

INTRODUCTION

The riparian forests of interior and south-central Alaska are arguably the most productive and important ecosystems within the portion of the State covered by the boreal forest. Recent large-scale mortality of thin-leaf alder (*Alnus incana tenuifolia*), one of the dominant species in these areas, has created the potential for deep-seated changes in these ecosystems. Alder is a symbiotic nitrogen-fixer, allowing it to thrive in low-nutrient soil. The long-term productivity of Alaskan riparian forests is directly related to the amount of nitrogen fixed and deposited in the soil during the alder-dominated stages of succession (Ruess and others 2009). In addition, because the streams and rivers of south-central Alaska are a critical resource for salmon reproduction, the Cook Inlet and Prince William Sound fisheries are, in part, dependent on the breeding habitat found in these waters (Roon and others 2012, Wipfli and Musslewhite 2004).

Three defoliating sawfly species feed on thin-leaf alder in riparian areas throughout south-central and interior Alaska. The circumpolar-striped alder sawfly (*Hemichroa crocea*) and two nonnative European species, woolly alder sawfly (*Eriocampa ovata*) and European green alder sawfly (*Monsoma pulveratum*), are the major sources of alder defoliation in Alaska. The green alder sawfly is the newest detection of a nonnative sawfly in Alaska, representing a new U.S. record (Kruse and others 2010, Smith and Goulet 2000). Significant defoliation by both exotic sawflies has been recorded in

south-central Alaska on the Palmer Hay Flats, Eagle River, Little Susitna River, and on the Kenai Peninsula (Cooper Landing, Quartz Creek, and Kenai River).

Discernible defoliation, branch dieback, and mortality of thin-leaf alder in Alaska was documented as early as 2003. By 2005, the green alder sawfly and the canker fungus *Valsa melanodiscus* were both implicated as possible causal agents or contributing factors (Adams and others 2010). While the green alder sawfly is an exotic insect new to Alaska, it has quickly become established on the Kenai Peninsula, the Anchorage bowl, and the Matanuska-Susitna Valley. It has since been found throughout the Pacific Northwest (Kruse and others 2010). In contrast, the fungus that causes alder canker is presumably a native, usually benign fungus for which conditions have changed to its advantage. To a lesser extent, two other alder species are also affected by alder canker, Siberian alder (*A. fruticosa*) and Sitka alder (*A. sinuata*).

Previous roadside surveys have detected widespread canker disease at over 100 locations across south-central and interior Alaska, with mortality reaching over 80 percent at some sites. The primary causal agent of canker on *Alnus tenuifolia* has previously been confirmed as *Valsa melanodiscus* (Stanosz and others 2011, Worrall and others 2010). *V. melanodiscus* also causes similar cankers on *A. fruticosa*, which may be more vulnerable when water stressed (Rohrs-Richey and others 2011a, 2011b). However, differences in canker morphologies and fruiting bodies suggest that other fungal species may also

CHAPTER 14. Alder (*Alnus incana tenuifolia*) Mortality Agent Complex Effects on Riparian Zone Habitat (Project WC-EM-B-10-01)

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be involved in dieback and mortality (Walker and others 2012). Two *Phytophthora* species have been suggested as possible contributors to the widespread alder mortality in Alaska (Adams and others 2008, Adams and others 2010, Aguayo and others 2013).

Little is known about how sawflies, canker, or other pathogens interact in regards to alder productivity and survival. This project served to investigate alder dieback in riparian areas previously observed via Alaska's aerial detection survey. We attempted to (1) identify the extent to which nonnative sawflies contribute directly to alder dieback, (2) identify the extent to which alder canker contributes directly to alder dieback, (3) identify the extent to which nonnative sawflies and canker may synergize to cause alder dieback, and (4) identify whether nonnative sawflies may serve as infection facilitators or otherwise predispose alder to pathogens.

