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Degree-Day Accumulation Related to the Phenology of Douglas-Fir Tussock Moth and White Fir During Five Seasons of Monitoring in Southern Oregon

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Abstract

Heat units were accumulated during the spring and early summer for five seasons to relate degree-days to tussock moth and host tree phenology. Little variation in the pattern and date of the phenological events was found during the five seasons of monitoring near Fort Klamath, southern Oregon.

Keywords: Phenology, insect populations, bud burst, Douglas-fir tussock moth, *Orgyia pseudotsugata,* white fir, *Abies concolor.*

Introduction

Earlier papers (Wickman 1976a, 1976b, 1977, 1978a) have described the phenology of Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough), and its apparent egg eclosion synchrony with host bud burst. This synchronous event assures that young tussock moth larvae have an adequate supply of required new foliage for feeding (Beckwith 1976). It also means that bud burst and shoot elongation of host trees can be useful indicators for timing sampling and or control operations (Wickman 1978b). The phenology of host tree and insect is determined by the accumulation of heat units or "degree-days" at any given site. This method of accumulating degree-days over a threshold value of about 42°F (5.6°C) has proven practical for a variety of forest insects (Bean and Wilson 1964, Cameron et al. 1968, Embree 1965, Ives 1973, Mingo and Dimond 1979, and Morris and Bennett 1967). Only rarely, however, have phenological measurements been carried on over a several year period on the same site (Morris et al. 1956); and in the case of the tussock moth, only 1 year's measurements were used from each of several sites to establish the degree-day and phenological relations in Oregon and California. It is very difficult to carry out long-term studies of the phenology of Douglas-fir tussock moth in most outbreak areas because populations persist for only 2 or 3 years and then decline to extremely low levels (Wickman et al. 1981). Some sites like one at Mare's Egg Spring near Fort Klamath, Oregon, however, have persistent low level populations that can be sampled and are useful for studying population dynamics and phenology[1] (Wickman 1977).

[1] Mason, R.R., and T.R. Torgersen. Natural mortality of larvae in stocked cohorts of the Douglas-fir tussock moth. Being prepared.

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This paper describes the relations among the phenology of the Douglas-fir tussock moth and its host tree and the accumulation of heat units in the late spring. It was based on measurements made at the same sites from 1976 to 1980.

Methods

Monitoring Plots

Monitoring sites were located near Mare's Egg Spring on the east slope of the Cascades 10 km southwest of Fort Klamath, Oregon. Each site was also the location of a population study plot which was sampled for Douglas-fir tussock moth larvae at 2- to 3-wk intervals during the growing season each year.[2] Two locations were sampled:

Population Plot C: 1 350-m elevation, eastern exposure, mixed old growth and second growth, thinned white fir stand, *Abies concolor* (Gordon and Glendenning) Lindley ex Hildebr., with a few ponderosa pine, *Pinus ponderosa* Dougl. ex Laws.

Population Plot H: 1 250-m elevation, eastern exposure, mixed understory white fir and Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, in a ponderosa pine old-growth stand. This stand was cutover during the fall of 1977, when all large pine and fir were removed.[3]

Temperature records.—Air temperature recording stations consisting of 31-day battery operated hygrothermographs and a maximum/minimum thermometer in a weather shelter, were located in an opening on each plot.

A threshold temperature of 42°F (5.6°C) was used for comparability with previous Douglas-fir tussock moth phenology studies. In many biological studies, 42°F has been used as the "base temperature for onset of vegetative growth" (Taylor 1967). Hardwick (1971) also used 42°F as a threshold for studies of noctuid moths.

The daily mean temperature was obtained by summing the maximum and minimum and dividing by 2. The starting date for accumulating heat units was arbitrarily selected during the first period in April when the average temperature exceeded the threshold for several days in a row. A pattern of threshold-plus temperatures usually was established about mid-April for most years.

Heat units were accumulated by subtracting 42°F from the mean daily temperature with each degree above 42°F termed a degree-day. The few instances where temperatures were low enough to result in negative values were assigned zero.

