BIOECOLOGY OF THE CONIFER SWIFT MOTH, KORSCHELTELLUS GRACILIS, A ROOT FEEDER ASSOCIATED WITH SPRUCE-FIR DECLINE

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INTRODUCTION

During the past two decades, the decline of red spruce, *Picea rubens* Sargent, and balsam fir, *Abies balsamea* (L.), at high elevations (900-1200 m) in eastern North America has evoked concern about the effects of anthropogenic deposition upon terrestrial ecosystems. In many high-elevation forests across New England, as many as 50 percent of the standing red spruce are dead (Hertel et al. 1987). Wood cores indicate that growth has been severely curtailed since the 1960s (Hornbeck and Smith 1985). Although acid rain is most commonly invoked as the principal causal agent of this decline, there is yet little hard evidence to support this claim (Johnson and Siccama 1983, Pitelka and Raynol 1989). A wide array of anthropogenic pollutants in combination with natural stress factors are probably involved. Above-ground portions of declining trees appear relatively pest free, and so do the roots except for observations of a few soil-inhabiting arthropods. The most prevalent among those few was a subterranean lepidopteran polyphage, *Korscheltellus gracilis* Grote, found to be extremely abundant in these declining forests (Tobi et al. 1989, Wagner et al. 1987). A member of the Hepialidae family, *K. gracilis* is relatively unknown both in habit and distribution. In North America, documented knowledge about the biology or feeding habits of Hepialidae is limited to cursory reports on *Sthenopis argenteomaculatus* Harris as a borer in maple, oak, chestnut, and alder (Felt 1906). *Sthenopis quadriguttatus* Grote bores into the roots of aspen, cottonwood, and willow (Furniss and Carolin 1977, Gross and Syme 1981). Only one species, *Hepialus mustelinus* Packard, has been reported as a borer in spruce (Felt 1906, Packard 1895). In Australia the Hepialidae are among the major pests feeding on pasture grasses (Tindale 1933), and as stem borers of living trees (Tindale 1953), and tree roots (Tindale 1964).

BARANCHIKOV, Y.N., MATTSON, W.J., HAIN, F.P., and PAYNE, T.L., eds. 1991. Forest Insect Guilds: Patterns of Interaction with Host Trees. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-153.

Adults of *K. gracilis* occur from June through early August and are active for 20 to 40 minutes during evening and dawn twilight. Inactive during the day, the cryptically marked adults rest on tree trunks or foliage. Eggs, scattered by females while in flight, hatch in 2 to 4 weeks. The whitish, unornamented larvae pass through two winters, attaining lengths of 35 to 45 mm before pupating in the upper layer of forest litter. At all locations where we studied this insect, abundance and marked scarcity of adults alternated from year to year, thereby suggesting a 2-year cycle.

Our studies represent an attempt to clarify the relationship of *K. gracilis* to its hosts, explain its apparent abundance in high-elevation forests, and increase information about its bioecology.

EXPERIMENTAL APPROACH

Densities and distribution of *K. gracilis* were determined in high-elevation forests in Vermont, New York, and New Hampshire, and at a sea level site of red spruce in Saulnierville, Nova Scotia. Quantitative estimates of larval and pupal densities were based upon examination of a series of 0.25 m^2 soil pits at elevations of 500, 700, 900, 1,100, and 1,300 m on Whiteface Mountain in New York and Mt. Moosilauke in New Hampshire. Two plots consisting of five subplots each were used to count fall and spring larval densities at each location-exposure. The relative abundance of adults was estimated by using two interception traps (1/4-m^2 sheets of clear plastic coated with Tanglefoot) placed 50 cm off the ground. On each mountain, plot transects were deployed at the point of maximal exposure to cloud base impact and on the lee side.

We measured feeding preference and seedling damage trials in the laboratory using field-collected mid-instar larvae 2 to 3 cm in length (Grehen et al. in press). Survival and weight gain on the predominant food sources available to this polyphage at high elevations and bordering lower elevation sites were evaluated to clarify relative suitability. In addition, three groups of 20, 2-year-old red spruce seedlings were inoculated with 0, 1, or 3 mid-instar larvae in the field at elevations of 700, 900, and 1,100 m. Seedlings were planted with their roots enclosed in saran screening so as to confine inoculated larvae within soil around the roots. This not only prevented larval escape, but also prevented other *K. gracilis* larvae or organisms from attacking the roots of the seedlings.

