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Western Hemlock Looper

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The western hemlock looper, *Lambdina fiscellaria lugubrosa* (Hulst) (Lepidoptera: Geometridae), is a destructive defoliator of its primary host, western hemlock *Tsuga heterophylla*, and associated conifers in northwestern North America (Figure 1).

Figure 1. Western hemlock looper adults at rest on Douglas-fir.

The inchworm type caterpillars feed on all ages of foliage; therefore, severe defoliation during outbreaks may cause tree mortality after a single year of feeding (Figure 2). Larvae are wasteful feeders that leave behind partially chewed needles giving tree crowns a red-brown, scorched appearance. The typical pattern on the landscape is discreet centers of defoliation most frequently in valley bottom and mid-slope locations with the heaviest

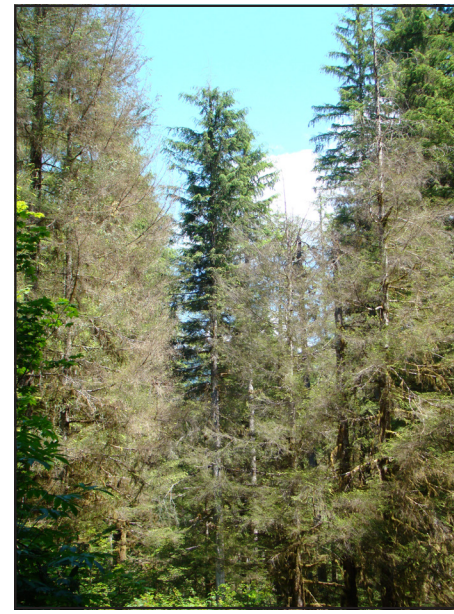

Figure 2. Western hemlock heavily defoliated by western hemlock looper.

defoliation and mortality in the interior of defoliated stands. Defoliation may appear in discrete elevational bands (up to 4,600 ft (1,400 m)), especially along river drainages.

Populations can irrupt rapidly to outbreak levels then, after two to three years of defoliation, collapse quickly due to natural controls. The primary natural controls are a

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nucleopolyhedrosis virus and, to a lesser extent, parasites and predators. Outbreaks ranging from one to five years in duration have been reported. Occurrence of outbreaks is sporadic with no predictable return interval, except in some areas of interior British Columbia where outbreaks may occur at 9- to 11-year intervals. Outbreaks tend to occur during periods of above-average temperature and below-average precipitation, conditions which produce needles with more carbohydrates, which are a more nutritious food for larvae. However, outbreaks have historically occurred in cooler and wetter watersheds in coastal areas and interior British Columbia where western hemlock and western redcedar are dominant.

The phantom hemlock looper *Nepytia phantasmaria* (Strecker) and the false hemlock looper *Nepytia canosaria* (Walker) are two related species that may co-occur with western hemlock looper, but are typically found in lower numbers. Larvae of other defoliator species with similar hosts, such as the western blackheaded budworm (*Acleris gloverana* (Walsingham)), the greenstriped forest looper (*Melanolophia imitata* (Walker)), and conifer sawflies (*Neodiprion* spp.), may also feed alongside western hemlock looper. Discrete sawfly outbreaks have been recorded following collapse of western hemlock looper populations.

Distribution and Hosts

Distribution: Western hemlock looper occurs throughout the range of western hemlock, its preferred host. Its range encompasses southeast Alaska, coastal and interior British Columbia, western Alberta, western Montana, northern Idaho, Washington, western Oregon, and northern California (Figure 3). Damaging outbreaks have never been recorded in California nor Alberta.