METHODS

In addition to roadside and opportunistic surveys, a network of monitoring plots was established to estimate the occurrence and severity of canker and sawfly activity along streams in three geographic areas. Nine plots (three in interior, three in south-central, and three on the Kenai Peninsula) were selected in early- and mid-succession alder stands. Plots were chosen in areas with known evidence of sawfly and/or canker. Plots were 18 m square, and divided into three equal transects (6 m by 18 m).

In early spring, five flight traps were placed at each of these nine plot locations prior to bud break for the host plant. Traps were hung at a height of 1 m, and one was placed at each corner of the plot, as well as at plot center. Traps were collected and replaced every 2 weeks throughout the summer during 2 consecutive years. Beat sampling for larva was conducted during early July in both years to provide a quantifiable estimate of larval numbers during peak density. Alder damage levels from sawfly defoliation and canker were each evaluated using ocular estimates to place observations into percentage classes. The naturally occurring gradient of sawfly population densities was used to test for relationships between sawfly feeding and canker infection. Larvae were collected adjacent to the study sites, and a host suitability feeding trial was conducted using leaves from three species of alder and from willow (*Salix* spp.). In addition, we investigated the observations of Pieronek (1980) regarding *M. pulveratum*'s unique ability amongst sawflies to overwinter in woody materials.

At each plot, all alder ramets > 1 inch in diameter were individually labeled, diameter measured, and assessed for presence, absence and progression of stem cankers. These measurements included all *Alnus* species found within the plots, including *A. tenuifolia*, *A. fruticosa*, and *A. sinuata*. The causal agents of canker-induced dieback and mortality on the three alder species were determined by pathogenicity tests to fulfill Koch's postulates; fungi were isolated from canker margins, identified via DNA sequencing, and inoculated

onto alder stems at two sites. Fourteen months after inoculation, the resultant cankers were measured and fungi re-isolated from the margins. Each site was inspected for typical symptoms of *Phytophthora* diseases. *Phytophthora* spp. were baited and trapped at each of these locations from roots and soil using thin-leaf alder twigs.

During both summers of the study, signatures of alders with active canker that could be reliably identified from the air were defined, and surveys for canker damage in Alaska were conducted as part of annual Aerial Detection Surveys for forest insects and diseases. Field verifications of the presence of both sawflies and

canker within areas identified by aerial surveys were conducted whenever possible.

RESULTS

The range of green alder sawfly was found to extend from the city of Juneau in southeast Alaska to the city of Fairbanks, approximately 700 miles to the north. The infestation appears to be centralized around the Kenai Peninsula and Parks Highway, with no adults caught on flight traps deployed in more remote portions of the State. The green alder sawfly infestation and defoliation were highest in pure thin-leaf alder stands in south-central Alaska and the Kenai Peninsula. Evidence of sawfly activity was much lower in interior Alaska (fig. 14.1). Siberian and