Periodically, larvae were collected from all sites, brought to the laboratory, and reared individually on carrots to enable us to rear out natural enemies.

RESULTS AND DISCUSSION

Densities of larval and adult *K. gracilis* were consistently highest at 900 and 1,100 m, and lowest below and above these elevations (Fig. 1). Mixed hardwood predominates below 700 m, whereas the proportion of spruce-fir increases from 700 to 1,100 m, and red spruce declines as balsam fir increases up to 1,300 m. There are few if any trees above 1,300 m. The abundance of *K. gracilis* corresponds roughly with that of red spruce, together with maximal tree decline and cloud-based impact. In the fall of 1987, larval densities were extremely high at Whiteface Mountain, New York, and Mt. Moosilauke, New Hampshire; estimated densities at 900 m were 5.6 and 14.8 larvae/m^2, respectively. At these two sites, however, larval densities declined over winter by 51 percent and 72 percent, respectively (Fig. 2).

The Hepialidae are extremely polyphagous and *K. gracilis* is no exception. Field observations verified larval feeding upon woody and nonwoody roots of red spruce and balsam fir. Seedling inoculation experiments (Fig. 3) demonstrated that larvae significantly affect root area and root weight at all elevations studied. Interestingly, the roots of uninfested seedlings had greater area and higher weight as elevation increased. Dieback of seedlings was most pronounced at 700 m with larval densities of three larvae/seedling.

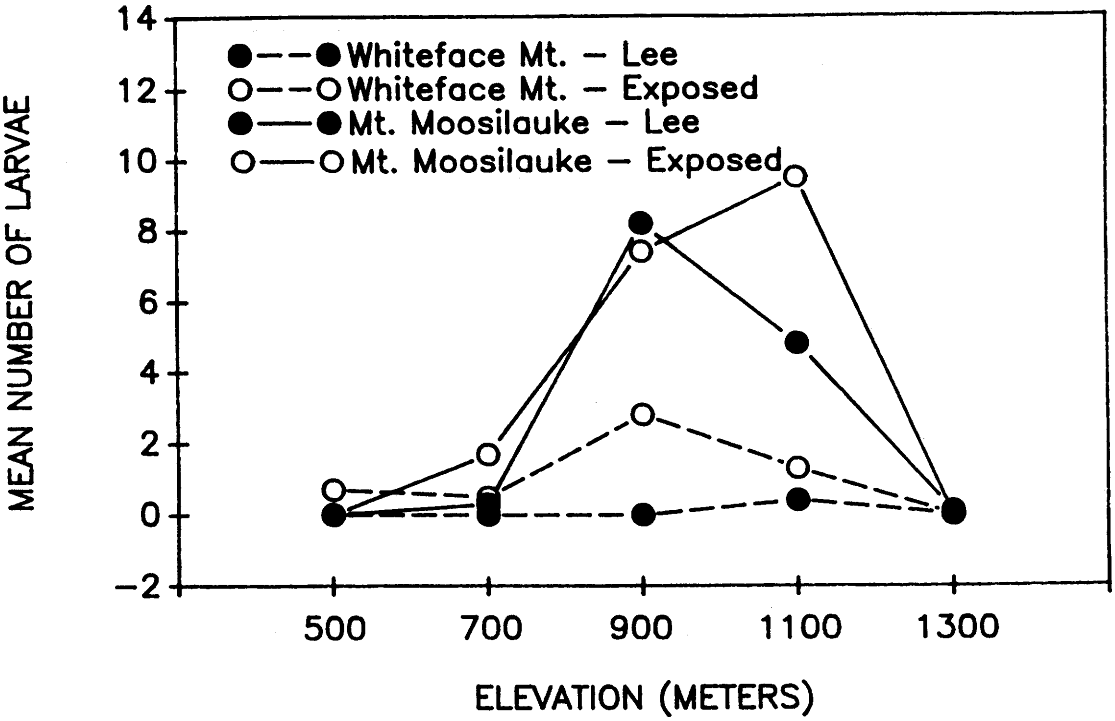

Figure 1. Fall distribution of the conifer swift moth, *Korscheltellus gracilis*, by elevation and location.

