CHAPTER 21

Biological Control of Ambermarked Birch Leafminer

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NON-TECHNICAL SUMMARY

The ambermarked birch leafminer (AMBLM), *Profenusa thomsoni* (Hymenoptera: Tenthredinidae), is a leaf-mining sawfly native to Eurasia, ranging from the United Kingdom to Turkey and Japan and invasive in North America. This leafminer was accidentally introduced into the eastern United States in about 1923 and subsequently spread to midwestern states and Canadian provinces. Reaching Alaska around 1996, infestations peaked at over 140,000 acres (56,600 ha) and spanned from Haines to Fairbanks. The most severe damage was found throughout the Anchorage area and other urban centers of the state such as Fairbanks and Soldotna. The damage caused by AMBLM is mostly aesthetic, but recent analyses show that it appears to also have slowed the growth rate of Alaska white birch trees, *Betula neoalaskana*, in the area. As a result, it is suspected that the loss of leaf area to leaf mining by AMBLM can affect tree growth, given the short growing season in Alaska.

To control the spread and damage from AMBLM, a biological control project was started in 2003, and the parasitoid wasp *Lathrolestes thomsoni* (Hymenoptera: Ichneumonidae) was selected for release. Parasitized leafminer larvae were collected from the provinces of Northwest Territories and Alberta in Canada and moved to Alaska where adult parasitoids were reared for release. From 2004 to 2008, 3636 adults of *L. thomsoni* were released in Alaska white birch stands in Anchorage, Soldotna, and Fairbanks, Alaska. As of 2011 when the control program ended, this parasitoid had established at most release sites.

Coinciding with the release and establishment of *L. thomsoni* in Alaska in 2006, permanent research plots were established to measure the density of AMBLM and determine the effectiveness of the biological control program. The percentage of leaves mined was determined annually at 20 research sites from 2006 to 2011 to monitor changes in pest density. By 2011, the percentage of leaves mined had declined from over 70% in 2006 to just 19%. Post-project sampling done in 2019 showed that the percentage of leaves mined had decreased further to around 8%.

Two additional ichneumonid parasitoids, adventive or perhaps native, were also discovered attacking AMBLM during the biological control project. These parasitoids, *Lathrolestes soperi* and *Aptesis segnis*, were found to have caused significant levels of mortality to AMBLM populations (27% and 14% mortality, respectively) in 2011. A follow-up survey in 2019 compared the relative abundance of the two *Lathrolestes*

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species that parasitize larvae in leaf mines. That study found that the combined parasitism by the two *Lathrolestes* species was 70%, of which two thirds was caused by the introduced agent *L. thomsoni*. While *A. segnis*, a soil-dwelling ectoparasitoid, was not resampled in 2019, it also likely contributed additional mortality to the pest population.

HISTORY OF INVASION AND NATURE OF PROBLEM

The Species Invasion

Figure 1. Ambermarked birch leafminer, *Profenusa thomsoni*, female ovipositing on a white birch leaf. (US Forest Service)

The ambermarked birch leafminer (AMBLM; **Fig. 1**), *Profenusa thomsoni* (Hymenoptera: Tenthredinidae), invaded North America at the beginning of the 20th century and was first reported in the eastern United States in 1923 (Ross, 1951; MacQuarrie, 2008) where it never became a high-density pest. In eastern North America, this sawfly occurs in the United States from New England to the Great Lake States and in Canada from the Maritimes to Manitoba. In western North America, this leafminer was first reported in Alberta, which it invaded before 1970 (Digweed, 1995) and where it reached high densities in the early 1990s (Digweed, 1995). From Alberta, the leafminer spread north and west in Canada. By 1991, AMBLM was first detected in Alaska in the town of Haines; however, the pest was not correctly identified until 1996 when many birch trees showed symptoms of damage in the Anchorage bowl region (Snyder et al., 2007). Surveys for this pest's damage in Alaska were done from 2004 to 2006 (Snyder et al., 2007) and showed that AMBLM was widespread in southcentral Alaska, as well as in the Fairbanks area. Aerial flight surveys in 2003 estimated that AMBLM damage affected over 32,000 acres (12,140 ha) in the Anchorage bowl and extended into the Matanuska-Susitna Valley (Wittwer, 2004; Snyder et al., 2007). Surveys conducted through 2006 found that AMBLM was present in >20% of the surveyed area. Due the geographic isolation in Alaska and limited transportation corridors, it was initially thought that there would be some protection from the spread of invasive species. However, the spread of AMBLM in Alaska suggested that there was a strong association of human population centers and major travel routes with the establishment of the leafminer (Snyder et al., 2007). Moreover, the speed at which the pest moved throughout the state, and the concentration of damage in the Anchorage bowl, made this a pest of primary concern for the USDA Forest Service (**Fig. 2**).