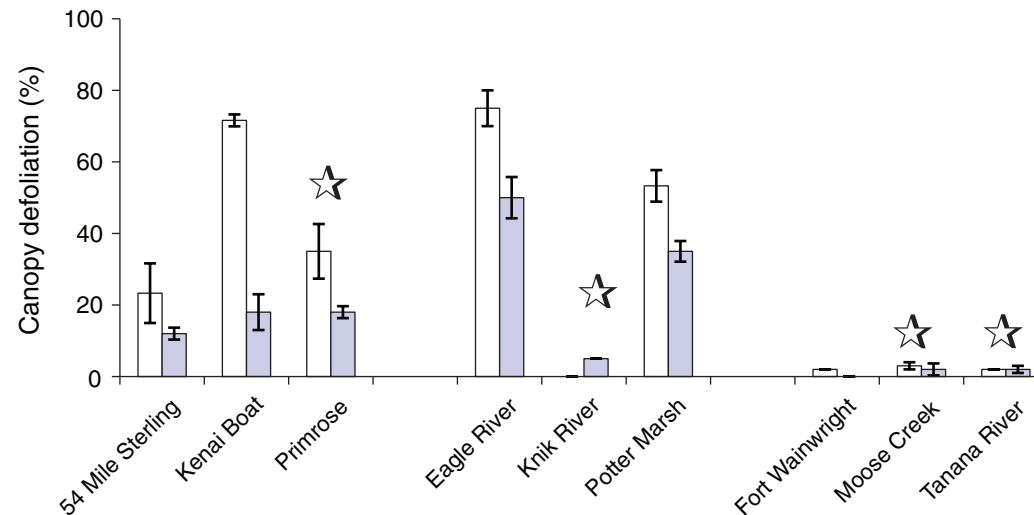


Figure 14.1—Total observed canopy defoliation based on ocular estimates taken during 2010 (white bars) and 2011 (gray bars). Stars indicate sites with strong components of *Alnus fruticosa* or *A. sinuata* in addition to *A. incana tenuifolia*. Error bars are ± 1 standard error.

Sitka alder do not appear to be suitable hosts for larval feeding, with 100-percent mortality occurring in captive larva when supplied with any food source other than thin-leaf alder. High adult catches in flight traps were correlated with high larva counts and defoliation levels during both study years.

Alder canker, by contrast, is widespread throughout Alaska, and was present to some degree in virtually every thin-leaf alder stand visited in this study. It was also found to infect all three species of alder found in south-central and interior Alaska. Of the nine sites in this study, three had > 30 percent mortality (fig. 14.2). At two sites near Anchorage, nearly 100 percent of the mortality was due to canker. The three sites with the least mortality were not in the pure stands of thin-leaf alder, but had a significant component of either Sitka or Siberian alder. Fifty-eight different fungal species were isolated from canker margins, and the 13 most common were used for artificial field inoculations at two sites. Analysis of variance showed highly significant differences in mean canker size among the fungal pathogens at each plot (fig. 14.3). *Valsa melanodiscus* and *Melanconis alni* both showed high levels of virulence on thin-leaf and Siberian alders. The most virulent of the 13 fungi tested on Sitka alder was *Melanconis stilbostoma*, which was not highly virulent on the other alder species. In 2010

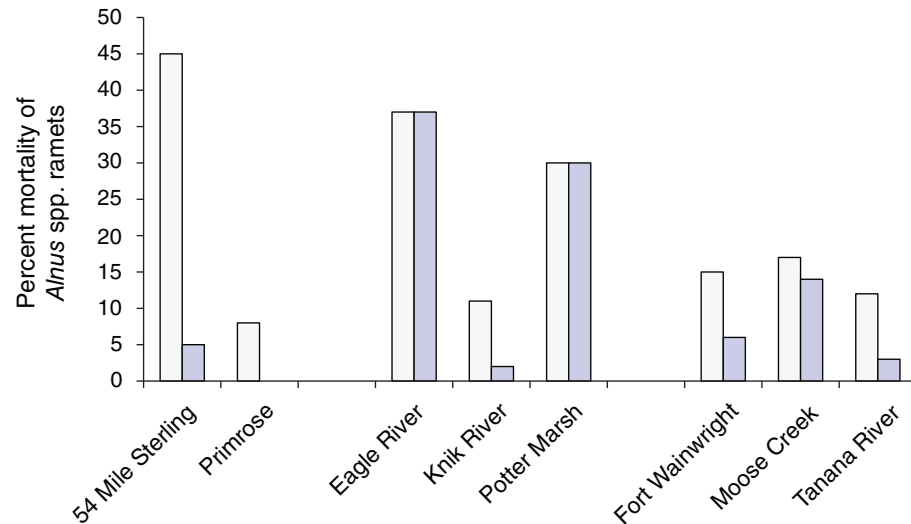


Figure 14.2—Percent of total *Alnus* ramets at each site dead (white bars) and percent of total *Alnus* ramets dead and known to be killed by alder canker (gray bars).

and 2011, over 700 *Phytophthora* isolates were obtained from alder stands in Alaska (Hansen and others 2010). However, no symptoms of *Phytophthora* diseases were observed (Adams and others 2010).