[2]Unpublished data of R.R. Mason on file at the Forestry Sciences Laboratory, USDA Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon.

[3]Because of the logging slash and burning operations, the thermograph was placed on a plot 4 km north at the same elevation for the 1978 season.

Foliage and insect sampling.—At each plot, eight open-grown white fir trees, about 5 m in height were selected and used for foliage measurements. Each tree had four tagged primary branches on the four cardinal sides of the mid-crown.

In 1976 and 1977, the terminal bud on each of the tagged branches was examined for bud burst and measured for shoot elongation at 3- to 6-day intervals from mid-May through the period of bud development, egg hatch, and dispersal of new larvae. Additional measurements were made at mid-season and after shoot growth ended (late August). In 1978, no foliage measurements were made. In 1979 and 1980, observations on bud burst were made at 2-wk intervals with initial bud burst estimated from degree-day accumulations in 1979 and determined during a plot visit in 1980. Shoot growth was measured at early, middle, and end of growing season in 1979 and 1980.

Douglas-fir tussock moth egg eclosion was determined from tagged local and laboratory-reared egg masses placed in the field in the fall. Laboratory stock was originally collected in the area. Egg masses were wired to foliage and examined periodically in spring for eclosion in 1976, 1977, and 1979. Larval dispersal and development was dated from observation of tagged egg masses or the first larval sample taken by Mason (see footnote 2) each season.

The threshold period for degree-day accumulation started by mid-April for Plot H during all 5 yrs of measurement. Plot C, at a higher elevation, reached threshold temperatures by mid-April only 2 of the 4 yrs of measurements. Plot C was consistently about 4-5 days behind heat unit accumulation on Plot H during all 4 seasons (table 1). This delay due to elevation is expected according to Hopkin's (1918) "bioclimatic law."

Table 1—Accumulated degree-days from the threshold through the early tussock moth larval periods on two sample plots at Mare's Egg Spring, Oregon

Date	1976	1977	1978*	1979	1980	$\bar{X}$	S.E.
Plot H							
April 5	0	32.5	0	15	0	—	—
15	9.5	114.5	125	19.5	30	59.7	24.8
25	20.5	214.5	181.6	26	108	110.1	39.4
May 5	81	267.5	389.6	91.5	237	213.3	57.8
15	240.5	287.5	474.7	170	269	288.3	50.7
25	347	342	481.6	345	362	375.5	26.7
June 5	419	507.5	493.5	502	419	468.2	20.2
15	536	570	565.4	642	505	563.7	22.8
25	725.5	964.5	707.2	779	653	765.8	53.6
July 5	908.5	1062.5	868	925	831	921	39.3
(*Plot A substituted)							
Plot C							
April 5	0	28	**	0	0	—	—
15	0	74	**	0	8	20.5	—
25	0	145.6	**	0	52	49.4	—
May 5	73.5	197.7	**	47	159	119.3	35.4
15	222	216.1	**	121	180	184.8	23.2
25	313.5	274.8	**	278	259	281.3	11.5
June 5	367	438.7	**	429	303	384.3	31.4
15	463	652.1	**	570	369	513.5	61.8
25	636.5	910.5	**	701	499	686.8	85.7
July 5	801.5	1166.6	**	868	664	875	106.1
(**No measurements)							

Results

Spring Degree-Days

Accumulated degree-days were graphed for each plot for the 5 yrs of measurements and showed similar patterns of heat unit development through the seasons (fig. 1 A-B). The 5-yr annual variations by date were indicated by standard errors which ranged from 4 to 35 percent of the mean (table 1, fig. 2). The least variation occurred during the late May to mid-June period. Bud burst and egg eclosion must be closely synchronous for young larvae to survive on new foliage. The periods of May 25 to June 15 (Plot H) and May 25 to June 5 (Plot C) had lower annual variation than other periods (table 1, fig. 1). This was also the period when most bud burst and egg eclosion occurred. A model of expected degree-day development for spring and early summer near Mare's Egg Spring was plotted based on means and standard errors of measurements taken from 1976 to 1980 on Plot H (fig. 2). This curve can be used as a standard degree-day model for the Mare's Egg Spring area by adjusting the date to compensate for elevational differences. For instance, the curve for Plot C would be about 4-5 days behind development on Plot H.