Nature of the Problem

The ambermarked birch leafminer is a serious defoliator of several species of birch (*Betula* spp.) and is a species of primary concern in the urban areas of Alaska where birch trees are dominant. The immediate impact of leaf mining of birch trees is aesthetic. Presently, there have been no studies on the long-term effect of leaf mining on the health and growth of birch, but in the northern latitude of Alaska where the growing season is short, it is likely to slow the growth of the tree (MacQuarrie, 2008; Van Driesche et al., unpub. data.). Additionally, it is suspected that severe defoliation could increase tree susceptibility to secondary infections (Hoch et al., 2000; Snyder et al., 2007).

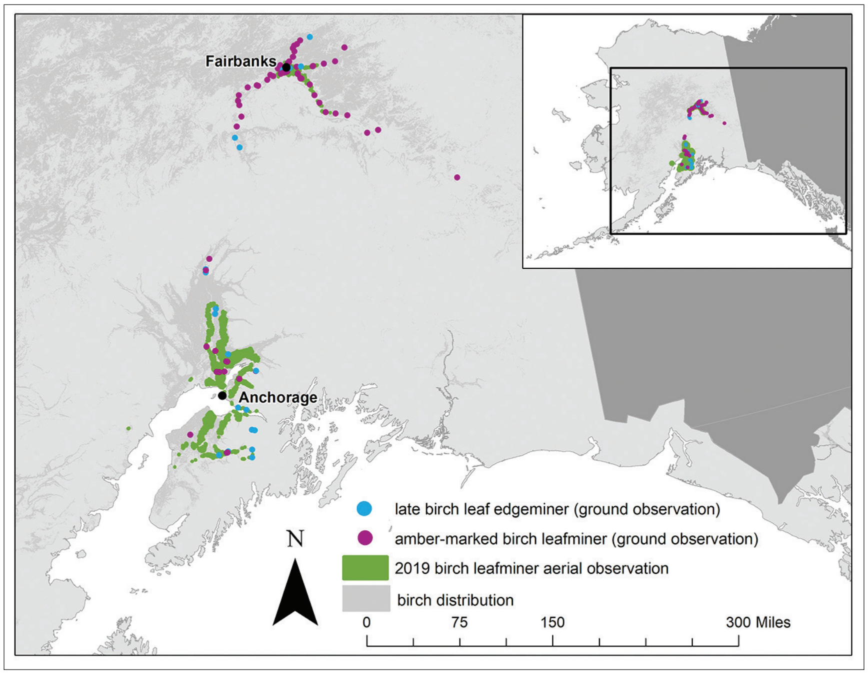

Figure 2. Map depicting the area and extent of ambermarked birch leafminer, *Profenusa thomsoni*, presence and defoliation in Alaska. (US Forst Service)

WHY CONTROL THIS INVASIVE SPECIES?

The invasion of AMBLM led to widespread browning (**Fig. 3**), due to leaf mines (areas of damage caused by larval feeding between the upper and lower epidermis of their host leaf) that occupied much of the leaf of Alaska white birch in urban and forested areas of the Anchorage bowl and parts of the interior. This mining, while primarily aesthetic, was suggested to have led to an increase in pesticide use, particularly in the Anchorage area, but records of changes in use levels are not available. While the initial goal of the biological control program was to reduce the use of pesticides and improve the trees' appearance, it was speculated that due to the short growing season in the Anchorage bowl, any type of leaf damage could result in reduced plant growth rates and overall health. Physiological impacts of the leafminer on birch trees were unknown when the biological control program was initiated. However, recently Van Driesche et al. (unpub. data) used tree-ring data to examine changes over time in the growth of Alaska white birch trees in the Anchorage Bowl from 1984 to the present. This dataset includes pre-introduction growth rates (from 1984 to 1995), peak outbreak growth rates (from 1996 to 2007), and post-biological control

