United States Department of Agriculture

Forest Service

Pacific Northwest Forest and Range Experiment Station

Research Note PNW-408
January 1984

Day-to-Day Survival of Late-Instar Western Spruce Budworm Larvae and Pupae

Robert W. Campbell and Nilima Srivastava

Abstract

For the western spruce budworm populations studied, day-to-day survival rates were close to constant in the interval from instar IV to residual pupae. In any given crown stratum, host-tree species, and site, day-to-day changes across this interval could be approximated very closely by the Malthusian equation $N_t = N_o e^{\alpha t}$.

Keywords: Insect populations, western spruce budworm, *Choristoneura occidentalis.*

Introduction

Survival from instar III to pupae was shown (Watt 1963) to be important in determining generation survival in populations of the spruce budworm, *Choristoneura fumiferana* (Clemens). Similarly, survival from instar IV to residual pupae (pupae remaining after predation) appears to be important in determining generation survival in populations of the western spruce budworm, *C. occidentalis* Freeman. For this reason, a model relating relevant habitat characteristics to budworm survival during this crucial interval would be useful to both researchers and managers.

In this paper, we suggest a simple analytical form for describing day-to-day changes in populations of the western spruce budworm from instar IV to adults. This form may prove to be useful in the subsequent development of a model relating habitat characteristics to the survival of the western spruce budworm and similar species.

Observations of day-to-day changes in budworm populations are labor intensive and may require special equipment. We have accumulated only two such observation sets on the western spruce budworm. Both sets represent the interval from just before pupation until all remaining insects had either died or become adults. From these data, we developed a model of day-to-day survival. Its behavior suggests that the model form is appropriate for a considerably longer budworm interval—the interval from instar IV to residual pupae.

Our objectives are: to describe day-to-day survival rates of several western spruce budworm populations from just before the onset of pupation until they either died or became adults; to show how these survival rates might be modeled to reflect relevant environmental characteristics; to show that day-to-day survival rates in these populations were approximately equal across the interval between instar IV and adult emergence; and to suggest that further investigation of how environmental factors influence the parameter α in the equation $N_t = N_o e^{\alpha t}$ may prove exceptionally useful in understanding the population dynamics of the western spruce budworm.

ROBERT W. CAMPBELL is a research entomologist, Pacific Northwest Forest and Range Experiment Station, U.S. Department of Agriculture, Forest Service, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oregon 97331. NILIMA SRIVASTAVA is a research associate, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow, Idaho 83843.

Methods

In 1979, branch tips representing the upper, mid, and lower crown thirds of about 12-m-tall Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco, were selected for day-to-day observations of their resident budworm cohorts. Four branch tips about 60 cm long were observed in each crown stratum of each of six trees in a site in the Okanogan highlands of north-central Washington. A truck-mounted, 8.5-m hydraulic lift was used as a platform to observe the cohorts in the mid and upper crowns. In 1980, similar budworm cohorts were studied on both Douglas-fir and grand fir, *Abies grandis* (Dougl.) Lindl., in a site in central Idaho. For each host species, we used the same number and vertical pattern of branch tips used in Washington.

Visits to each tree began shortly before the insects started to pupate. During each visit, all budworm larvae, pupae, and pupal exuviae on each labeled branch were recorded. For each site, host species, and crown stratum, an observation was defined as the larvae and pupae found on that day, plus all pupal exuviae found on that day and earlier.

Densities of instar IV (N_L) and of pupae remaining after predation (N_{P2}) per square meter of foliage were determined by destructively sampling branch tips from nearby host trees with a basket and pole pruner.

Standard graphic and multiple-regression techniques were used to determine relations between variables.

Results

Day-to-day numerical changes in the budworm cohort in each crown third are shown for the population in the north-central Washington site in figure 1. Similar changes are shown for the population in central Idaho in figures 2 and 3. As previously noted, counts commenced just before pupation and continued until all insects had died or emerged.

