranean shelters.

Adults of *C. tarsalis* and *C. inornata* entered and rested in mammalian burrows during late August. They preferred the larger horizontal burrows (Fig. 2) such as those of badger, *Taxidea* sp.; skunk, *Mephitis mephitis;* marmot, *Marmota flaviventris nosophora;* and the less common dens of porcupine, *Erethizon dorsatum nigrescens;* and coyote, *Canis latrans*. Burrows of Richardson's ground squirrel, *Citellus richardsoni,* were not inhabited by mosquitoes.

Early in the autumn, when the mean air temperatures were still above 50° F.,

[1] Yellow Springs Instrument Co., Inc., Yellow Springs, Ohio.

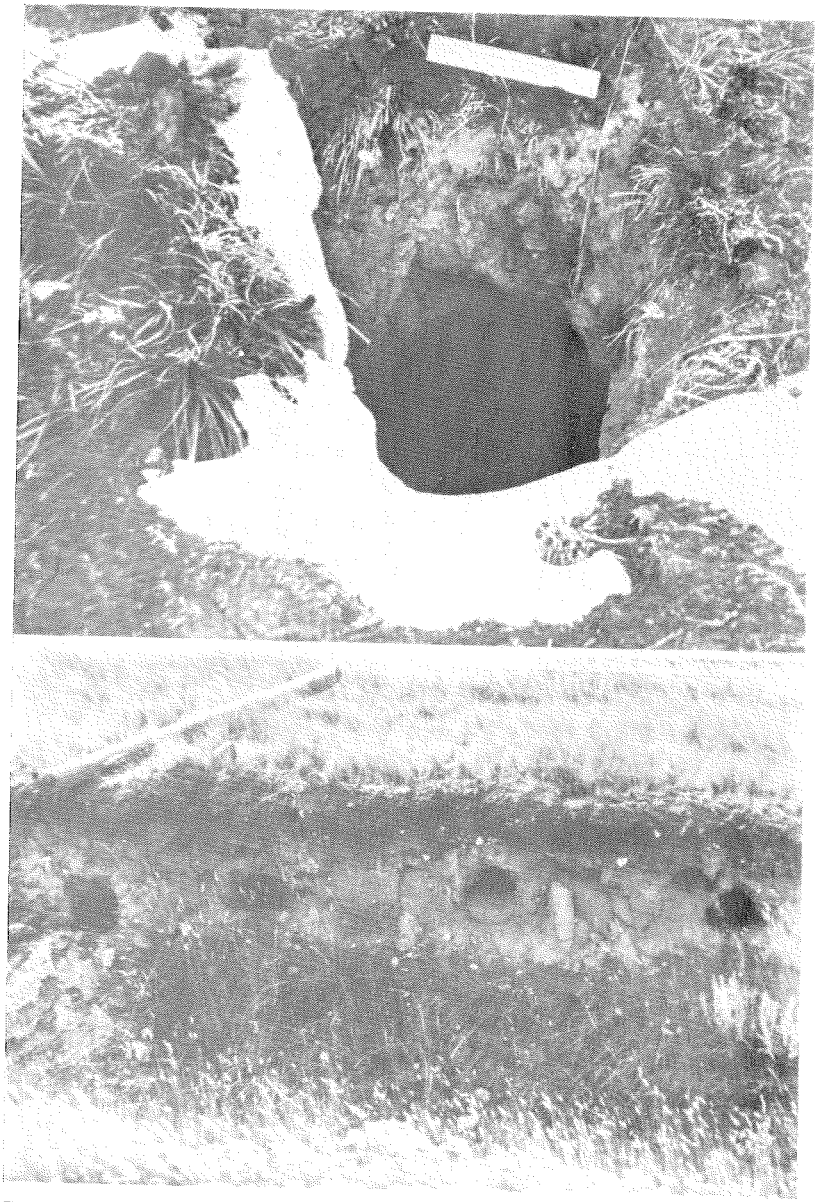

FIG. 2.—Badger burrow (top) approximately 7 inches in diameter in earth bank and skunk burrows (bottom) in earth bank, suitable mosquito hibernation sites.