Figure 3. Alaska white birch tree leaves showing leaf mining damage from ambermarked birch leafminer, *Profenusa thomsoni*, larvae. (US Forest Service)

growth rates (2008–present). Based on their analyses of Alaska white birch growth rings, Van Driesche et al. (unpub. data) found that growth rates before the outbreak of AMBLM averaged around 2.1 mm (0.08 in) per year. However, after the outbreak of AMBLM in the region, growth dropped significantly to around 1.8 mm (0.07 in) per year. Their data also showed that after the achievement of biological control of AMBLM in the region, growth rates continued to decrease before stabilizing at around 1.3 mm (0.05 in) per year (95% CI: 1.21 to 1.52). Whether this continued reduction is the result of the emergence of a second pest in this system, the late birch leaf edgeminer, *Heterarthrus nemoratus* (Hymenoptera: Tenthredinidae), or is indicative of the inability of birch species in high-latitude locations to rebound after damage from AMBLM is unknown. However, in a similar high-latitude setting, birch trees that suffered defoliation in northern Fennoscandia caused by the feeding of two moths, *Epirrita autumnata* and *Operophtera brumata* (both Lepidoptera: Geometridae), failed to fully recover even one hundred years after their initial defoliation events (Vindstad et al., 2019). In that region, climate change (Jepsen et al., 2008), as well biotic factors such as tree age (Young et al., 2014), may be interacting to compound the effects of tree stress in northern latitudes. Taken together, the results from Van Driesche et al. (unpub. data) and the results from northern Fennoscandia suggest that moderate amounts of leaf damage, as might be expected from a leafminer, could result in profound and cascading effects for birch tree growth and fitness in northern latitudes.

THE ECOLOGY OF THE PROBLEM

Life history information and life tables for Alaska populations of AMBLM were developed by MacQuarrie et al. (2008). In Alaska, AMBLM has one generation per year, the population is parthenogenetic, and no males are known (Benson, 1959; MacQuarrie, 2008). Adults emerge from late-June to August and deposit their eggs singly on the central midrib of birch leaves (Martin, 1960; Digweed, 2006). Many eggs can be laid per leaf by one or several females when population densities are high. In late July and August, larvae feed on the inner tissues of the leaf, and leaves turn brown and cease to photosynthesize effectively. In mid-to-late-August, mature larvae drop to the soil, where they form earthen cells and overwinter as prepupae or pupae (Digweed, 2006). The adult sawflies emerge the following summer from June through August.

PROJECT HISTORY THROUGH AGENT ESTABLISHMENT

The classical biological control program against AMBLM was started in Alaska in 2003 through the combined efforts of the USDA Forest Service, the Canadian Forest Service, and the University of Alberta, with the goal of introducing a highly specialized parasitoid known at the time as *Lathrolestes luteolator* (Hymenoptera: Ichneumonidae), but which is now correctly recognized as *L. thomsoni* (**Fig. 4**). This parasitoid had been observed attacking AMBLM populations in Edmonton, Alberta, where it was associated with the collapse of the leafminer population there (Digweed et al., 2003; MacQuarrie, 2008). Subsequently, additional leafminer populations from Edmonton and Edson in Alberta, and Hay River and Fort Smith in the Northwest

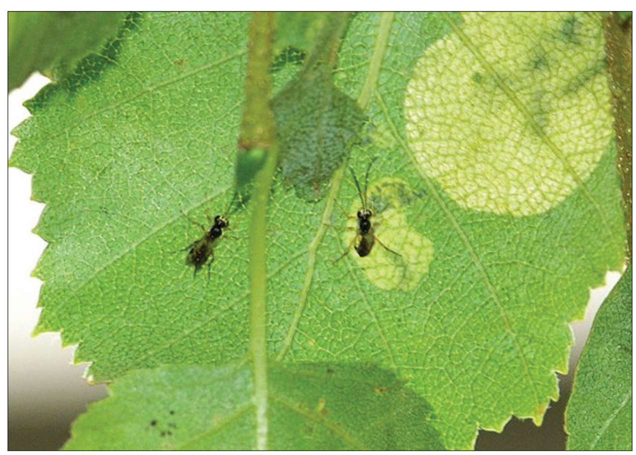

Figure 4. The introduced biological control agent *Lathrolestes thomsoni* inspecting ambermarked birch leafminer, *Profenusa thomsoni*, mines before parasitizing the larvae. (A. Soper, Cal Poly)

Territories, were used as sources to collect parasitized leafminers to then rear parasitoids for release in Alaska. *Lathrolestes thomsoni* parasitoids were collected as either immature stages inside parasitized host larvae in the year preceding their release or as adults in July and August of the year of release. Individuals collected were then either reared to the adult parasitoid stage before release or were released directly if adult parasitoids had been field-collected.

