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Yellowheaded Spruce Sawfly—Its Ecology and Management

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Contents

Introduction

The yellowheaded spruce sawfly (YHSS), *Pikonema alaskensis* (Rohwer), (Hymenoptera: Tenthredinidae), defoliates spruce, *Picea* sp., throughout the Northern United States and Canada. YHSS defoliation can result in substantial growth reduction and tree mortality. Young, open-grown trees, 3 to 18 feet in height and 5 to 9 years old, are more vulnerable to YHSS damage than are understory trees, older trees, or trees in dense stands. Young plantations and naturally regenerated stands of spruce often sustain YHSS defoliation, particularly in the Great Lakes region. Many Christmas trees, nursery stock, roadside and windbreak trees, and ornamental spruce are also damaged. Susceptibility to YHSS drops sharply once trees reach 10 to 12 years of age and stands reach the stage of crown closure.

Many aspects of YHSS biology have been extensively studied and related to the occurrence, or degree of defoliation sustained during outbreaks. Large-scale outbreaks in spruce plantations, especially in Minnesota in the 1970's, stimulated increased research efforts on YHSS. However, much of this information is scattered in unpublished theses, reports, and other difficult to locate sources. Recent damage to plantations in southwestern Michigan and to roadside trees throughout the Lake States has renewed regional interest in YHSS (McCullough 1994, Minnesota Department of Natural Resources 1994).

Our objectives here are to review and summarize the literature pertaining to YHSS, identify research gaps, and use existing information to develop long-term silvicultural management strategies for YHSS and perhaps similar defoliators. This research paper is divided into five major parts:

1) YHSS biology, distribution, hosts, and the signs and symptoms of damage;

2) Ecology and dynamics of YHSS populations;

3) Prevention and control tactics;

4) Survey procedures to assess YHSS populations and defoliation; and

5) Guidelines for selecting appropriate management strategies.

Biology, Distribution, Hosts, and Damage

Description of the Insect....

Taxonomy—*Pikonema alaskensis* (Rohwer) is in the order Hymenoptera, suborder Symphyta, superfamily Tenthredinoidea, family Tenthredinidae. The approved common name in North America (Entomological Society of America) is yellowheaded spruce sawfly. The YHSS was originally described as *Pachynematus alaskensis* by Rohwer (1912). In 1937, Ross erected the genus *Pikonema*, based on adult genital characters, including ovipositor sheath length and shape of the male subgenital plate (Ross 1937, 1938). *Pachynematus ocreatus* and *Pachynematus picea* are other synonyms of *Pikonema alaskensis*; *P. ocreatus* has been called the brown-headed sawfly in the literature (Mitchener 1931).

Egg—Eggs are pearly-white and ovate with a finely stipuled shell. Eggs average 1.3 mm long and 0.7 mm wide (Nash 1939). As the embryo develops, the egg swells and black eyespots become evident.

Larva—Full-grown larvae are about 18 mm long (fig. 1). They have a mottled yellow to reddish-brown head; the body is olive green, with six gray-green longitudinal stripes. A small spot is present near the prolegs on all except the last segment of the body. Larval color variation is frequent in this species, with color ranging from green to rose (Morton 1948). Forbes (1949) found three distinct larval color phases in the Maritime Provinces of Canada: yellow, brown, and green. All larval stages have a characteristic shiny, oily appearance. Several keys and diagrams exist to distinguish YHSS larvae from other sawflies (Schaffner 1943, Craighead 1950, Wilson 1977), including other sawflies found on spruce in Ontario (Lindquist and Miller 1971).

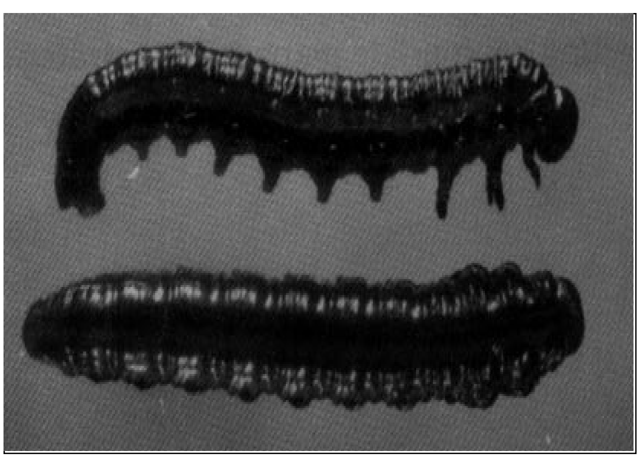

Figure 1.—*Full-grown larvae of the yellowheaded spruce sawfly.*

Prepupa—The prepupa is the cocoon-spinning, last larval stage. Prepupae are similar to the last-instar larva, though prepupae contract to about 8.5 mm in length after the cocoon is spun (Nash 1939).

Cocoon—The cocoon is thin, dark brown, and fibrous, often with attached soil granules (fig. 2). Both ends are blunt, and one end is wider than the other. Female cocoons (4.6 x 11.3 mm) are larger than male cocoons (3.8 x 9.4 mm) (Houseweart and Kulman 1976a). The pupa, which forms inside the cocoon, is a light cream color. When it emerges, the adult sawfly cuts a circular emergence hole at the larger end of the cocoon.

Adult—Males and females appear similar, though male YHSS (7.5 mm long) are slightly smaller than female YHSS (9 mm long) (Rohwer 1912). Antennae are setaceous, nine-segmented, and about one-half the length of the body (Morton 1948). The basic color of the adults is straw yellow. In some individuals, the head is black only on the frons around the ocelli and mouthparts; on others, the head is almost entirely black (Morton 1948). The thorax may also have black markings. Ross (1938) reported entirely black adults. Morton (1948) did not observe black adults, but stated that males tended to be darker than females. Reproductive systems of both males and females have been described (Morton 1948) and diagrammed (VanDerwerker *et al.* 1978).

Distribution....

The geographical distribution of YHSS coincides generally with the range of spruce in North America. The range of YHSS extends from Alaska to Newfoundland, south to Wyoming and Idaho, across Michigan, Minnesota, and Wisconsin and into the Northeastern United States (Nash 1939, Ross 1938, Shenefelt and Benjamin 1955).

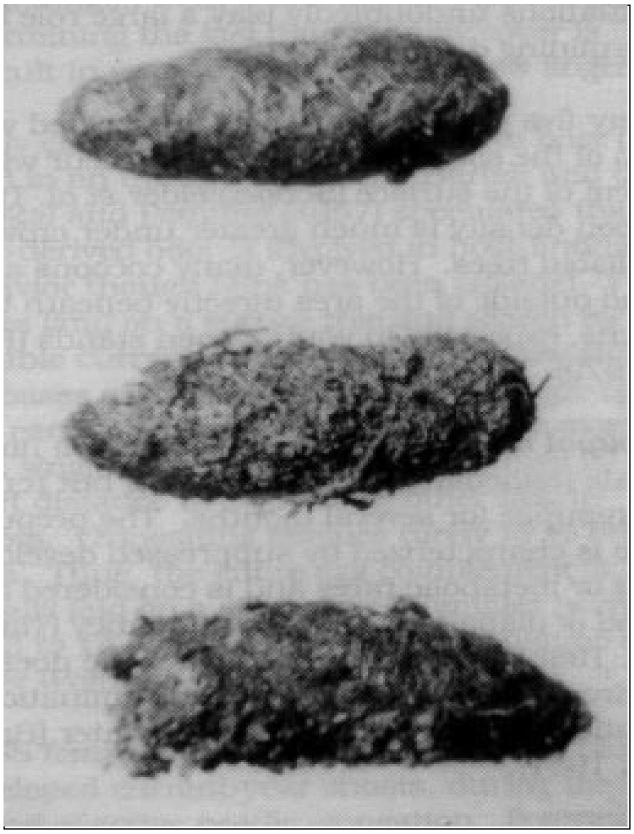

Figure 2.—*Cocoons of the yellowheaded spruce sawfly.*

Hosts and Host Preference....