Alaska's Aerial Detection Survey mapped alder dieback for the first time in 2010, when 44,230 acres were recorded. While most of the affected acreage was mapped near streams, many were found up to 2 miles from riparian areas and up to 1,500 feet elevation. In 2011, 142,005 acres of alder dieback were recorded (fig. 14.4).

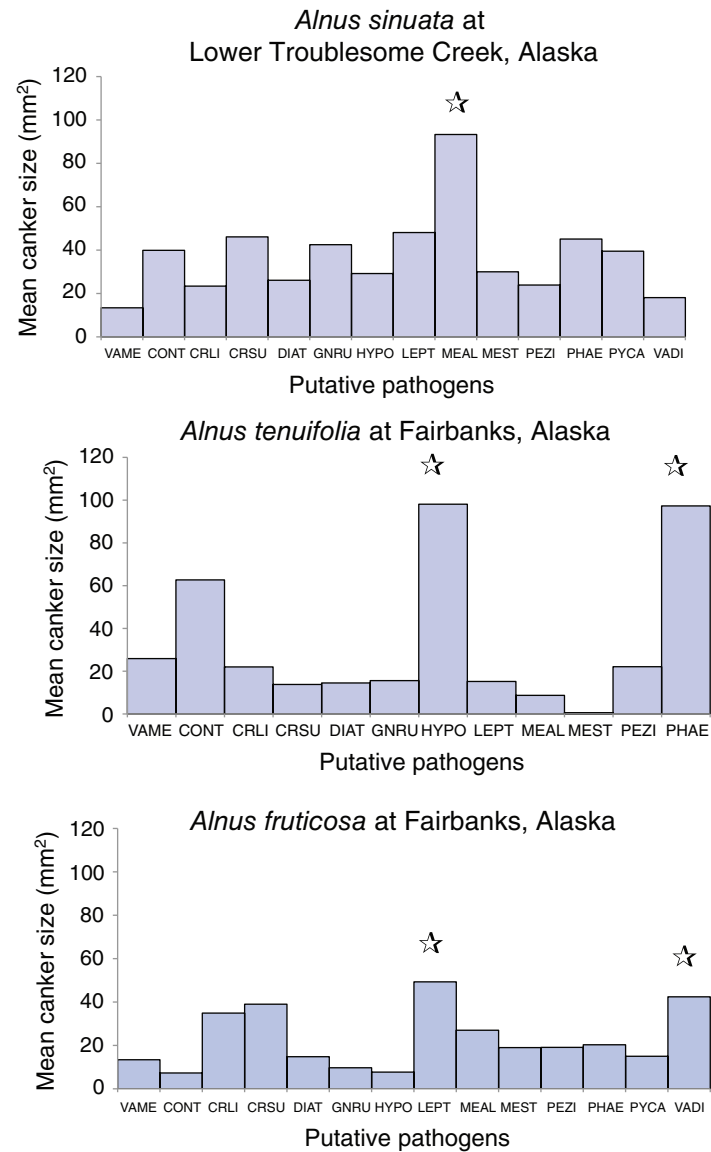


Figure 14.3—Disease response on three alder species to inoculations with the fungal pathogens. VAME= *Valsa melanodiscus*, CONT=Control (no pathogen), CRLI=*Cryptosphaera ligniae*, CRSU=*Cryptosporella suffusa*, DIAT=*Diatrype spilocea*, GNRU=*Gnomonia rubi-ideae* (= *Valsalnicola oxystoma*), HYPO=*Hypoxylon fuscum*, LEPT=*Leptographium piriforme*, MEAL=*Melanconis alni*, MEST=*Melanconis stilbostoma*, PEZI=*Pezicula* sp., PHAE=*Phaeomollisia*/*Phialocephala fortinii*, PYCA=*Pyrenochaeta cava*, VADI=*Valsa diatrypoides*. Stars indicate species that differ significantly from the controls.