Most of the adult parasitoids released in Alaska were obtained by rearing parasitized leafminers, using techniques modified from Fuester et al. (1984) and described in detail by MacQuarrie (2008). Infested leaves were collected from urban birch trees (located in city parks or landscaped yards) in western Canada between late-July and early-September and then placed in tubs of soil for host pupae to overwinter. Leafminers in tubs were either overwintered in Alberta, and then taken to Alaska in the spring, or were transported in fall to Alaska and overwintered there. In spring, cages were checked daily for insect emergence from mid-June until parasitoid emergence ended, typically around mid-August. The first releases of this parasitoid in Alaska were made in 2004 and 2005 by Chris MacQuarrie, then a graduate student at the University of Edmonton, Alberta. In 2006, the University of Massachusetts Amherst joined the biological control program and continued the project until the end of 2011.

In August 2007, Andrew Bennett, an ichneumonid Research Taxonomist with the Canadian National Collection of Insects, determined that the parasitoid being released in Alaska was not *L. luteolator* as previously believed and that past publications had applied that name incorrectly to specimens from Canada. In 2009, Alexey Reshchikov of the University of St. Petersburg revised the Nearctic members of the genus *Lathrolestes* and described the parasitoid being released as a new species. Based on his results, it was determined that there were no records of the European species *L. luteolator* from North America, and the parasitoid being released for biological control of AMBLM in Alaska was then described as *L. thomsoni* to reflect its host association (Reshchikov et al., 2010).

During studies evaluating the establishment of *L. thomsoni* in Alaska, two other ichneumonid parasitoids of unknown origin were found attacking AMBLM. The first new parasitoid was an unnamed endoparasitoid of AMBLM larvae in leaf mines, which was later described as *Lathrolestes soperi* (Reshchikov et al., 2010). The second parasitoid was first noticed in 2007 among insects caught in emergence cones placed over soil under birch trees infested with AMBLM. Andrew Bennett of the Canadian National Collection identified that species as *Aptesis segnis*, but little was then known about this species apart from inferences made from notes on specimens in museum collections and old agricultural reports (Parrott and Fulton, 1915). More recently, Soper and Van Driesche (2019) compiled a synthesis of its life history and its role in the life cycle of AMBLM in Alaska. The species seems to be broadly distributed across Canada, having been collected from Saskatchewan, Alberta, and Quebec (Krombein et al., 1979).

During the beginning phases of the biological control project, the presence of these two additional parasitoid species led to some concern that they would hinder the establishment of the introduced biological control agent. As a result, a DNA analysis was developed to identify the species of *Lathrolestes* larvae or eggs found in parasitized hosts from leaf mines. These analyses showed that *L. soperi* contributed significant mortality to AMBLM larvae, with parasitism by *L. soperi* increasing from 8% in 2006 to over 27% in 2011 at non-release sites (Soper and Van Driesche, 2019). In 2019, total parasitism from both species of *Lathrolestes* was 70%, and the introduced species *L. thomsoni* was responsible for more than two thirds (71%) of total parasitism, with the remainder (29% of total) being from *L. soperi* (Andersen et al., 2021).

HOW WELL DID BIOLOGICACL CONTROL WORK?

In univoltine pests and parasitoid systems, population adjustments often require several years to reach new equilibria after agent introduction (Huffaker et al., 1976). Formal funding for the project ended in 2011, but some further post-release monitoring eight years later proved important in gaining a final understanding of the outcomes in the system (Andersen et al., 2021). In 2019, fifteen years after the first releases of *L. thomsoni*, a survey found that AMBLM had been reduced to non-pest status across most study sites in the Anchorage Bowl (Andersen et al., 2021). Results presented by Soper et al. (2015) and Andersen et al. (2021) showed that the percent of leaves mined by AMBLM decreased from ~ 70% in 2006 to ~ 8% in 2019, and that concurrent with this decline in the level of leaf mining by AMBLM in the Anchorage bowl, the proportion of AMBLM that were parasitized increased from ~10% in 2006 to ~70% in 2019 (**Fig. 5**). Surveys of long-term study sites established by Soper et al. (2015) beginning in 2006, found high levels of parasitism by *Lathrolestes* species at most of the 11 study sites: nine sites had parasitism rates ≥67%, and two sites had parasitism ≥95% (Andersen et al., 2021). DNA analyses showed that both *Lathrolestes* species have persisted or increased, with *L. soperi* present at most sites at levels similar to those observed in 2011, while *L. thomsoni* contributed high levels of additional, new parasitism (Andersen et al., 2021).