YHSS has been reported to feed on all spruce species native to North America (table 1) (Houseweart and Kulman 1976b). It has also been reported to feed on Norway spruce, a widely planted exotic in North America (Nash 1939).

Table 1.—*Hosts of the yellowheaded spruce sawfly in North America*

Common name	Native or Exotic	Scientific Name
Black spruce	Native	*Picea mariana* (Mill.) B.S.P.
Blue spruce	Native	*P. pungens* Engelm.
Engelmann spruce	Native	*P. engelmannii* Parry ex Engelm.
Red spruce	Native	*P. rubens* Sarg.
Sitka spruce	Native	*P. sitchensis* (Bong.) Carr.
White spruce	Native	*P. glauca* (Moench) Voss
Norway spruce	Exotic	*P. abies* (L.) Karst.

Although YHSS feeds on a variety of trees, host preference appears to vary geographically. In Minnesota, white spruce is the only commonly utilized host (Houseweart and Kulman 1976b) even though black spruce is abundant and often grows in close association with white spruce. Naturally occurring differences in YHSS defoliation were assessed in an 11-year-old plantation in Minnesota containing 1 black spruce and 23 white spruce seed sources (Pauley and Mohn 1971). No consistent variation in YHSS defoliation among the white spruce seed sources was discerned in 3 years of observation, but black spruce trees were never attacked. In a second Minnesota plantation, YHSS defoliation was observed on 65 percent of the white spruce trees and less than 2 percent of black spruce trees. Defoliation of black x white spruce hybrids was intermediate (24 percent). In Ontario, however, YHSS may preferentially select either black or white spruce in areas where both species occur (Pointing 1957). A provenance plantation of black spruce in southwestern Michigan, consisting of several North American seed sources, was severely defoliated in 1993 and 1994 (McCullough 1994).

Synchrony between bud burst and emergence of YHSS females may play a key role in determining host suitability (Pointing 1957). Bud burst in white and black spruce is typically distinct; bud burst of white spruce precedes that of black spruce by about 10 days (Blais 1957).

Life History and Habits....

YHSS has a single generation per year. It is capable of prolonged diapause, which is discussed below.

Egg stage—In field investigations, average fecundity ranged from 36 eggs in Ontario (Pointing 1957) to 64 eggs per female in Minnesota (Houseweart and Kulman 1976a). Eggs in sunny locations were observed to hatch in as little as 4 days, while eggs in shaded locations took 8 to 12 days to hatch (Pointing 1957).

Larval stage—The duration of the larval feeding period varies regionally. Larvae fed from 10 to 21 days in Minnesota (Valovage and Kulman 1986), 26 to 30 days in Manitoba (Mitchener 1931), 30 days in Ontario (Pointing 1957), and 30 to 40 days in Maine (Nash 1939).

First-instar larvae consume only small parts of the new needles. As the larvae develop, they skeletonize new needles at first and then consume them entirely (fig. 3). Late-instar larvae can feed on foliage from previous years (Wilson 1971). If complete defoliation occurs, larvae may feed on the tender cortical tissue of new growth, at times severing the central axis of current year shoots (Pointing 1957).

Figure 3.—*Full-grown yellowheaded spruce sawfly larvae feeding on white spruce.*

VanDerwerker and Kulman (1974) determined that male YHSS larvae have five stadia and that about 66 percent of females have an additional sixth stadium. Earlier studies reported seven to eight stadia (Forbes 1949) and six to nine stadia (Duda 1953). VanDerwerker and Kulman (1974) speculated that inadequate diet likely altered the number of molts in these laboratory studies.

When they stop feeding in mid-summer to late summer, larvae drop from infested trees and search for cocooning sites in the soil. Cocooning has been reported to begin in mid-July in Manitoba (Mitchener 1931), in late July to August in Wisconsin (Shenefelt and Benjamin 1955), and from early July (Nash 1939) to early August (Duda 1953) in Maine. Yearly weather fluctuations undoubtedly play a large role in determining development times.

Ninety-five percent of cocoons are located within 2 cm of the soil surface, and most occur within 0.1 cm of the surface (Schoenfelder *et al.* 1978). Cocoon density is much greater under crowns of defoliated trees. However, many cocoons are found outside of the area directly beneath tree crowns, especially in young, open stands (Rau *et al.* 1979).

Prepupal and pupal stages—Larvae do not pupate immediately after cocooning but remain as prepupae for several months. The prepupal stage is characterized by suppressed development or metabolic rates and is considered a period of diapause-mediated dormancy (Tauber *et al.* 1986). Although YHSS diapause does not require chilling temperatures for termination, pupation will not occur until late winter (Bartelt *et al.* 1981).

Some individual prepupae, in both field (Duda 1953) and laboratory reared (Bartelt *et al.* 1981, Eller *et al.* 1989) populations, underwent prolonged prepupal diapause for 2 or more years. This phenomenon has been reported for other sawfly species (Drooz 1960, Sullivan and Wallace 1967) and may be a population survival mechanism, especially for insects found in unpredictable environments.

Adult stage—Warm temperatures in the spring initiate development of the pupae, and emergence of adults is highly synchronous. In Minnesota, 63 percent of YHSS adults emerged within a span of 3 days and 94 percent emerged within 8 days (Bartelt *et al.* 1982a). Reported dates of emergence have ranged from 30 May through 8 June in Manitoba (Mitchener 1931), from 10 June through 17 June in Ontario (Morton 1948), and from 19 May to 29 June in Minnesota (Morse *et al.* 1984).

Morse and others (1984) used degree-days to forecast YHSS adult emergence. Using the last date of snow cover as a starting point, they determined that adult emergence required 343 degree-days, using a temperature threshold of 1.6°C (35°F). Degree-day accumulation was based on estimated soil temperatures at a 0.1 cm depth predicted from daily minimum and maximum air temperatures. Yearly differences between predicted and observed emergence dates ranged from 0 to 6 days. Unfortunately, determining the last date of snow cover is difficult in years when traces of snow linger.

Newly emerged females fly directly to host trees, often in an upwind direction. Bartelt and others (1982a) and Pointing (1957) speculated that a host-derived odor is involved in host-finding behavior though none has been isolated. Females land on a spruce tree and search for suitable current-year foliage. They saw slits into the bases of needles and deposit a single egg into each slit. Commonly, females lay most eggs on a single shoot, but occasionally they fly a short distance to oviposit on other nearby shoots. Ovipositing females rarely fly to other trees. Thus, the entire egg complement is usually laid on a single tree. Females normally live 3 to 14 days and apparently consume only water (Pointing 1957).

YHSS females preferentially oviposit on partially developed current-year shoots, during the period of active needle elongation. Pointing (1957) reported that in Ontario, YHSS eggs were found on shoots whose bud cap or scales covered 40 percent or less of the needles, or on shoots from which the scales had recently dropped. Eggs were not found on shoots with caps covering more than 60 percent of the new needles. In Minnesota, peak oviposition occurred when 80 percent of new shoots were just barely retaining the bud cap (Houseweart and Kulman 1976a). Pointing (1957) observed that YHSS females rarely succeeded in ovipositing on fully developed shoots. He speculated that needles that had diverged from the axis of developed shoots were too flexible to support YHSS females as they cut egg slits.

