SOIL TEMPERATURE AND THE EMERGENCE OF *CULEX TARSALIS* FROM HIBERNATION

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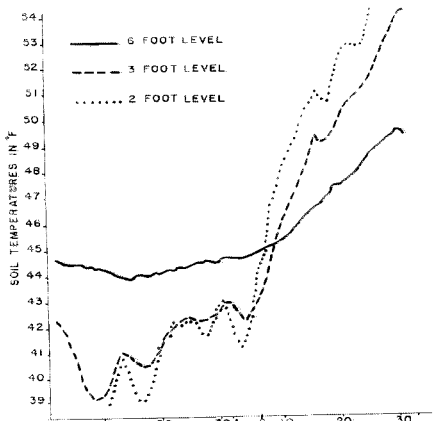
Encephalitis investigations in the Midwest have included studies on the hibernation of *Culex tarsalis* Coquillett because this species may provide the overwintering reservoir for the western equine encephalitis and St. Louis encephalitis viruses. The fact that hibernating *tarsalis* have been collected in cellars (Keener 1952) and mines (Greeley Field Station 1955; Dow, Mail, and Richards 1956) suggests that hibernation takes place underground. Their disappearance from such places before the time of general emergence also suggests that more successful hibernation takes place in smaller sites such as animal burrows.

As these studies progressed, the emergence of female *tarsalis* from hibernation was recorded by John Blackmore who observed that each spring these mosquitoes emerged quite suddenly over wide areas of Weld County, Colorado. The data presented here show that the emergence of this species from hibernation is related to soil temperature inversion phenomena which occur simultaneously over large areas. This soil temperature inversion (see chart) is a situation which occurs twice a year, once in the spring when the surface soil becomes warmer than the subsoil and again in the fall when the surface soil becomes colder than the subsoil.

Holmquist (1928) illustrated a soil temperature inversion phenomenon in connection with ants which emerge after the inversion. McColloch and Hayes (1923) found that white grubs, which hibernate deep in the soil, emerged on March 22, 1920, and March 12, 1921. The soil temperature inversions occurred March 15–20, 1920, and March 1–7, 1921. Daily temperatures were taken at every foot to a depth of six feet and provided a timing for the control measure, plowing.

The same inversion was illustrated by Mail (1930) who indicated that many insect species hibernate above the frost line but due to a lowered freezing point could withstand the frost (Robinson 1927). McColloch, Hayes and Bryson (1928) report that in the area of their investigation the ground seldom freezes at nine inches and at twelve inches rarely gets to 32° F. making subsurface soil a good habitat for hibernation.



A SOIL TEMPERATURE INVERSION WHICH OCCURRED AT FT. COLLINS, COLORADO, APRIL 6, 1954

METHODS AND DISCUSSION. Temperature data were obtained near the Greeley Field Station with thermistors buried at six inches, three feet, and six feet. Additional soil temperature data were made available by Mr. Maxwell Parshall of the Fort Collins, Colorado, weather station. These

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temperature data when plotted show that the inversions occurred in Fort Collins March 28, 1953; April 6, 1954; April 14–15, 1955; and March 25, 1956. At Greeley, twenty miles from Fort Collins, the thermistors indicated that the inversions occurred on April 15, 1955, and March 23, 1956.

The first female hibernators were observed to emerge March 24, 1953; April 6, 1954; April 15, 1955; and March 25, 1956. These dates agree closely enough to indicate that this species does not emerge until the soil temperature has inverted and that soil temperature data could provide timing for early spring control measures.

Culex tarsalis observed hibernating in a number of mines and cellars are quite active and very few live to the date of general emergence. This is probably due to the rather higher temperatures of 50°–55° and suggests that these mosquitoes hibernate more successfully at lower temperatures of 40°–50° F. which obtain 2–3 feet below the soil surface (Dow, Mail, and Richards 1956). Khelevin (1941) observed that *Anopheles maculipennis* females died in warm basements due to premature exhaustion of the fat bodies.

In the spring of 1955 two *tarsalis* hibernators were taken by traps over wild animal burrows. In the fall of the same year a group of 223 female *tarsalis* were released in a ground level 4′ x 4′ x 4′ cage, the bottom of which was provided with three 4-inch openings to 3 vertical, 10-inch shafts extending six feet down into the soil. These females had fat bodies and disappeared from the cage in October. The next spring (1956) traps placed over the openings recovered only four mosquitoes after the temperature inversion. In this dry soil, the mosquitoes might have been more successful in shorter shafts at lower temperatures which would decrease activity and maintain a higher relative humidity.

The longevity of insects is usually lengthened by a decrease of temperature which seems also to be the main factor in the emergence of insects from hibernation (Holmquist 1928; Dowdy 1955). One explanation for the emergence of large numbers of mosquitoes shortly after temperature inversion each spring is suggested by the work of Nicholson (1934). He noted that when the temperature rose above the thermal threshold, blow flies became more fidgety until all commenced flight at the same temperature and time.

SUMMARY. *Culex tarsalis* females emerge from hibernation at or shortly following the spring soil temperature inversion. Two *tarsalis* females have been taken during the spring emergence from wild rodent burrows and four were recovered after successful hibernation in an artificial burrow.

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