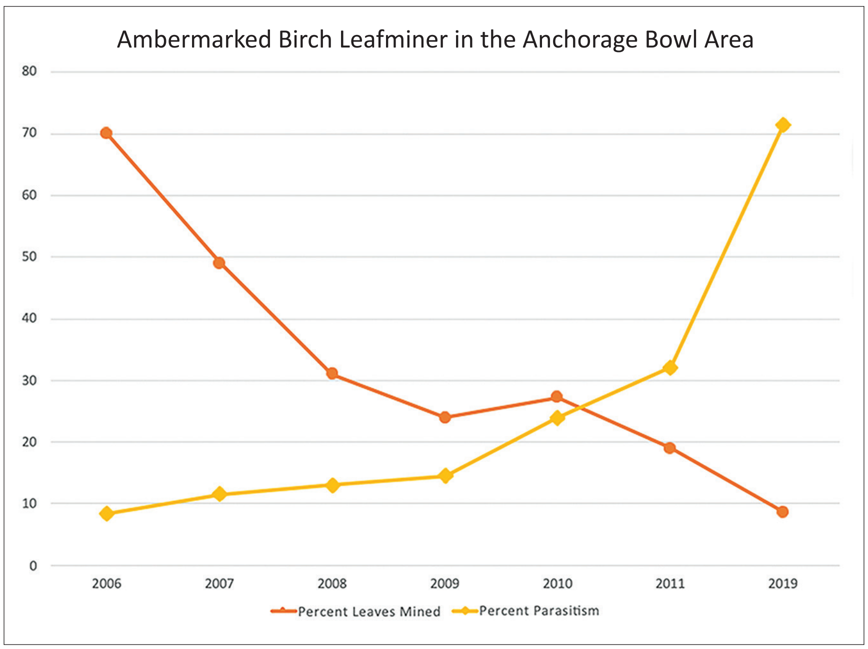

Figure 5. The change in the percent parasitism of ambermarked birch leafminer (*Profenusa thomsoni*) (gold) and the corresponding decrease in the percent of leaves with ambermarked birch leafmines (orange) from 2006 to 2019. (modified from Andersen et al., 2021)

While the efforts to suppress AMBLM were highly successful, a second invasive European tenthredinid leafminer, *H. nemoratus*, has subsequently reached the Anchorage bowl area and greatly increased in density (Van Driesche et al., unpub. data). This species was first noted in Alaska in 2003 (Snyder et al., 2007). Lundquist et al. (2012) reported 36% of the leaves were mined by *H. nemoratus* (a number comparable to AMBLM at the time). As AMBLM's density declined, the density of leaves mined by *H. nemoratus* increased, ultimately accounting for >90% of all leafmines in 2021 (Van Driesche et al., unpub. data). Following the suppression of AMBLM through biological control, *H. nemoratus* has become the dominant leafminer attacking Alaska white birch in the Anchorage Bowl.

BENEFITS OF BIOLOGICAL CONTROL OF AMBLM

Classical biological control of AMBLM met its goal of reducing the pest's density. This likely had the effect of reducing pesticides applied for its control in urban areas, but no records exist that quantify this result. Tree growth rates of Alaska white birch declined during the period of highest AMBLM density. However, based on Van Driesche et al. (upub. data), suppression of AMBLM did not result in the return of birch growth rates to pre-invasion levels. While retrospective correlations of tree growth and observed events do not prove causality, it appears that the most likely cause of the decline of birch growth was indeed leaf mining and the failure of growth to rebound after suppression of AMBLM may have been due to the invasion of a second leaf mining species, *H. nemoratus*, concurrent with the suppression of AMBLM. Alternatively, it could be indicative of the sensitivity of birch species to defoliation in northern latitudes. Further work is required to understand stressors for birch trees in Alaska, and a logical next step would be to bring *H. nemoratus* under biological control, possibly using agents that were studied and introduced into the northeastern United States in the 1930s (Dowden, 1941).

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