Mating is not required to initiate YHSS oviposition, although nonmated females produce only male offspring (Houseweart and Kulman 1976a). Males hover around host trees and scramble over foliage until they locate a female. Mating, as in other sawflies, is end-to-end with both individuals dorsal side up, and it lasts about 10 to 15 seconds (Bartelt *et al.* 1982a).

Ovipositing YHSS females show a marked preference for spruce growing in full sunlight. The positive response of YHSS to light was demonstrated when all light-competing vegetation within 1.5 m of host trees was removed in a 5-year-old white spruce stand overtopped by aspen. Defoliation by YHSS was six times greater on released trees than on overtopped controls (Morse and Kulman 1984b). Once a plantation or an open-grown natural stand reaches crown closure, YHSS susceptibility is greatly reduced. This preference for sunlight remains poorly understood.

The apparent preference of YHSS for light may arise from aspects of YHSS pheromone chemistry. Mating and ovipositing YHSS show a marked preference for spruce growing in full sunlight, and larval populations were consistently higher in the upper crown than in the lower crown (Houseweart and Kulman 1976b).

YHSS females produce a multicomponent sex pheromone to attract males (Bartelt *et al.* 1982a, Bartelt and Jones 1983). The major component of the female-produced sex pheromone is an aldehyde compound, (Z)-10-nonadecenal. This aldehyde is produced by oxidation of any of 10 (Z,Z)-9,19 dienes ranging from 28 to 37 carbons in length (Bartelt and Jones 1983). The oxidation reaction occurred readily only when virgin females were placed in full sunlight (Bartelt *et al.* 1982b, Bartelt and Jones 1983). The 10 dienes were located on wings, legs, heads, thoraces, and abdomens; they amounted to approximately 10 percent of the hydrocarbons in females but only 0.1 percent of the hydrocarbons in males (Bartelt *et al.* 1984).

A secondary alcohol-based pheromone, (Z)-5-tetradecen-1-ol, is used by males to locate virgin females at close range. The combination of the primary component and the secondary component was as attractive to males as were virgin females (Bartelt *et al.* 1983). Bartelt and others (1983) speculated that host odors and perhaps other secondary components were involved in the complete YHSS pheromone system. They found that mating occurred much more frequently when females were present on spruce foliage than on nonspruce foliage (Bartelt *et al.* 1982a).

The pheromone system of YHSS appears to be vastly different from that of diprionid sawflies, which do not use hydrocarbons. The YHSS pheromone system is more similar to that found among Diptera, where pheromonal activity is associated with unsaturated hydrocarbons (Bartelt *et al.* 1982b).

Effects of YHSS Defoliation....

Trees—Defoliation by YHSS (fig. 4) can significantly affect growth of white spruce trees. YHSS larval preference for current-year foliage results in loss of the most photosynthetically active tissue. In addition, YHSS defoliation occurs during spring needle expansion, when new needles function as major nutrient sinks (Kramer and Kozlowski 1979). Loss of new tissue can affect length and mass of current-year shoots and needles, as well as reduce the amount of photosynthate available for shoot growth the following year (Pointing 1957, Kulman 1971a). Trees sustaining heavy defoliation produced shorter shoots and short, closely spaced needles the year following defoliation (Kulman 1971a). Kulman (1971b) showed that even 1 year of moderate defoliation of white spruce substantially reduced shoot and terminal length, although between-tree variation was high. Terminal shoot length recovered after 1 year, but length of lateral shoots was still reduced 2 years after defoliation. Heavy defoliation in 2 or more consecutive years greatly reduces growth; terminal and lateral shoots were 20 to 60 percent shorter than shoots of undefoliated trees after 2 years of defoliation. Significant reductions in terminal growth were also observed in Minnesota, where regression analysis indicated that percentage defoliation and tree height accounted for 75 percent of the variation in terminal growth (Cook and Hastings 1976). Ford (1979) related YHSS populations to defoliation levels in a Minnesota white spruce plantation. Defoliation averaged 40 percent and was associated with a mean count of 512 larvae per tree. This level of defoliation caused 4 percent reduction in tree height growth and 57 percent reduction in lateral shoot length. Heavily defoliated trees produced smaller buds (Ford 1979), and bud flush tended to occur later than in lightly defoliated trees (Cook 1976). Severe defoliation can also lead to forked branches due to terminal bud mortality as well as attacks along the trunk by the whitespotted sawyer, *Monochamus scutellatus* (Say), a cerambycid beetle (Pointing 1957).

Figure 4.—*White spruce tree following severe defoliation by the yellowheaded spruce sawfly.*

Stands—Some tree mortality is typically observed after YHSS defoliation. Morse and Kulman (1984b) reported that 2.3 to 2.7 percent of white spruce died in Minnesota white spruce plantations defoliated by YHSS between 1974 and 1979. However, they also observed small areas where mortality was as high as 15 percent. Individual white spruce trees were observed to survive even 100 percent defoliation (Kulman 1971b), suggesting this species may be fairly tolerant of defoliation, at least under certain conditions.

Long-term effects of YHSS defoliation have not been examined. Defoliation of other conifers sometimes results in higher long-term stand productivity due to decreased competition among trees and possibly enhanced nutrient cycling (Mattson and Addy 1975; Wickman 1980, 1988; Haack and Byler 1993). However, defoliation of white spruce by YHSS generally occurs before canopy closure, when competition for light is presumably low. Defoliation by YHSS is unlikely, therefore, to increase long-term growth. Future researchers should consider establishing permanent plots to collect long-term data on response of both individual trees and stands to YHSS defoliation.

Host resistance—Clumped or spotty defoliation and heavily defoliated trees adjacent to undamaged trees (Cook 1976) suggested possible intraspecific differences in resistance to YHSS. Nienstaedt and Teich (1972) observed that YHSS defoliation rates among 28 white spruce seed sources in 1968 were significantly correlated with defoliation in 1970. They noted, however, that differences among seed sources were apparent only when infestations were light; no differences were observed in another plantation when the same seed sources were heavily defoliated. This observation suggested female YHSS may discriminate among provenances only at low populations or prior to heavy defoliation. As populations and defoliation increased, fewer suitable buds may be available, restricting any potential female discrimination. YHSS preference for specific provenances might relate to timing of bud burst (Cook *et al.* 1978). Bud burst among white spruce provenances may vary by up to 28 days (Nienstaedt and Teich 1972). However, Connor and others (1982) found no differences in either bud development or YHSS oviposition rates when adult YHSS were caged on trees from 25 white spruce seed sources. They noted, however, that caging sawflies did not allow adult females to demonstrate any potential oviposition preferences. Also, only three trees per seed source were tested, making it difficult to detect subtle seed source differences. They could not detect any differences among seed sources in survival of fourth and fifth instars; survival of early instars was not examined.

Nienstaedt and Teich (1972) suggested that components of YHSS resistance be identified for subsequent white spruce breeding and selection programs. Numerous genetically based traits exist that could potentially affect YHSS. Leaf cortical monoterpenes differed significantly among a rangewide provenance plantation of white spruce growing in Michigan (Wilkinson *et al.* 1971), but allelochemicals have not yet been related to YHSS success. Other morphological and growth-related traits, including needle color and stiffness, also differed among white spruce provenances (Nienstaedt and Teich 1972), but possible effects on YHSS are unknown.

Outbreaks....