With naturally occurring densities of *K. gracilis* often averaging $10/m^2$, it is very probable that larvae significantly reduce both spruce and fir regeneration.

In laboratory rearings on 10 potential food sources found in the high-elevation forests, *K. gracilis* accepted most of those offered (Table 1). Only in rotten wood did larvae fail to survive. The other food sources with which survival was greater than 50 percent were those commonly found in high-elevation forests. Sugar maple commonly occurs in mixed stands below 700 m; whereas white birch occurs in forests up to 1,200 m and mountain ash is common up to 900 m, but their proportion is low between 700 and 1,200 m. It is interesting to note that red spruce and balsam fir were once common at lower elevations, but are now more restricted to the higher elevations. Densities of *K. gracilis* are highest at elevations where spruce and fir dominate, and its survival is best on these hosts. Its poor performance on deciduous species may influence *K. gracilis* distribution and indicate that it is a weak polyphage.

It is generally accepted that larval weight gain over time (expressed as weight change from initial) is a reasonable indicator of host suitability. In our studies, carrot yielded not only highest survival but also weight gain, probably because it contains high protein and low toxic chemical levels. Another tuberous species, *Dryopteris* fern, a common component of high-elevation spruce/fir stands, showed relatively low percentages of survival and weight gain. Larvae commonly tunnel into the roots of fern in the field, but our data suggest that it is only marginally suitable. Weight gain on spruce and fir was equivalent to relative growth rates of 0.03 mg/mg/day. These growth rates are low for lepidoptera, but not unusual since tree roots are low in nitrogen (Slansky and Scriber 1985).

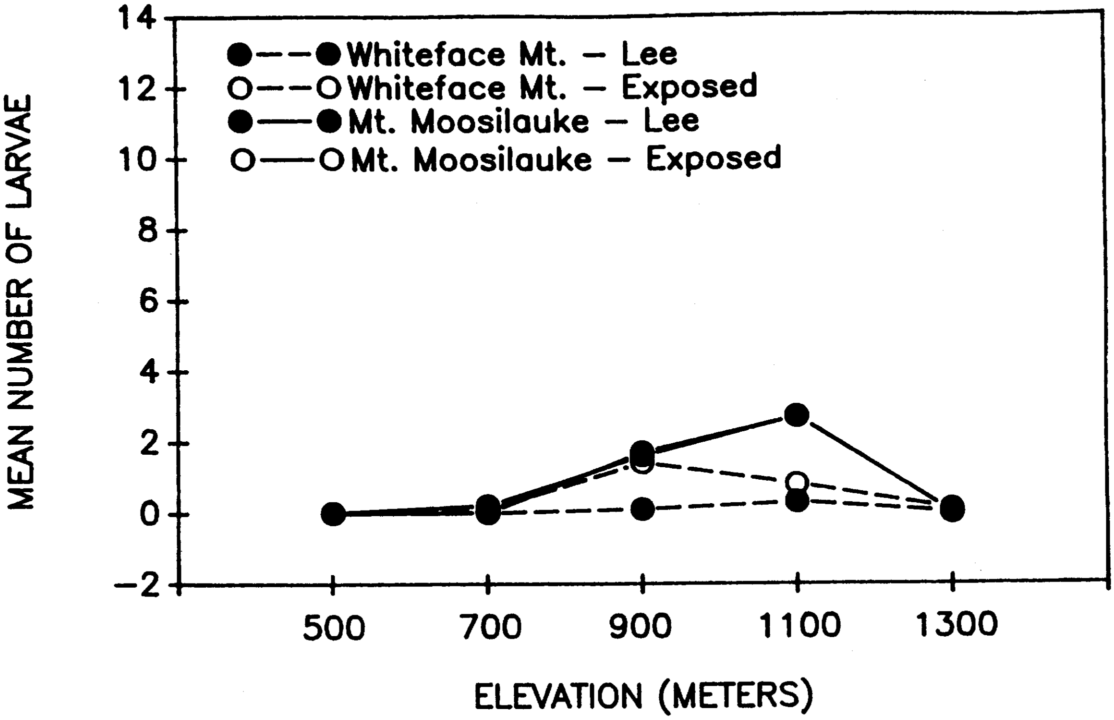

Figure 2. Spring distribution of the conifer swift moth, *Korscheltellus gracilis*, by elevation and location.