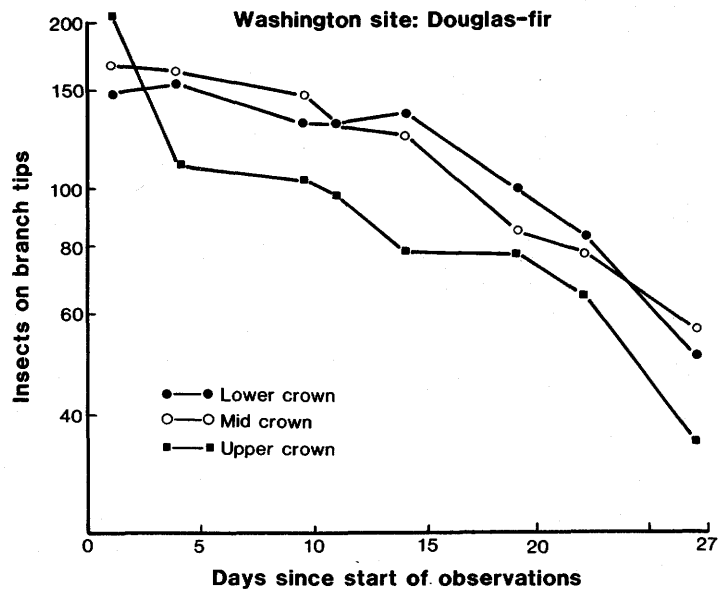

Figure 1.—Day-to-day budworm changes on Douglas-fir in the north-central Washington site (late-stage larvae to residual pupae).

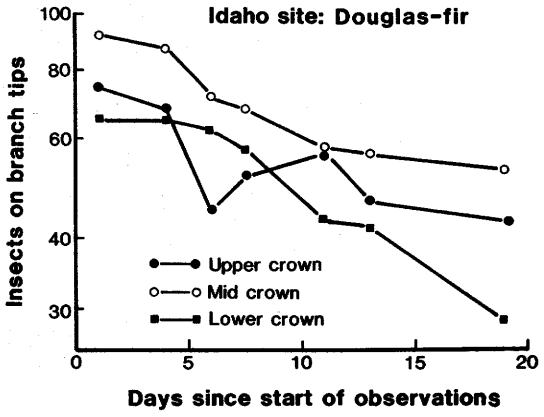

Figure 2.—Day-to-day budworm changes on Douglas-fir in the central Idaho site (late-stage larvae to residual pupae).

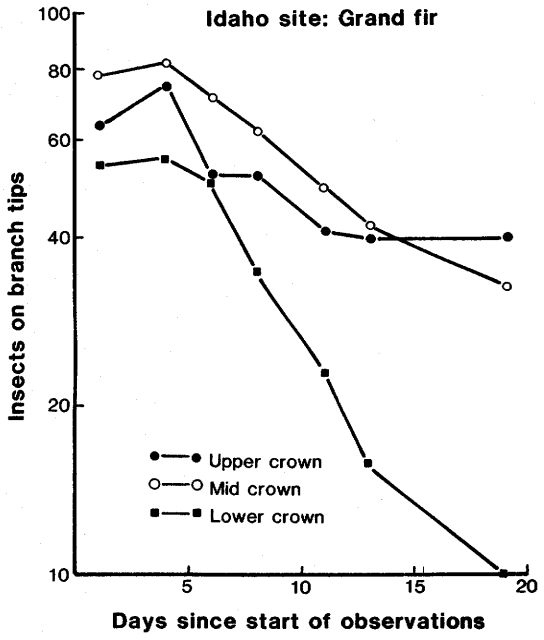

Figure 3.—Day-to-day budworm changes on grand fir in the central Idaho site (late-stage larvae to residual pupae).