It appears that outbreak populations of YHSS can be found somewhere within the range of spruce every year. Figure 5 illustrates the outbreak history of YHSS in Minnesota, Wisconsin, Michigan, and Ontario during the past few decades as reported in their respective annual pest reports (updated from Haack and Mattson 1993). Although no consistent reporting procedures were used among the three States and Ontario to estimate defoliation severity, these observations illustrate that outbreaks occur frequently and cause noticeable impacts. Most reports of YHSS defoliation have dealt with white spruce rather than black spruce, perhaps reflecting the greater market value for white spruce and its wider use in roadside plantings and as a Christmas tree. Morse and Kulman (1985), who worked in Minnesota, noted that local outbreaks generally lasted about 3 years.

YHSS defoliation was reported to be heavy or severe in at least one location in Ontario in 97 percent of the 34 annual forest pest reports observed (fig. 5). Similarly, YHSS defoliation was reported as high or severe in 60 percent of the 25 Minnesota reports, 23 percent of the 40 Wisconsin reports, and 19 percent of the 42 Michigan reports. This trend may reflect the

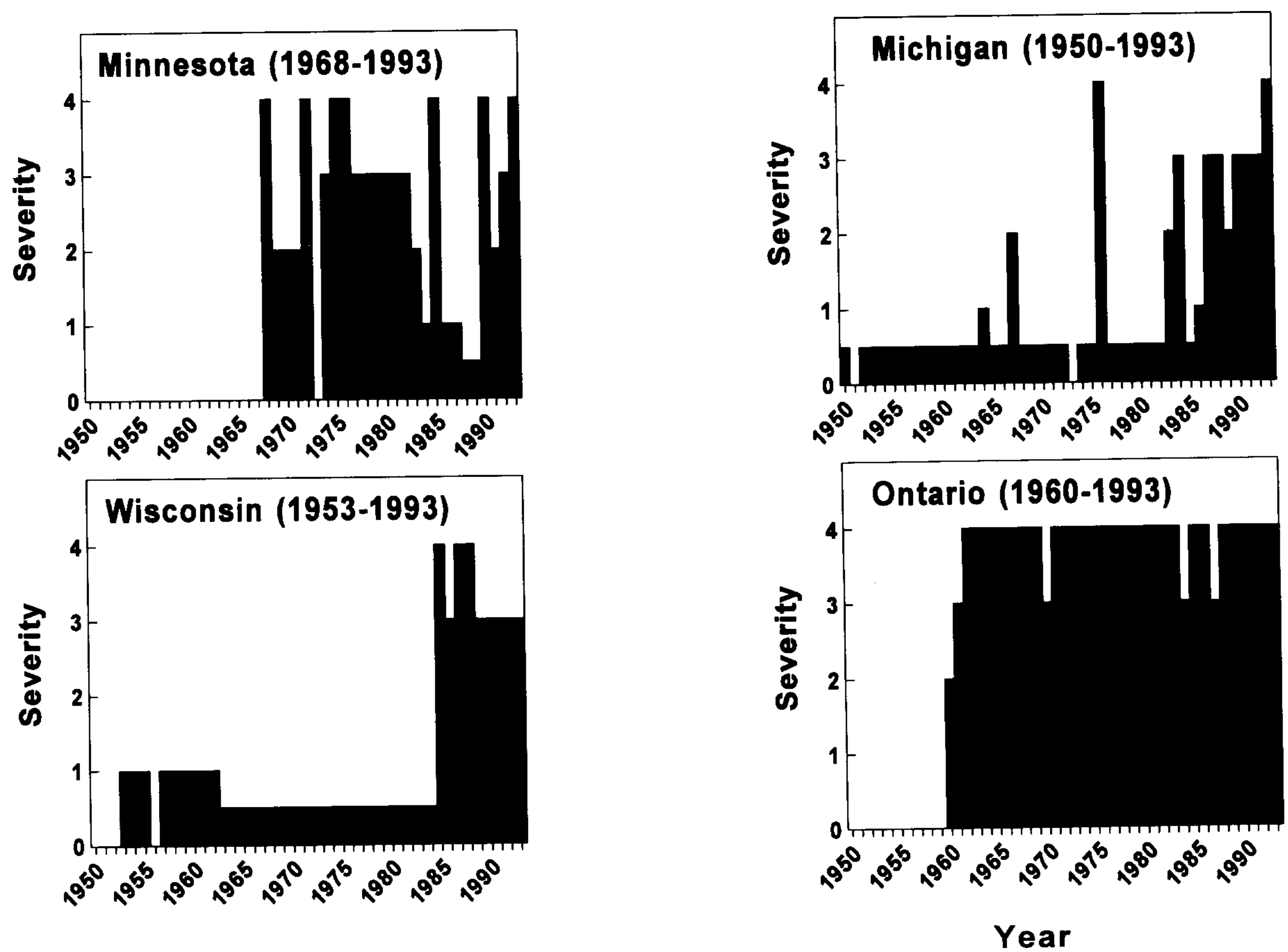

Figure 5.—*Outbreak history of yellowheaded spruce sawfly in Michigan, Minnesota, Wisconsin, and Ontario as reported in their respective annual pest reports. Data were available for the years 1968 to 1993 for Minnesota (25 years; missing 1973), 1953 to 1993 for Wisconsin (40 years; missing 1956), 1950 to 1993 for Michigan (42 years, missing 1951 and 1973), and 1960 to 1993 for Ontario (34 years). Defoliation severity values were assigned as follows: severe defoliation = 4, heavy = 3, medium = 2, low = 1, no YHSS defoliation reported = 0.5, or annual report not located for a particular year = 0. The most severe YHSS outbreak condition reported in each annual report was the value used to rank defoliation severity for that particular year and region. See details in Haack and Mattson (1993).*

acreage of forest land in each State or Province that is covered by spruce (table 2). For example, black and white spruce cover 41.8 percent of Ontario's 93 million acres of forested land (Ontario Ministry of Natural Resources 1987), 9.6 percent of Minnesota's 14.8 million acres (Miles and Chen 1992), 2.3 percent of Wisconsin's 14.8 million acres (Raile 1985), and 3.3 percent of Michigan's 18.6 million acres (Leatherberry 1994a, 1994b; Schmidt 1993, 1994).

Parasites, Predators, and Pathogens....

A 3-year life-table study of YHSS populations in Minnesota indicated that egg survival was high, 97 percent, as was survival of early instars (1 to 3), 73 percent. Survival decreased to 16 percent for later instars (4 to 6) (Houseweart and Kulman 1976a). Survival of cocoons was 44 percent. A survivorship curve for these YHSS populations resembled a Type I curve as described by Slobodkin (1962), where mortality of eggs and early instars (1 to 3) is minimal, but mortality of late instars increases rapidly (Houseweart and Kulman 1976a) (fig. 6). Similar survivorship curves have been reported for *Neodiprion* spp. sawflies (Lyons 1977). Type I survivorship curves are fairly unique since mortality rates for most insects are relatively constant (e.g., Type III curve).