adults of *C. tarsalis* and *C. inornata* were observed resting in the openings of burrows and on the grass or ground immediately adjacent to them. At this stage the adults were very easily disturbed and took flight readily, but flew near the ground for only short distances (20–30 feet) before settling to the ground. As the season progressed the numbers of adults present in the openings of burrows decreased until by the end of November no adults were seen. When warm air from the mouth was blown into the burrow a few adults were forced out, but their flight was very sluggish and they settled to the ground only a few feet (3–6) away from the burrow. When air temperatures fell below freezing no adults could be forced out of the burrows by blowing.

In 1963, *C. tarsalis* and *C. inornata* females emerged from the burrows during April, May, and June (Table 1). The numbers collected were not high, but burrows are numerous in the area and this low recovery rate probably indicates only a small fraction of the surviving population. Also the populations were progressively depleted each time the same burrows were sampled. Black widow and other spiders were numerous in burrows and they webbed the openings into the traps and destroyed some of the catches, thus further reducing recovery.

TABLE 1.—Mosquitoes trapped from mammalian burrows from 1 September 1962 to 30 June 1963 in the open prairie region in southern Alberta.

Month	No. of burrows	*C. tarsalis* ♀	*C. tarsalis* ♂	*C. inornata* ♀	*C. inornata* ♂
Sept.	62	23	4	176	11
Oct.	61	7	0	29	2
Nov.	46	1	0	0	0
Dec.	43	3	0	4	0
Jan.	46	1	0	3	0
Feb.	44	0	0	0	0
March	59	0	0	0	0
April	62	2	0	1	0
May	62	2	0	15	0
June	31	1	0	0	0

No adults of *A. earlei* were trapped during the winter of 1962–63 because studies were limited to the open prairie region of southern Alberta where this species is not abundant. This species is found in the aspen grove and the wooded region of the province.

In 1964, females of *C. tarsalis, C. inornata,* and *A. earlei* emerged from burrows during April, May, and June (Table 2). *C. inornata* females were taken throughout the whole study area (Fig. 1). *C. tarsalis* was taken in the open prairie region, whereas *A. earlei* was collected only in the more northerly parkland belt. Thus it was apparent that *C. inornata* overwinters in burrows over a wider geographical range than *A. earlei* or *C. tarsalis.* The reason for the absence of *C. tarsalis* from burrows in the more wooded areas of the study area is unknown, as *C. tarsalis* is known to be present in these areas during the summer months. Possibly *C. tarsalis* in this area prefers other hibernation sites, or perhaps the burrows sampled were not typical for the region.

Emergence of *C. tarsalis* females from the burrows in the southern region started in April and continued through May and June. *A. earlei* females from the northern part of the area emerged in April and May.

C. tarsalis and *C. inornata* females emerged from the burrows during the period in the spring when the surface soil becomes warmer than the subsoil (Fig. 3). This has been observed previously by Bennington *et al.* (1958) in Colorado. Soil temperatures at depths of 50 cm. or greater remain close to or only slightly below freezing without too much fluctuation (Fig. 3). However, in the burrows there is a greater variability in temperature (Table 3). The fluctuation in temperature in burrows that are exposed to wind and lack snow cover follow closely the fluctuations of the atmosphere (Fig. 4) and these conditions are too severe for survival. As the temperature of the in-

TABLE 2.—Mosquitoes trapped from mammalian burrows during April, May, and June 1964 in Alberta.

Month	No. of burrows checked	No. of times burrows checked	Number of females trapped		
			C. tarsalis	*C. inornata*	*A. earlei*
March	176	1	0	0	0
April	176	2	1	0	116
May	176	3	4	9	271
June	141	3	1	64	0

sect depends entirely on that of its immediate surroundings, the depth of the burrow below the surface is of major importance and explains the prolonged emergence period. In addition, a mosquito becoming active deep in the burrow in response to warming may, in moving towards the exit, encounter colder conditions resulting from short-term weather changes and become inactive again. Therefore, the deep horizontal mammalian burrows in earth banks are the most suitable for hibernation. The survival of the adults depends to a great extent on weather and the amount of snow cover. The spring survival then regulates the rate of buildup of the mosquito population the following summer.