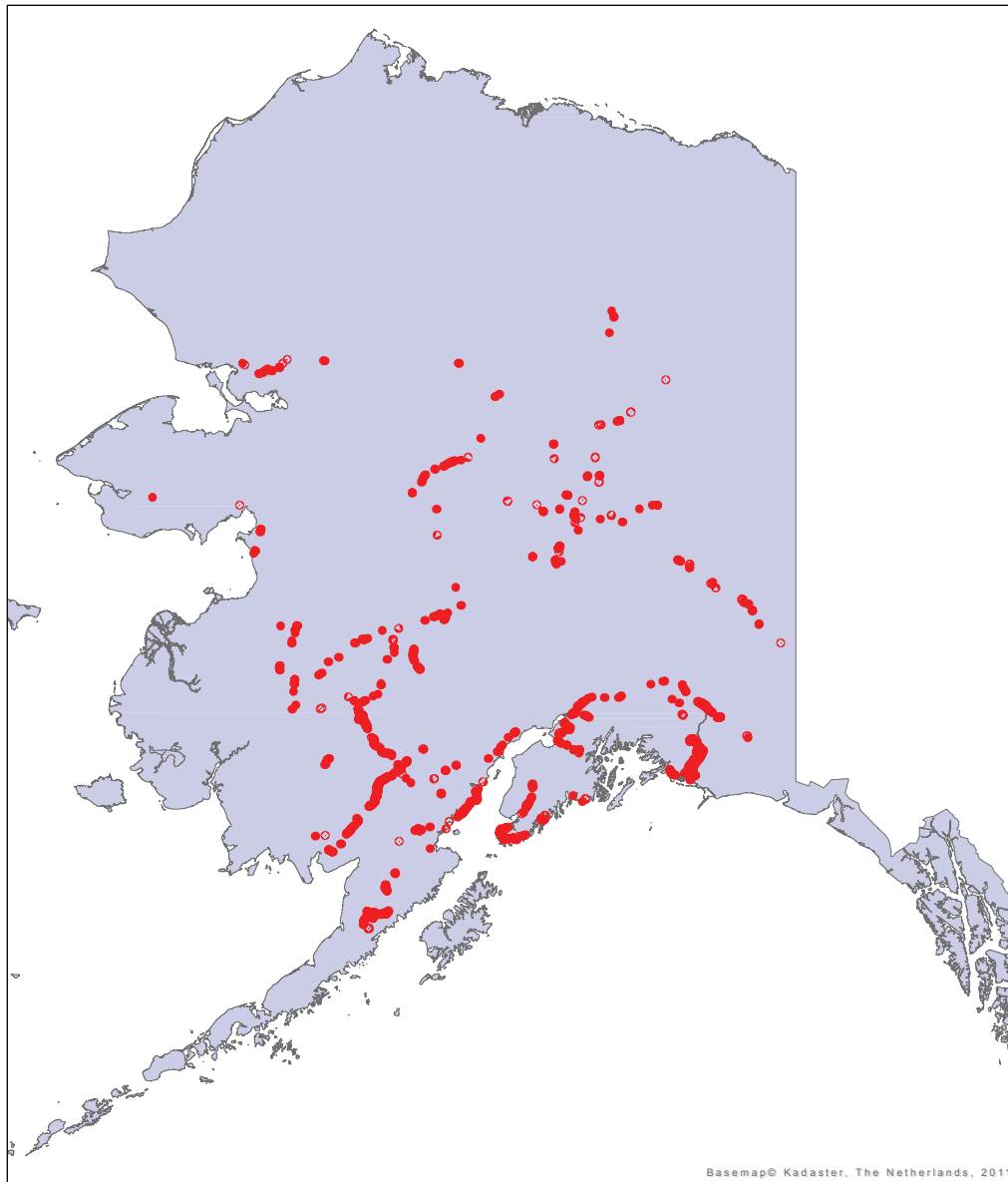


Figure 14.4—Distribution of alder dieback mapped during 2011 Aerial Detection Survey.

Although there appeared to be an ecologically significant correlation between alder canker mortality and sawfly abundance, there was insufficient evidence to support a statistically significant relationship, and the causal mechanisms remain largely unknown (fig. 14.5).