Infertility, desiccation, and predation were probably responsible for YHSS egg mortality in the Minnesota life table study. Egg parasites were not observed, and their absence presumably contributed to high YHSS egg survival (Houseweart and Kulman 1976a). Pointing

Table 2.—*Estimated black spruce and white spruce area, number of live trees, and net volume at the time when various forest inventories were conducted in Minnesota, Wisconsin, and Michigan*

State	Spruce species	Year of inventory	Area	Thousands of live trees	Net volume	Source*
			Acres		*Thousands cubic feet*	
Minnesota	Black	1962	1,152,000	—	—	1
		1977	1,042,000	844,736	552,013	1, 4
		1990	1,322,000	1,039,448	745,825	4
	White	1962	57,300	—	—	1
		1977	79,200	63,944	183,887	1, 4
		1990	93,800	78,622	295,108	4
Wisconsin	Black	1968	235,900	203,992	92,206	5, 9
		1983	273,000	262,568	123,955	5
	White	1968	75,200	53,573	81,855	5, 9
		1983	61,400	75,451	199,628	5
Michigan	Black	1966	421,000	—	257,000	6
		1980	520,600	362,257	343,500	6
		1993	460,800	328,395	363,058	2, 3, 7, 8
	White	1966	146,000	—	272,500	6
		1980	100,100	130,353	396,700	6
		1993	145,200	144,760	492,458	2, 3, 7, 8

**Source: 1 = Jakes (1980), 2 = Leatherberry (1994a), 3 = Leatherberry (1994b), 4 = Miles and Chen (1992), 5 = Raile (1985), 6 = Raile and Smith (1983), 7 = Schmidt (1993), 8 = Schmidt (1994), and 9 = Spencer and Thorne (1972).*

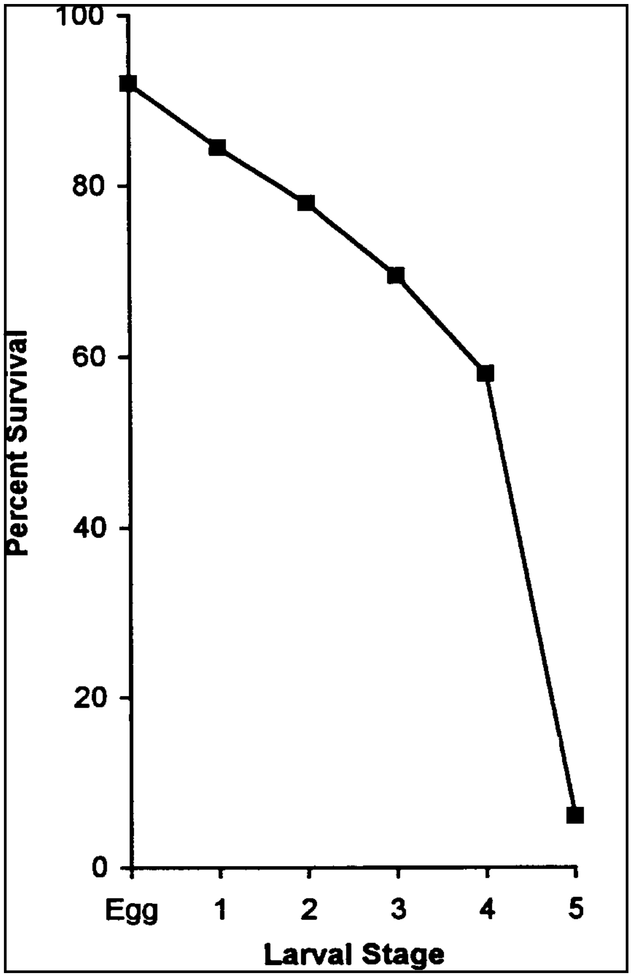

Figure 6.—*A survivorship curve for yellow-headed spruce sawfly taken from Houseweart and Kulman 1976a.*

(1957) also reported finding no egg parasites after a survey in Ontario. The only recorded egg parasites of YHSS were found in Maine and were *Trichogramma minutum* Riley (Nash 1939, Duda 1953), and *Tetrastichus* n. sp. (Duda 1953). Duda reported that in one case, about a third of the YHSS eggs were parasitized by *Tetrastichus*. A survey in 1976 failed to relocate either of these egg parasites in Maine or Nova Scotia (Thompson and Kulman 1980). Wilson (1971) mentions *T. minutum* as a common egg parasite, though he did not provide location data for these observations.

In a life-table study in Minnesota, the impact of parasites, predators, or other agents was much greater among instars 4 to 6 than among instars 1 to 3 (Houseweart and Kulman 1976b). No other data are available to confirm this trend, although most of the reported parasites of YHSS have been reared from late-instars and cocoons. In North America, 32 Hymenoptera and 9 Diptera species have been reported to parasitize YHSS (table 3). Larval parasitism rates averaged 12 percent in Maine, 47 percent in Nova Scotia (Thompson and Kulman 1980), and 1.5 to 21 percent in Minnesota (Houseweart and Kulman 1976b, Valovage and Kulman 1986). Of these 41 parasite species, apparently only a few have a significant impact on YHSS populations. In Minnesota, the tachinid fly *Bessa harveyi* is the dominant larval parasite. *Bessa harveyi* is a polyphagous parasite that concentrates on the predominant host in its range (Valovage 1979; Valovage and Kulman 1983, 1986). In Minnesota, YHSS was a second preference behind the larch sawfly, *Pristophora erichsonii* (Htg.) (Turnock and Melvin 1963). Another larval parasite, the ichneumonid wasp *Syndipnus rubiginosus* was also common in Minnesota (Rau 1976). The icneumonids *Rhorus bartelti* and *S. rubiginosus* were the most common parasites of YHSS in Maine (Thompson and Kulman 1980, Luhman 1981). In Nova Scotia, the ichneumonid *Aderaeon bedardi* and *B. harveyi* were prevalent (Thompson and Kulman 1980). Other ichneumonids in the genus *Rhorus* were reported as common YHSS larval parasites in southern Ontario (Raizenne 1957) and in Saskatchewan (Bradley 1951).

Cocoon parasitism may also be important. The ichneumonid wasp *Endasys pubescens* was responsible for 15 to 35 percent of the parasitism occurring at three sites in Minnesota from 1972 to 1974 (Rau 1976). Rau noted that this species was also common in Manitoba and Ontario.

Although birds, insects, and small mammals are known to feed on larvae, no quantitative estimates have been made of their overall impact on YHSS populations. Houseweart and Kulman (1976b) suggested that predation of cocoons was more important than predation of larvae. In a 1973-1975 study, 67 percent of overwintering cocoons were killed by predators: 28 percent by insects and 39 percent by small mammals. Primary insect predators were elatarid and carabid beetle larvae (Schoenfelder *et al.* 1978). The most common small mammal predators found in areas with YHSS were the masked shrew, *Sorex cinereus* Kerr, and the short-tailed shrew, *Blarina brevicauda* (Say) (Houseweart and Kulman 1976b).

