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DEGREE-DAY SUMMATION AND HATCHING OF THE FOREST TENT CATERPILLAR, *MALACOSOMA DISSTRIA* (LEPIDOPTERA: LASIOCAMPIDAE)

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The forest tent caterpillar, *Malacosoma disstria* (Hübner), is a common defoliater of deciduous trees throughout most of the United States and Canada. It is a well known outbreak species, whose populations erupt periodically (every 10 to 16 years) when forest conditions are suitable. Typical outbreaks last three to six years in a given geographic area and then collapse as quickly as they arise.

This note documents the relation between forest tent caterpillar egg hatching in the field and heat accumulation (degree-days) leading up to hatch. This information will permit (a) predicting the date on which eggs will hatch by summing degree-days during the insect's overwintering period, and (b) comparing with populations in other years and areas. The data came from an outbreak in northern Minnesota that began near International Falls in 1966 and collapsed in 1972 (Witter et al., 1975).

METHODS

Dates of egg hatch were observed for eight consecutive years near International Falls, Minnesota. Degree-day accumulations up to the day of hatch were calculated using the formulas in Ives (1973) which require knowing daily air temperature maxima and minima, the developmental threshold temperature (see Lin et al., 1954 for a discussion of thresholds), and the length of the overwintering period. Temperature maxima and minima were derived from records of the National Oceanic and Atmospheric Environmental Data station at International Falls. We arbitrarily selected two threshold temperatures (32° and 40°F) because they were suggested by the laboratory studies of Hodson and Weinman (1945). We arbitrarily selected two dates, October 13 and November 13, for beginning the overwintering period because Ives (1973) had selected the former date and Hodson and Weinman (1945) concluded that larvae terminate diapause and enter their overwintering condition sometime in November in Minnesota.

Hodson and Weinman (1945) reasoned that the hatching threshold was somewhere between 41° and 50°F because the larvae would not chew through the egg chorions or hatch at temperatures lower than 41°F. However, this does not imply that the developmental threshold is between 41° and 50°. On the contrary, Hodson and Weinman's (1945) data suggest that it must be lower because the longer eggs were held at overwintering temperatures of 35.6°F and 23°F, the quicker they hatched when brought to temperatures of 77°F. For example, eggs held for three and six months at 35.6°F hatched in 11.7 and 4.8 days, respectively, when temperature was increased to 77°F. Thus, the data clearly show that larvae were developing or becoming more prepared to hatch at temperatures lower than 41°F.

RESULTS & DISCUSSION

Eggs required an average of 178 and 261 degree-days to hatch for overwintering periods beginning November 13 and October 13, respectively, using 40°F as the developmental threshold (Table 1). The corresponding coefficients of variation (CV) were 14 and 19 percent, respectively.

Eggs required an average of 416 and 615 degree-days to hatch for overwintering

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Table 1. Degree-days required for hatching forest tent caterpillar egg masses in the field near International Falls, Minnesota, using two developmental threshold temperatures and starting dates for overwintering.

Year	Hatch date[a]	32°F Threshold Oct. 13→ hatch	32°F Threshold Nov. 13→ hatch	40°F Threshold Oct. 13→ hatch	40°F Threshold Nov. 13→ hatch
1967	May 21	604.2	463.1	236.6	180.6
1968	Apr 30	589.9	399.2	227.8	154.1
1969	May 1	615.7	382.4	318.6	208.5
1970	May 12	525.5	368.1	180.7	134.5
1971	May 6	670.7	415.1	304.1	193.9
1972	May 11	712.5	457.3	331.6	206.2
1973	May 6	557.2	439.4	218.2	179.7
1974	May 16	642.7	403.6	270.8	166.4
Mean	May 9	614.8	416.0	261.1	178.0
Standard deviation		60.3	34.5	53.8	25.6
Coefficient of variation		.10	.08	.21	.14
Standard error		21.3	12.2	19.0	9.1

[a]Years 1967 to 1969 are from Witter et al. (1972).

periods beginning on November 13 and October 13, respectively, using 32°F as the threshold (Table 1). The corresponding CV's were 8 and 10 percent.

These data reveal that using 32°F as the threshold and November 13 as the beginning of the overwintering period gives the least variable degree-day totals. For example, the standard error for 32°F (November 13) was only 3 percent of the mean. Other standard errors expressed as percentages of their respective means were as follows: 4 percent (32°F, October 13); 5 percent (40°F, November 13); 7 percent (40°F, October 13). The results suggest that selecting the lower developmental threshold is more important in reducing variability than is manipulating the beginning date of the overwintering period.

Degree-day accumulations for 1970 and 1972, years with lowest and highest totals, respectively, show that 57 to 70 percent of the heat accumulates after April 1, and 30 to 52 percent accumulates before November 13, if one uses October 13 as the starting date. On the other hand, if one uses November 13 as the starting date, then 91 to 99 percent of the heat accumulates after April 1. In other words, few degree-day heat units accumulate between November and April because of persistently low winter temperatures in the International Falls area.

Data from two studies (in Ives, 1973) indicated that an average of 370 (range: 326-403) and 340 (range: 231-450) heat units above 40°F are required for hatching forest tent caterpillar eggs. Still another study (Table 4, Hodson and Weinman, 1945) indicated that about 355 (range: 294-403) heat units above 40°F are required for hatching. However, our field studies near International Falls (1967 to 1974) and Ontonogan, Michigan, (1977) indicated that only 261 (range: 181-322) and 264 heat units are required.

Some of this discrepancy may be attributable to different populations of insects, but probably much may also be attributable to differential heating of eggs by short- and long-wave radiation (varying with years and environments), thereby causing egg temperatures to differ markedly from ambient air temperatures (Porter and Gates, 1969; Casey, 1976). For example, Wellington (1950) reported that a forest tent caterpillar egg mass was as much as 9° warmer than ambient air on a February day. Brief exposures to temperatures above the threshold can often start development and cause it to continue even after temperatures fall below the threshold (Lin et al., 1954). Such influences of radiant heating must vary between environments and so contribute significantly to observed variations in degree-day estimates required for hatching.

We know little about variations between populations, but presumably the hatching of each will be synchronized with the leaf flushing of its primary host plants just as Wickman (1976) reported for the Douglas-fir tussock moth, *Orgyia pseudotsugata.* Therefore, one may expect differences, particularly among populations adapted to feed on host plants that have different vernal phenologies. For example, preliminary laboratory studies indicate that forest tent caterpillar eggs from sugar maple, *Acer saccharum,* in Indiana may require 60 to 80 percent more heat to hatch than eggs from trembling aspen, *Populus tremuloides,* in northern Michigan.

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