Table 1. Average survival and weight gain for the conifer swift moth reared on ten hosts

Host	Percent survival	Percent weight gain
Carrot	85.00	817.6
Moss	70.00	302.4
Fir	61.11	79.6
Hairy moss	60.00	277.0
Red spruce	55.56	93.2
Ash	44.44	1.4
Birch	33.33	105.1
Fern	33.33	32.8
Sugar maple	17.65	60.8
Rotten wood	0.00	----

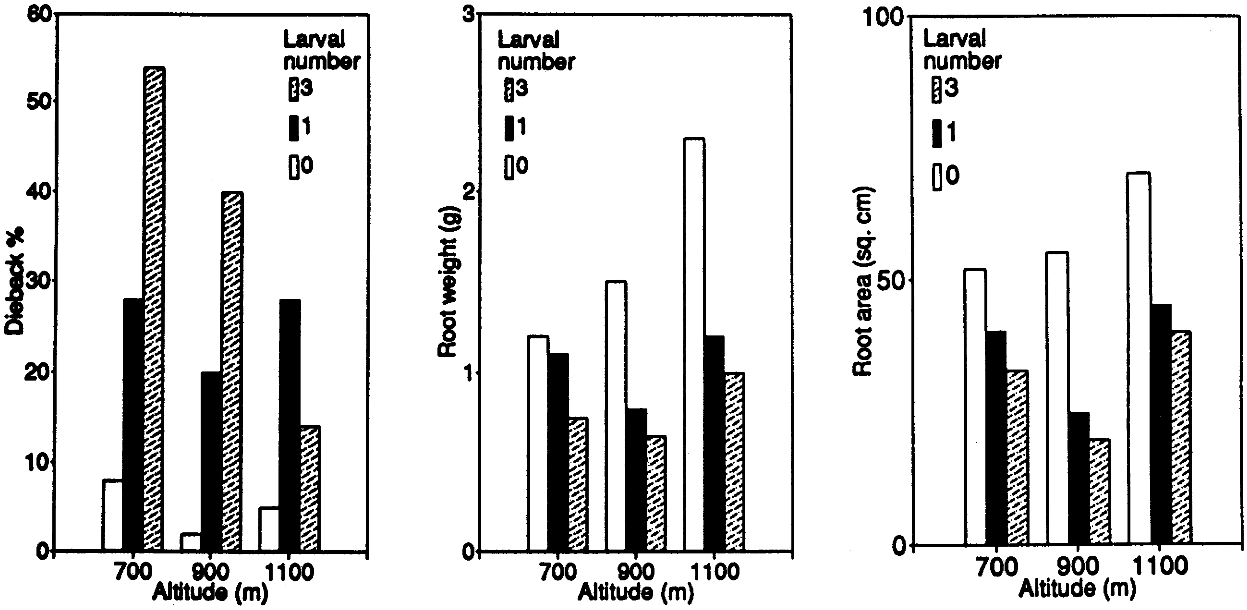

Figure 3. Response of red spruce seedlings to different densities of *Korscheltellus gracilis* larvae at different altitudes on Mt. Mansfield, VT.

The impact of *K. gracilis* feeding on roots of mature trees is less clear. We have observed larval root damage on numerous spruces and firs. In one case, a 50-year-old balsam fir contained more than 30 feeding scars. The larvae feed through the bark, but do not penetrate deeply into the xylem, creating elongate lesions along the axes of second to fourth order roots, fascicles of orange-brown frass and wood chips accumulating on either side of the wound. Such feeding sites provide entry courts for pathogens or nematodes. In fact, a wood-staining fungus has been found in association with *K. gracilis* feeding wounds in Vermont (Dale Bergdahl, pers. comm.).

The spruce-fir decline at high elevations in eastern North America is a complex process involving several factors. The fact that *K. gracilis* larvae occur at high densities in declining forests suggests that they may reduce tree regeneration and produce large numbers of feeding wounds on mature trees and thus may be one of those factors. Trees weakened by air pollution may subsequently be attacked by *K. gracilis*, or pollution-induced changes in the chemistry of the soil environment may permit unusual increases in the population of the insect, which then damages healthy trees.

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