Table 3.—*Reported parasites of the yellowheaded spruce sawfly*[1]

Diptera
- Phoridae
  - *Rhyncophoromyia conica* (Malloch)
  - *Megaselia pulicaria* (Fallen)
- Tachinidae
  - *Bessa harveyi* (Townsend)
  - *Euphorocera* sp.
  - *Diplostichus lophyri* (Townsend)
  - *Palexorista bohemica* Mesnil
  - *Zygobothria gilva* Hart
  - *Spathimeigenia aurifrons* Curran
  - *Spathimeigenia spinigera* Townsend

Hymenoptera
- Bethylidae
  - two undetermined species
- Braconidae
  - *Ichneutes pikonematis* Mason
  - *Icheutidae proteroptoides* Viereck
- Chalcidoidea
  - *Brachymeria compsilurae* (Crawford)
- Eulophidae
  - *Tetrastichus* sp.
- Ichneumonidae
  - *Adelognathus* sp.
  - *Aderaeon bedardi* (Provancher)
  - *Ctenochira pikonematis* Townes & Townes
  - *Ctenochira quebecensis* (Provancher)
  - *Cubocephalus* sp.
  - *Endasys pubescens* (Provancher)
  - *Endasys subclavatus* (Say)
  - *Hyperbatus marmoratus* Luhman
  - *Lamachus angularius* (Davis)
  - *Excavarus velox* (Walley)
  - *Hypamblys* sp.
  - *Lamachus lophyri* (Ashmead)
  - *Lamachus ruficoxalis* (Cushman)
  - *Lethades* sp.
  - *Mastrus laplantei* Mason
  - *Mesoleius* sp.
  - *Pleolophus indistinctus* (Provancher)
  - *Rhorus bartelti* Luhman
  - *Rhorus gaspesianulus* Luhman
  - *Rhorus nervierxii* (Provancher)
  - *Smicroplectrus incompletus* Walley[2]
  - *Syndipnus gaspesianus* (Provancher)
  - *Syndipnus rubiginosus* Walley
- Pteromalidae
  - *Tritneptis diprionis* Gahan
  - *Tritneptis klygii* (Ratzeburg)
- Trichogrammatidae
  - *Trichogramma minutum* (Riley)

[1]Parasite information taken from Houseweart *et al.* (1984).

[2]Recorded from *Pikonema* sp.

Effects of pathogens on YHSS are largely unknown. An unidentified "wilt" disease may have killed a large number of YHSS larvae in Maine in 1947 (Duda 1953), but the causal organism was not identified. YHSS larvae were tested against one strain of *Bacillus cereus*. In that test, 100 larvae were fed the Mu-3055 strain. Of these, 16 larvae died, whereas the control treatment had no mortality. It was concluded that the *B. cereus* strain tested had relatively low pathogenicity against YHSS (Heimpel 1961).

Environmental Factors....

Environmental factors affect YHSS host preference and the ability of trees to tolerate defoliation. Studies with other sawfly species have suggested a link between poor growing conditions or environmental stress and sawfly success (McLeod 1970, Knerer and Atwood 1973, Smirnoff and Bernier 1973, Averill *et al.* 1982, Wagner and Evans 1985). Morse and Kulman (1986) observed that tree mortality attributed to YHSS defoliation exhibited a clumped distribution in Minnesota white spruce plantations. Clumps or pockets of mortality were most common in open areas on steep, south-facing slopes, where trees were smaller. Ovipositional preference of YHSS for sunny locations with resultant higher rates of defoliation and, presumably, lower tree vigor due to water stress on the steep slopes, likely contributed to the observed mortality patterns.

Another Minnesota study conducted during an exceptionally wet summer indicated that excessive moisture could also reduce tree resistance to YHSS defoliation (Cook 1976, Cook and Hastings 1976). More defoliation occurred on poorly drained soils with high silt and clay content than on sites with sandier soils. The authors noted that soil moisture in August was 23 to 35 percent higher in areas of heavy defoliation than in areas of light defoliation. However, soil moisture levels between heavily and lightly defoliated areas differed by only 5 to 7 percent in two plantations and by 20 percent in the third plantation during the time of larval feeding in June and July. Thus, the large difference in August soil moisture measurements may have been a result of reduced transpiration and water uptake by heavily defoliated trees.

Host Availability....

YHSS has been a notorious problem in plantations, but rarely causes damage in naturally regenerated spruce stands. The reasons for this are not well understood, though forest monocultures have long been recognized as likely areas of pest concern (Graham 1925). Bartelt and others (1982a) and Pointing (1957) speculated that host odors played a role in female oviposition behavior. Abundance of non-host trees in a naturally regenerated stand may impact the ability of females to locate suitable hosts. In the Lake States, white spruce rarely occurs naturally in pure stands, normally making up approximately 30 percent of a total stand (Rauscher 1984). Haack and Mattson (1993) used circumstantial evidence to speculate that the large reliance on pine in reforestation efforts in the Lake States led to an increase in outbreaks of pine-feeding diprionid sawflies. It seems probable that a similar relationship could exist between increased planting of white spruce in the Great Lakes region and increased YHSS outbreak frequency (fig. 5). The many spruce plantations established throughout the Great Lake States in the 1930's and 1960's may have contributed to more frequent YHSS outbreaks in this region.

Host Phenology....

Phenology and effects of previous defoliation can also affect YHSS population dynamics. Since synchrony of YHSS adult emergence and new shoot expansion affects oviposition success, any change in the timing of bud flush or bud size could have implications for subsequent YHSS generations. Cook (1976) noted that oviposition was more common on smaller, tighter buds produced by trees that had sustained moderate to heavy defoliation the previous year. However, these trees also tended to flush later than trees not previously defoliated. Pointing (1957) speculated that delayed bud break caused by prior-year defoliation may enable trees to recover from attack. These trees would be less likely to be infested the following year if bud burst was significantly delayed relative to YHSS adult emergence.

Host Nutrient Availability....

Several projects addressed relationships among soil nutrient availability, YHSS success, and defoliation in Minnesota white spruce plantations. One repeated observation was that YHSS defoliation tended to be higher when availability of soil nutrients, particularly nitrogen (N), was low. Cook (1976) reported that low soil N was associated with severe defoliation in Minnesota. An unrelated study found that heavily fertilized white spruce sustained lighter defoliation than unfertilized trees (Popp *et al.* 1986). Windrowing, commonly used for site preparation of spruce plantations, can concentrate organic matter in windrows, affecting availability of nutrients on the site (Morris *et al.* 1983). Morse and Kulman (1984b) found that trees growing near windrows were larger and sustained less defoliation than trees growing further from windrows. If low N sites produce trees with low N foliage, then the observations that severe defoliation is common on low N sites could reflect increased feeding by YHSS larvae to compensate for low foliar N levels (Mattson and Scriber 1987, Scriber and Slansky 1981).

However, YHSS success may be reduced if foliar N levels are too high. When white spruce trees were fertilized with NH_4NO_3 at 0, 224, and 448 kg/ha, foliar analysis indicated that a transition from N deficiency to sufficiency occurred at the intermediate fertilization level (Popp 1982, Popp *et al*. 1986). Ovipositing sawflies did not discriminate among the three fertilization regimes. Larval survival, however, was greatest on trees treated with the intermediate fertilization regime. Survival was lower when sawflies fed on trees with very high or very low foliar N levels. The authors speculated that the transition from deficiency to sufficiency provided the optimal N levels for feeding larvae. Higher N levels may have disrupted ratios among N and other nutrients (House 1969, Ingestadt 1960), altered amino acid levels and availability of N to sawflies (Cockfield 1988, Durzan and Steward 1967), or changed allelochemic levels (McCullough and Kulman 1991, Nienstaedt and Teich 1972).

Prevention and Control Tactics

Tactics to prevent and control YHSS have been proposed or have been used to reduce YHSS damage. Prevention, especially through the use of silvicultural practices, should be stressed for long-term YHSS control.

Biological Control....

No large-scale biological control programs have been attempted for YHSS management. Houseweart and Kulman (1976a) recommended targeting YHSS eggs and early larval stages for introduction of biocontrol agents, because of the high survival of these stages in a life-table study. Late YHSS larval stages and cocoons were well controlled by existing parasites and predators.

Unfortunately, few parasites have been identified that would impact either the egg stage or early larval stage. As mentioned earlier, the two identified egg parasites are *Trichogramma minutum* and *Tetrastichus* n. sp. No collections of *Tetrastichus* n. sp. from YHSS eggs have been made since that reported by Duda (1953), despite searches in the 1970's (Thompson and Kulman 1980). *Trichogramma minutum* is a generalized egg parasite of many species, but none of the extensive Minnesota studies have recovered it as an egg parasite of YHSS. Therefore, although Wilson (1971) considered *T. minutum* as a common egg parasite of YHSS, its generalist nature and infrequent collection record from YHSS eggs suggest that it has little potential as a control agent for YHSS.