Inspection suggested—and analyses confirmed—that successive budworm counts could be approximated by the famous Malthusian equation for population growth (Pielou 1977), $N_t = N_o e^{\alpha t}$; that changes in the mid and upper crown were very similar for both sites and species; and that changes in the lower crown differed both from site to site and between the cohorts on Douglas-fir and grand fir. We determined that:

- For mid and upper crown,
$N_t = N_o e^{-0.039t}$; $r^2 = .88$, $n = 44$.

- For lower crown,
$N_t = N_o e^{-0.061t}$ if Washington
$N_t = N_o e^{-0.050t}$ if Idaho Douglas-fir;
$N_t = N_o e^{-0.102t}$ if Idaho grand fir.
} $R^2 = .96$, $n = 22$.

Starting from observed instar IV per square meter of foliage, we used the above equations to project the density of residual pupae per square meter of foliage on each host species and in each crown stratum and site. The relation between predicted and observed densities of residual pupae is shown in figure 4.

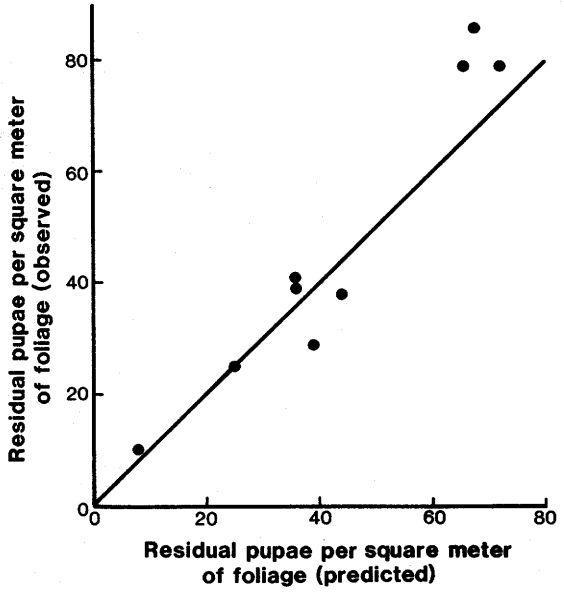

Figure 4.—Observed residual pupae per square meter of foliage and residual pupae predicted from observed instar IV.

Discussion

Numerical changes in the western spruce budworm in the interval from just before pupation until the insects had either died or emerged could be approximated very closely by the Malthusian equation. For the two sites studied, day-to-day changes in any given crown stratum, host-tree species, and site depended only on the value of the parameter α in the equation $N_t = N_o e^{\alpha t}$. Further, for any given environmental stratum, this equation accurately projected the density of residual pupae from observed density at instar IV. For these populations, budworm survival rates from day to day appear to have been relatively constant across the entire interval from instar IV to residual pupae.

Apparently, α can be approximated for any given site, host-tree species, crown stratum, and budworm generation from estimates of densities of instar IV and residual pupae, together with the dates of the two density estimates. In turn, α may prove to be a function of the underlying environmental processes that determine budworm survival during this critical interval.

Acknowledgments

We thank Clinton E. Carlson, Forestry Sciences Laboratory, Missoula, Montana, and Max W. McFadden, Forest Insect Research, USDA Forest Service, Washington, D.C., for their careful reviews of an earlier draft of this manuscript. Work leading to this publication was funded by the U.S. Department of Agriculture, Forest Service, Canada/United States Spruce Budworms Program, Washington, D.C.

Literature Cited

Pielou, E. C. Mathematical ecology. New York: Wiley – Interscience; **1977.** 385 p.

Watt, K. E. F. The analysis of the survival of large larvae in the unsprayed area. In: Morris, R. F., ed. The dynamics of epidemic spruce budworm populations. Mem. Entomol. Soc. Can. 31: 52-63; **1963.**

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Pacific Northwest Forest and Range
Experiment Station
809 N.E. Sixth Avenue
P.O. Box 3890
Portland, Oregon 97208