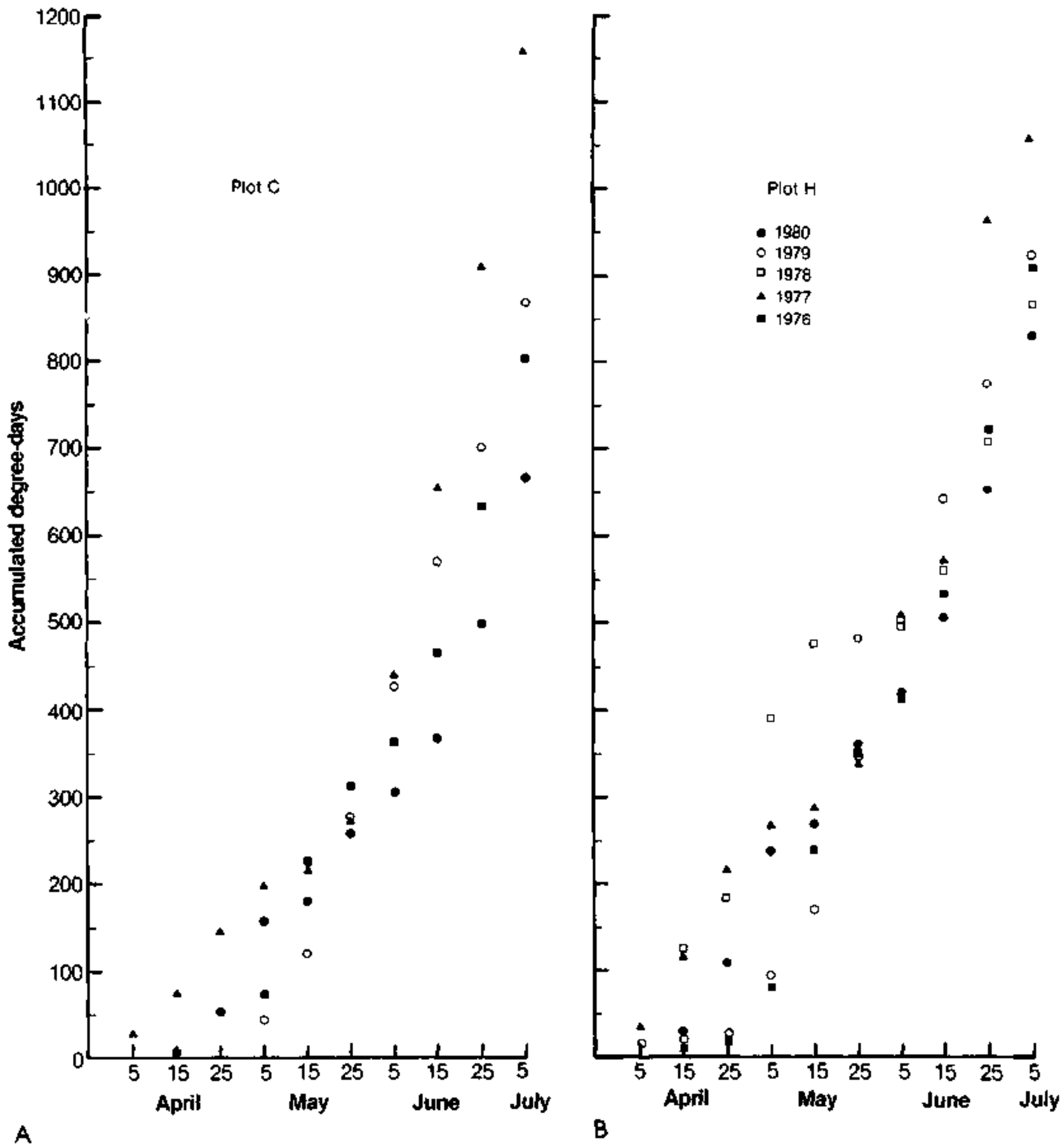

Figure 1 —A Degree-day accumulation, by year, Plot C, Mare's Egg Spring, Oregon B. Degree-day accumulation, by year, Plot H, Mare's Egg Spring, Oregon