Mechanical Control....

Handpicking YHSS larvae from foliage may be a viable control alternative for ornamental trees or similar situations. Kusch and Cerezke (1991) suggest that young larvae may be washed off the foliage with a strong jet of water. They also suggest that ornamental spruce that have been severely attacked for 1 or more years be pruned to encourage new growth and to reshape the crown.

Silvicultural Control....

Several studies indicate that YHSS impacts can be minimized by not establishing new stands or plantations on sites susceptible to YHSS outbreaks. South-facing slopes (Morse and Kulman 1984a) and sites subject to poor drainage or with heavy, clayey soils (Cook 1976) should be avoided. Avoiding such sites will also reduce white spruce plantation failure due to drought, frost, flooding, and exposure (Stiell 1958). Rauscher (1984) reported that these sites were low in productivity. Further, Harding (1982) found that white spruce plantations in Minnesota that grew on slopes greater than 10 percent tended to be low in productivity.

Site preparation should be monitored closely to minimize loss of soil organic matter and nutrients from the site. Removal of organic matter through windrowing may contribute to tree mortality in the presence of YHSS defoliation (Morse and Kulman 1984a). Site disturbance also may reduce populations of small mammals that play a major role in YHSS population dynamics through cocoon predation.

Planting density should be carefully considered. Because of shading, dense stands may be less susceptible to YHSS outbreaks and may provide greater stocking in the event of defoliation-induced mortality. Overstocking, however, may result in stagnant growth or increased competition, potentially reducing the ability of trees to recover from stress.

Foresters can take advantage of the YHSS affinity for light when managing young spruce stands. Morse and Kulman (1984b) suggested maintaining a light overstory over young white spruce stands to reduce YHSS defoliation. Thinning or release of white spruce stands should be delayed until trees are about 10 feet tall (Anonymous 1992). This may be most appropriate on sites with south-facing slopes, which are likely to support high YHSS populations. Rauscher (1984) noted that a nurse-canopy of aspen or white birch that reduced full sunlight by 25 to 30 percent would allow maximum height growth of white spruce seedlings and would protect them from spring frost damage as well. Mixing fast-growing shrubs with roadside spruce plantings may also provide sufficient shade to reduce YHSS susceptibility for several years.

Insecticides....

Application of insecticides to control YHSS on ornamentals, Christmas trees, shelterbelts

(Rose and Lindquist 1985) and forest plantations (Anonymous 1981) has been necessary in some cases. Many insecticides will control YHSS if applied at the proper time. Rose and Lindquist (1985) recommended that on white spruce, insecticides be applied about 10 days after bud caps have been shed. The Minnesota Department of Natural Resources recommended spraying as soon as larvae are found (Anonymous 1992). DeGroot (1995) summarized experimental field trials with chemical insecticides for control of YHSS, conducted in Canada from 1972 to 1979. DeGroot noted that in comparison with other forest insect pests, control of YHSS is not difficult. Table 4 identifies products that have been historically registered or used for control of YHSS.

Table 4.—*Historical insecticide recommendations for control of YHSS*

Insecticide	**Reference**
Arsenate of lime	Mitchener 1931
Lead arsenate Nicotine sulfate	Nash 1939
DDT Lead arsenate Benzene hexachloride Rotenone or pyrethrum dusts	Peterson 1950, Shenefelt and Benjamin 1955
DDT Benzene hexachloride	Wilson 1962
Dimilin	Valovage and Kulman 1977
Sevin	Anonymous 1981
Carbaryl, malathion Acephate, methoxychlor	Anonymous 1992
Carbaryl, diazinon Cyfluthrin, malathion Chlorpyrifos, acephate	Hahn *et al.* 1992

Scouting and Surveillance

Young spruce stands and open-grown spruce stands of any age should be regularly monitored for YHSS. Once crown closure is achieved, susceptibility drops significantly and close surveillance is not necessary. In our experience, defoliation typically occurs in similar locations within stands year after year. Regular scouting of such areas should increase the likelihood of identifying YHSS before damage occurs. Both **risk** rating and **hazard** rating are important components of pest surveys. Risk rating is used to identify where defoliation is likely to occur. Hazard rating is used to identify where damage is likely to occur after defoliation. In addition, pheromone traps can be used to monitor population fluctuations.

Stand Risk and Hazard Rating....

Identifying stands susceptible to YHSS outbreaks (high risk) or vulnerable to damage if outbreaks occur (high hazard) allows managers to prioritize scouting and control efforts. Risk and hazard rating could also help managers avoid establishing plantations on sites likely to be defoliated and damaged.

A risk-rating model was developed and validated for white spruce plantations in Minnesota (Morse and Kulman 1986). All the variables used in this risk rating system were topographical and are readily available. The model, which incorporated slope and aspect, correctly classified stands into light or heavy defoliation categories on 70 out of 100 plots used for validation. Stands on steep, south-facing slopes were most likely to sustain high defoliation. The final risk rating model was:

$$P = [1 + \exp -\{-0.73 + 0.075 \text{ steepness} + 0.46 \sin(x) - \cos(x)\}]^{-1}$$

where P was the probability of defoliation. Steepness was measured in seven 5 percent categories with an eighth category for slopes greater than 40 percent. Slope aspect (x) was a circular variable, measured in degrees from north. It was transformed to sine(x) (north vs. south) or cosine(x) (east vs. west).

Cook (1976) attempted to relate physiographic traits to stand vulnerability using such variables as percentage clay at 30 cm below soil line, percentage sand at 60 cm, thickness of B2+B3 horizons, and soil nitrogen levels. His results indicated that stands growing on heavy, poorly drained soils were most likely to sustain heaviest defoliation. Direct measurement of the variables used in Cook's model, however, is likely to be impractical in most cases.

Detection Survey....

The purpose of a detection survey is to learn whether YHSS or its damage is present at any particular time or place, as well as to map its range. A detection survey for YHSS can be done on the ground or from a low-flying aircraft. Ground surveys can locate either feeding larvae or the defoliation that results from YHSS feeding. Larval presence is seasonal. Defoliation, on the other hand, is present over a long period of time and is very characteristic. YHSS defoliation is concentrated in the top third to half of the crowns of scattered trees or in clumps of trees, and both new foliage and old foliage are often consumed. In contrast, eastern spruce budworm, *Choristoneura fumiferana* L. (Lepidoptera: Tortricidae), feeding is usually found on new foliage only, and occurs over most trees in a stand. In addition, spruce budworm larvae produce silk webbing that remains on twigs and foliage until the winter following defoliation, whereas YHSS larvae do not produce any silk webbing.

Aerial surveys to detect defoliation may be less effective for YHSS than for other defoliators. YHSS defoliation and tree mortality within plantations is often spotty and may go unnoticed. Morse and Kulman (1984) used small-format, 35-mm color-infrared and color film at a scale of 1:9600 to assess mortality in 11- to 12-year-old white spruce plantations in Minnesota. Results indicated that photos were accurate when used to estimate numbers of live spruce. However, the aerial photos were less accurate when used to identify dead spruce, because of poor contrast with ground cover. Photography was taken in northern Minnesota in mid-May when ground vegetation was brown in contrast with the green of living spruce trees. The authors did not think the color infrared film increased accuracy of mortality estimates over color film.