Humidity in the burrows was not measured, but the hoarfrost formation in the openings of the burrows indicated that the humidity was near saturation in practically all of the burrows from which mosquitoes emerged in spring.

There was no apparent preference by mosquitoes for burrows that were occupied by mammals. Both abandoned and occupied burrows contained mosquitoes in the spring. The mortality of mosquito females was higher in the abandoned burrows because more spiders were present in them.

TABLE 3.—Temperatures (° F.) taken periodically in mammalian burrows in southern Alberta.

Date	Range	Mean	No. of burrows checked
Nov.	28–43	36±3.9	28
Dec.	35–47	40.1±3.5	46
Jan.	6–44	27.7±10.7	58
Feb.	19–44	31.4±4.9	34
Mar	36–56	44 ±5.6	77
April	38–61	46.5±5.4	98
May	47–55	52.1±2.7	19

SUMMARY. In Alberta, where winter conditions are severe, burrows of larger mammals such as the badger, skunk, and marmot are suitable natural overwintering shelters for *C. tarsalis, C. inornata,* and *A.*

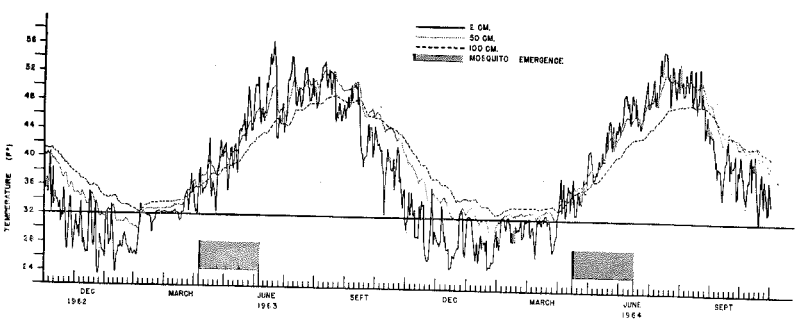

FIG. 3.—Emergence from burrows of *C. tarsalis* and *C. inornata* when the surface soil becomes warmer than the subsoil.