DISCUSSION

Green alder sawfly caused significant defoliation to thin-leaf alder stands in south-central Alaska, including the Kenai Peninsula. Although few alder ramets were killed as a direct result of the sawfly feeding, defoliation at these high levels is known to affect symbiotic nitrogen fixation associated with alder (Ruess and others 2009). Defoliation also reduces the tree's ability to respond to other sources of stress. In comparison, alder canker directly caused significant mortality in thin-leaf alder

stands, with limited signs of recovery or new recruitment. Permanent removal or reduction of thin-leaf alder from riparian ecosystems on a landscape scale would adversely affect long-term nutrient cycling and forest productivity, aesthetic value, allochthonous inputs to rivers and streams, reduce shading of streams that would increase temperatures, and reduce prey abundance and quality in salmonid breeding areas.

The extent to which alder sawflies and alder canker may synergize is not yet known. Other defoliators are known to increase susceptibility of their host plants to other insects and diseases, but the presence or absence of alder sawflies or other defoliators did not enhance or impede infection rates or death rates of alder due to alder canker. Alder sawfly and alder canker occurrence are clearly correlated; however, it

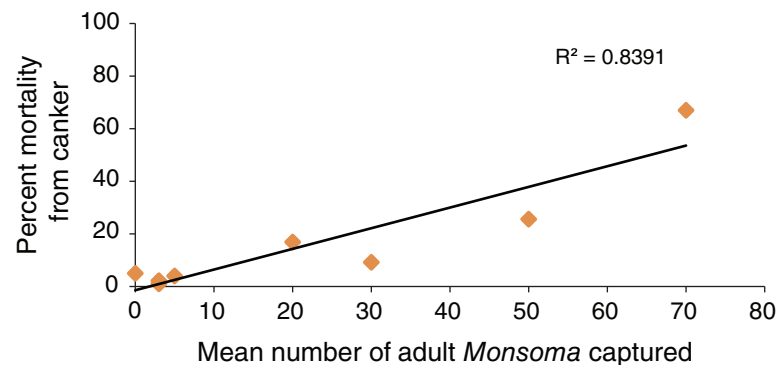


Figure 14.5—The apparent relationship between the number of *Alnus* ramets at each site killed by alder canker and the number of *Monsoma pulveratum* sawflies caught by flight traps.

may be that alder sawfly is somehow attracted to alder canker infestations, or the introduction of alder sawfly is coincident with hot spots of alder canker occurrence. That said, there are still plenty of areas in the State where alder canker exists in high abundance without sawflies, but no known areas where sawfly occurs in high numbers in the absence of alder canker.

Ethanol release by *Phytophthora ramorum* cankers on coast live oak (*Quercus agrifolia*) has been implicated in the attraction of bark and ambrosia beetles (*Scolytinae*) (Kelsey and others 2013). In a pilot study, canker-infested alder ramets contained ethanol concentrations comparable to the amounts recorded in *P. ramorum* cankers on coast live oak.¹ Relatively high tissue concentrations and release rates of ethanol by healthy ramets located near canker-infested ramets on the same genet both suggest a possible sympathetic response, but higher ethanol concentrations within canker-infested stands also potentially increase the attraction of sawflies. This work will be continued in collaboration with the Pacific Northwest Research Station.

CONCLUSION

Canker may occur where sawflies do not, but sawflies do not occur in high numbers in the absence of significant canker infestation.

¹ Personal communication. 2012. Rick Kelsey, Research Forester, U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station, 3200 Southwest Jefferson Way, Corvallis, OR 97331.

Future work will continue to explore possible relationships. Prior to this project, little was known about many basic aspects of *Monsoma pulveratum* natural history in North America, or its relationship to alder canker. This study provided important information regarding the range, extent, and host suitability of *M. pulveratum*, including successful overwintering populations at all nine study locations. This includes all three interior Alaska locations studied, where only two individual specimens had previously been recorded and no established populations were previously known.

CONTACT INFORMATION

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