Ground surveys would be required with all aerial surveys to confirm that YHSS was the responsible agent because other defoliators or tree-killing agents can cause similar damage.

Population Evaluation Survey....

Evaluation surveys are used to determine the current insect population level or the actual or potential injury from a given insect population. These surveys often require specific sampling procedures and correct timing. Population evaluation surveys can be used to monitor population trends or to make decisions about possible management options.

Pheromone trapping may be useful in some areas to monitor YHSS population trends, an important component when determining the need for control. Pheromone trap catches were examined by Morse and Kulman (1985), who monitored YHSS populations in northern Minnesota. A population trend index I was used to signify whether populations were building ($I > 1$) or declining ($I < 1$). Unfortunately, YHSS trap catches alone were not directly related to population size, trend, or defoliation. However, combining trap catch data for both YHSS and a major YHSS hymenopteran parasite, *Syndipnus rubiginosus*, whose sex pheromone had also been identified (Eller 1982, Eller *et al.* 1984), resulted in significant correlations with subsequent defoliation levels. Fewer than one *S. rubiginosus* per trap was caught during the pre-outbreak phase compared to an average of 28 parasites per trap in the post-outbreak phase.

Morse and Kulman (1985) developed a model using pheromone trap catch of YHSS sawflies (S), parasites (P), and their interaction term ($S*P$), as well as tree height (Ht), to significantly predict the defoliation trend (I) in subsequent years. The model was:

$$\log(I) = 1.36 - 0.17\log(S) - 0.25\log(P) + 0.13\log(S*P) - 0.3\log(Ht)$$

They concluded that if damage had been observed in previous years, and the trend index (I) was > 1, direct control should be considered. However, a trend index < 1 indicated that a natural population reduction was likely to occur and no direct control was required. Morse and Kulman (1986) suggested pheromone trapping should be concentrated on high-hazard areas or sunny locations where ovipositional activity was expected. They also noted that the model was applicable only to areas where *S. rubiginosus* was an important parasite of YHSS.

Degree-day models are often used to improve timing of insect survey or control efforts, since phenological development varies among years. Morse and others (1984) developed a degree-day model to forecast emergence of adult YHSS. However, problems with determining a consistent starting point for accumulation of degree-days make this model difficult to implement. More research to link adult emergence with conventional degree-day accumulations (e.g., base 50^{o} F) could provide a useful tool for prediction of adult activity and oviposition.

Surveys of YHSS egg or early larval populations can allow managers to implement control treatments if severe defoliation is expected or predicted. However, no sampling scheme has been developed for YHSS eggs or early larvae that could be implemented in field operations. One model was used by Houseweart and others (1974) to predict the numbers of eggs and first-instar larvae per tree using tree height and counts of these life stages on a sample of shoots. This model involved two regression equations: one that estimated number of eggs or larvae per branch, and the other that estimated number of branches per tree. Both regressions were used together to obtain an estimate of the number of insects per tree. This model was used to develop YHSS life-tables and is probably not practical for field surveys.

Management of YHSS

Many aspects of YHSS life history have been studied intensively, including feeding and ovipositional preferences, chemical ecology, and biological control. Although chemical control may be appropriate in some cases, we can apply life history information to anticipate and silviculturally minimize YHSS impacts. Our conclusions and recommendations are aimed primarily at white spruce stands in the Great Lakes region, where most research has been conducted. However, these recommendations should be generally appropriate for other regions and spruce species where YHSS problems exist.

Site evaluation—YHSS management begins with estimating the risk of buildup by the sawfly on a particular site. Potential impacts of YHSS can be minimized by establishing new stands on appropriate sites. The available hazard rating system should be used to determine the likelihood of defoliation and damage.

Further, insect problems are typically more frequent and more severe when trees occur on sites not suited for spruce. Selecting appropriate sites for growing spruce can be difficult. However, ecological classification systems, such as the habitat type system developed for Wisconsin (Kotar *et al.* 1988), may provide an excellent tool for locating sites where spruce are well adapted. Resource managers should become aware of regional ecological classification systems and integrate them into forest pest management activities whenever possible.

Management guideline No. 1: Do not plant white spruce on steep south-facing slopes or on poorly drained sites where the risk of YHSS damage is high.

Management guideline No. 2: Grow spruce on ecologically appropriate sites.

Competing vegetation—White spruce are generally considered tolerant of overhead shade. Therefore, forest managers can take advantage of shade to reduce YHSS defoliation. For example, Rauscher (1984) found that a nurse-canopy of aspen or white birch, which reduces full sunlight by 25 to 30 percent, permits maximum height growth of young spruce while protecting them against spring frost damage.

Management guideline No. 3: Delay release of established white spruce stands until trees are 10 to 12 feet tall, at which point they are less susceptible to YHSS defoliation. In some stands, use a light overstory of aspen or other species until trees outgrow their susceptibility to YHSS. Maintaining an overstory would be more important on high-hazard sites such as south-facing slopes.

Management guideline No. 4: Plant fast-growing shrubs with roadside spruce plantings for several years to provide shade and reduce susceptibility to YHSS.

Soil nutrients—The relationship between host nutrient levels and YHSS performance is not well understood. However, trees growing on poor sites, such as those with little organic matter, are more likely to sustain significant damage if defoliated.

Management guideline No. 5: Reduce windrowing and other site preparation practices to minimize the removal of organic matter and top soil from planting sites.

Natural enemies—Certain predators and parasites help maintain YHSS populations at low levels. Many management practices can either encourage or discourage predators and parasite abundance. Small mammal predators would benefit from hiding places such as an abundance of large woody material on the ground. Many adult parasites would benefit from nectar sources, such as flowering plants. A diverse ecosystem with spruce as a component would likely provide for many of the special needs of parasites and predators.

Management guideline No. 6: Discourage site disturbance, especially windrowing, when establishing spruce plantings. Allow some woody material to remain on the site to provide habitat for predators such as small mammals and insects.

Management guideline No. 7: Encourage white spruce as a component of stands rather than as a single species plantation.

Direct control—Insecticidal control of YHSS can be selectively used in forest plantations.

However, reported tree mortality levels of only 2 to 3 percent are likely to be acceptable in most white spruce plantations. Pockets of mortality as high as 15 percent may occur on high-hazard sites. In these areas, and where growth loss is a concern, direct control measures using insecticides could be used.

YHSS may be a more notable concern in Christmas tree plantations, and on ornamental, roadside, and shelterbelt trees. Frequently, trees in these situations may be exposed to full sunlight for many years, increasing the likelihood of YHSS infestations. This, combined with the inherent high value of these trees, may justify direct control measures. Insecticides should be applied to early instar larvae, before defoliation becomes significant. Regular scouting and monitoring should be done to detect YHSS populations before significant damage occurs.

Management guideline No. 8: Carefully consider costs and benefits of using insecticides to control YHSS.

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Pesticide Precautionary Statement....

Pesticides used improperly can be injurious to humans, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed them thoroughly. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

Katovich, Steven A.; McCullough, Deborah G.; Haack, Robert A.
1995. **Yellowheaded spruce sawfly—its ecology and management.** Gen. Tech. Rep. NC-179. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 24 p.

Presents the biology and ecology of the yellowheaded spruce sawfly, and provides survey techniques and management strategies. In addition, it provides information on identification, classification, host range, and the historical records of outbreaks in the Lake States.

KEY WORDS: Yellowheaded spruce sawfly, *Pikonema alaskensis*, pest management, spruce, prevention, risk-rating, hazard rating, sampling, survey, spruce silviculture.