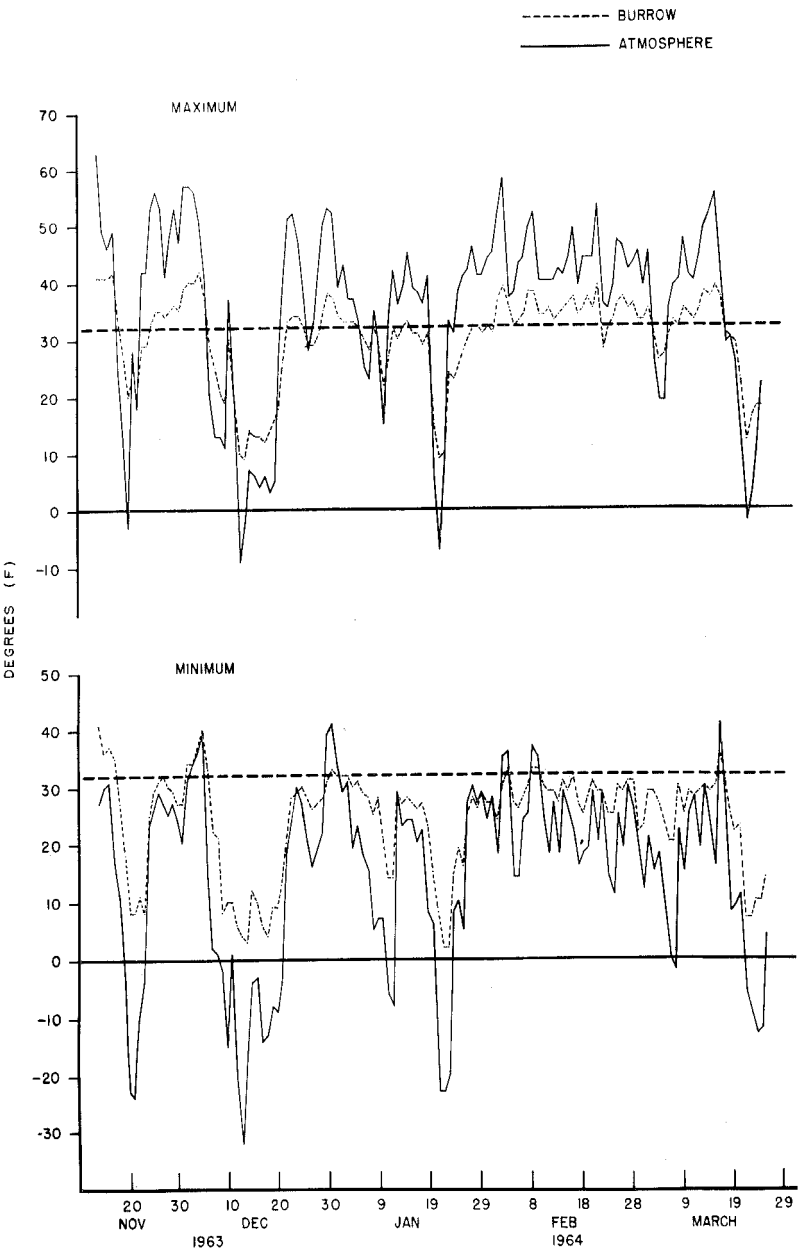

FIG. 4.—Record of temperature in one mammalian burrow approximately 5 feet deep and exposed to winds from November 14, 1963 to March 20, 1964 near Lethbridge, Alberta.

earlei. Females emerge from the burrows in spring when the surface soil becomes warmer than the subsoil. Survival of mosquitoes in burrows depends greatly on the type of burrow, amount of snow cover, and exposure to winds during the winter.

ACKNOWLEDGMENTS. The assistance of M. C. Qually, technician, Veterinary-Medical Entomology Section, Canada Agriculture Research Station, Lethbridge, is gratefully acknowledged.

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OVIPOSITION OF THE MOSQUITO *CULEX TARSALIS* IN RESPONSE TO LIGHT CUES [1]

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The problem of cyclic oviposition in mosquitoes has been investigated before (*Aedes aegypti*, Haddow and Gillett, 1957; *Aedes africanus*, Gillett and Haddow, 1957; *Aedes apicoargenteus*, Haddow, Corbet and Gillett, 1960; and *Taeniorhynchus fuscopennatus*, Haddow and Gillett, 1958). In each case a clearly defined oviposition cycle was discovered; diurnal for the three species of *Aedes* and nocturnal for *Taeniorhynchus*. Furthermore, these rhythms are circadian, being maintained for some time under constant light or dark conditions.

The experiments described in this paper were conducted in an attempt to determine the nature of the relationship between photoperiod and oviposition in the mosquito *Culex tarsalis*. As soon as the presence of a daily rhythm under various light conditions was confirmed, particular emphasis was placed on the possibility of an internal rhythm governing oviposition.

MATERIALS AND METHODS. A strain of *Culex tarsalis* originating from Washington was used. For each experiment, egg rafts were taken from the stock culture and reared in incubators where temperature and light conditions were controlled. The pupae were transferred to another incubator which contained a screen cage and the egg collecting apparatus. This consisted of 13 small water-filled jars placed in a circle, above which rotated a disc with a single hole of the same diameter as a jar. Thus only one jar was uncovered at any one time. Rotation of the disc by a motor was controlled by an automatic timer. At each position a protuberance contacted a microswitch stopping advancement to the next jar until activation by the timer. After a period of as long as 2 days, (using 4-hour intervals) the jars were removed, the egg rafts counted and discarded, and the jars replaced.

Food supplied to the larvae was based on herring meal, (Harwood and Halfhill, 1964). Adults had a 10 percent sucrose solution available constantly, and for each

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