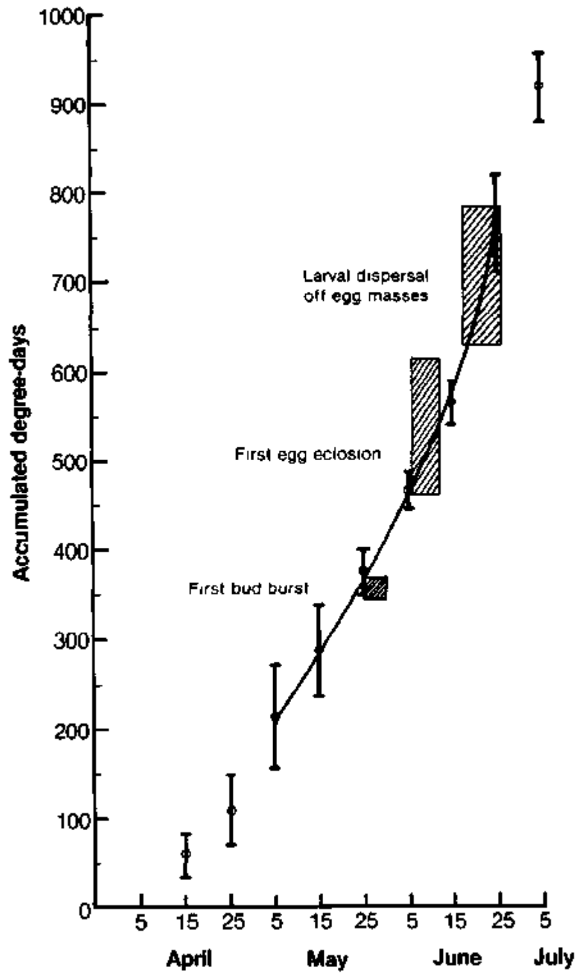

Figure 2.—**Average degree-day accumulation from 1976-1980, and relation to bud-burst, egg eclosion, and dispersal. Plot H. Mare's Egg Spring.**

Bud burst and egg eclosion.—Plot H has the most complete record of measurements and visits through the 5 yrs and was used to illustrate the phenology of host tree and insect at Mare's Egg Spring (fig. 2). The dates and degree-days for three phenological events, bud burst, egg eclosion, and larval dispersal off the egg masses are given in table 2. Generally, bud burst occurred about May 25-31 at 342-370 degree-days, followed by egg eclosion from June 6-16 at 462-614 degree-days, and larvae dispersed off the egg masses from June 18-26 at 630-784 degree-days. Visits were not made to the plot at appropriate times for measurements during all years of the study resulting in some gaps in table 2.

Shoot elongation at the end of June varied from 65 percent completed in 1976 (Wickman 1977) to 90 percent completed in 1977, the warmest year of the study (fig. 3). Shoots were more than 50 percent elongated at the time of larval dispersal off the egg masses for all years of the study.

Table 2—Phenology of white fir bud burst and Douglas-fir tussock moth egg eclosion on Plot H Mare's Egg Spring, 1976-80

	First bud burst		First egg eclosion		Egg eclosion complete (dispersal)	
	Date	Degree-days	Date	Degree-days	Date	Degree-days
1976	5/25	347	6/9	462	6/25	726
1977	5/25	342	6/6	540	**6/18**	784
1978	—	—	—	—	6/26	724
1979	5/31	370	6/12	614	6/19	664
1980	**5/25**	**362**	—	—	6/23	630

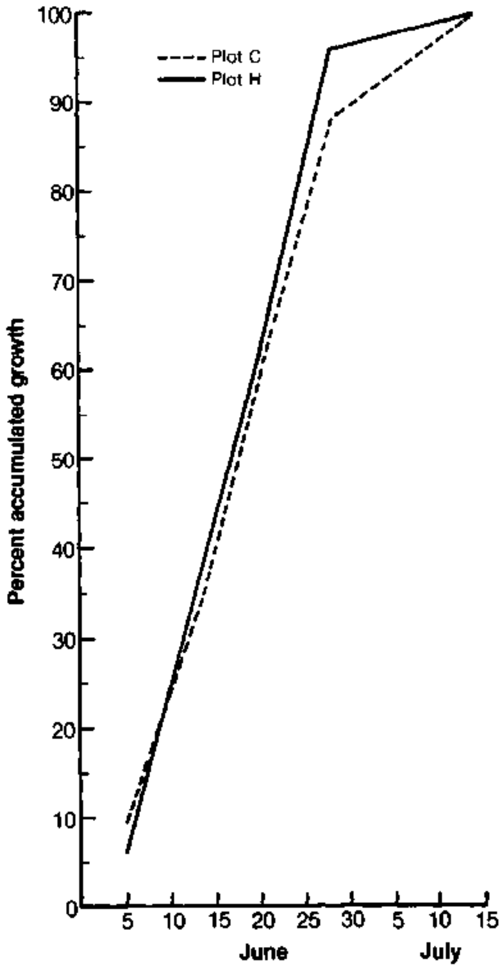

Figure 3 —White fir shoot growth, Plots C and H, Mare's Egg Spring, 1977

Discussion

The use of degree-days for predicting insect development is becoming a common integrated pest management practice for several agricultural pests (Toscano et al 1979, Sevacherian et al 1977) Where temperature instru mentation can be readily established in outbreak areas, it is a practical way to forecast development In most forest situations where instrumentation of the many varied sites is difficult, however, foliage development can be used to predict Douglas-fir tussock moth egg eclosion and dispersal to new foliage (Wickman 1978b)

It would also be helpful to know if the heat unit development at a given site varied much from year to year during the late spring season This knowledge would help determine starting dates for foliage examinations In fact, the temperature measurements taken at Mare's Egg Spring from 1976 to 1980 indicate that annual degree-day variation was very low during the critical period from bud burst through dispersal off the egg masses and these phenological events occurred at about the same dates each of the 5 yrs This is even more surprising when considering that threshold temperature dates in April varied as much as 30 days between some years The close synchrony of degree-days and phenological events and the small amount of annual variation, during the 5-yr period monitored, enhanced larval survival

The extremely close synchrony also points up a vulnerable period for young larvae Any unseasonal temperatures, like a late frost destroying new foliage (Mason and Baxter 1970) or some other environmental anomaly, can place young Douglas-fir tussock moth larvae in an extremely precarious survival position Asynchronous spring phenological events in some stands could in fact be an important limiting factor to the development of Douglas-fir tussock moth outbreak populations By the same standard, spring phenological development unfavorable to predators and parasites of Douglas-fir tussock moths could be a fortuitous event for young larvae and help set the stage for an outbreak episode Mason and Torgersen (see footnote 1) have determined that young larvae are highly vulnerable to predation Their rate of mortality also sets the stage for overall generation survival and future trend of the population [4] A low rate of predation could thus lead to increasing populations We know little about the phenology of the entire Douglas-fir tussock moth life system, but it is becoming increasingly evident that spring development of insect, host, and natural enemies may be a critical point in the population dynamics of Douglas-fir tussock moth Even though monitoring heat accumulation on a variety of forest sites is difficult, it should be an integral part of population dynamic studies

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[4] Mason R.R. Predicting size and change in non outbreak populations of the Douglas fir tussock moth In press

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