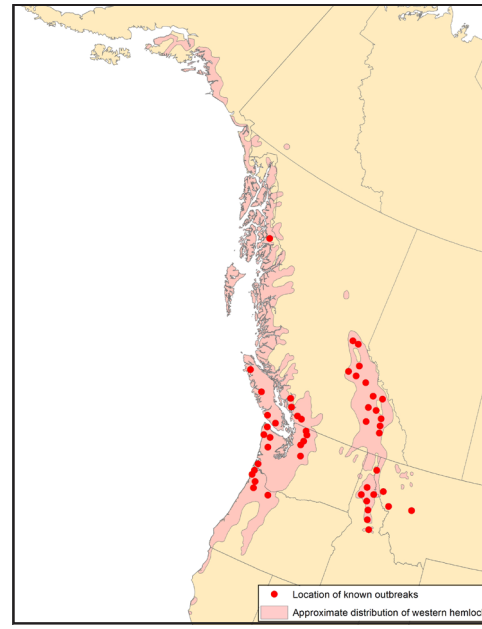

Figure 3. Recorded outbreaks of western hemlock looper in western North America.

Hosts: Western hemlock is the primary host; however, larvae will feed on several conifer hosts associated with hemlock, including Sitka spruce (*Picea sitchensis*), Engelmann spruce (*Picea engelmannii*), white spruce (*Picea glauca*), Douglas-fir (*Pseudotsuga menziesii*), subalpine fir (*Abies lasiocarpa*), grand fir (*Abies grandis*), Pacific silver fir (*Abies amabilis*), western white pine (*Pinus monticola*), lodgepole pine *(Pinus contorta),* western larch (*Larix occidentalis*), and western redcedar (*Thuja plicata*). Recent outbreaks in Montana and Idaho have occurred in Douglas-fir dominated host types. Almost any species of deciduous tree or shrub growing among the primary conifer hosts may also be fed on. Common deciduous tree hosts are maple (*Acer* spp.), red alder (*Alnus rubra*), dogwood (*Cornus nuttallii*), willow (*Salix* spp.), and crab-apple (*Malus fusca*). Understory shrub hosts include salal (*Gaultheria shallon*), thimbleberry (*Rubus parviflorus*), huckleberry (*Vaccinium* spp.) and spirea (*Spiraea* spp.).

Outbreak History

Historically, specific regions of northwestern Oregon, western Washington, northern Idaho, and southern British Columbia have experienced recurrent outbreaks (Figure 3). Infrequent outbreaks have occurred in western Montana and southeast Alaska. The first known record of a widespread forest defoliator in the western United States was an outbreak of western hemlock looper from 1889-1891. That outbreak occurred in western hemlock and Sitka spruce in Tillamook and Clatsop counties in Oregon and Grays Harbor County in Washington. There have been at least thirteen recorded outbreaks in western Oregon and Washington since that time. Southern British Columbia has experienced at least seventeen outbreaks since the first was recorded from 1911 to 1914 in Stanley Park near Vancouver. Regions of British Columbia that have experienced outbreaks include Vancouver Island and watersheds in the vicinity of Vancouver, and interior forests near Prince George, McBride, Williams Lake, Revelstoke, and Vernon. Some of the largest outbreaks ever recorded have occurred in southeast and southcentral British Columbia, causing mortality in western hemlock, true firs, Douglas-fir, spruce, and western redcedar.

The first records of aerial pesticide application against western hemlock looper in British Columbia occurred near Vancouver in 1929 along the Indian River and in 1930 in Stanley Park and along the Seymour River. The first aerial application of pesticides for suppression of a forest defoliator in the United States was also for western hemlock looper in 1931. It occurred during an outbreak lasting from 1929 to 1932 in Pacific and Grays Harbor counties, Washington that killed over 200 million board feet (472,000 cubic meters) of western hemlock.

The first outbreak recorded in northern Idaho and western Montana defoliated "several hundred thousand acres," primarily grand fir and Douglas-fir, from 1937 to 1939 (Evenden 1938). Three subsequent, smaller outbreaks have occurred in Idaho and Montana, followed by a larger outbreak in 2019 (approximately 385,000 acres (156,000 ha) in Idaho and 12,600 acres (5,090 ha) in adjacent Montana). The largest outbreak in the Pacific Northwest occurred from 1961 to 1963, covering 70,000 acres (28,000 hectares) in Pacific County, Washington and 33,000 acres (13,000 ha) in Clatsop County, Oregon. Only one outbreak has been recorded in Alaska, primarily damaging Sitka spruce, along the Bradfield River in the coastal Tongass National Forest from 1965 to 1967. The largest outbreak ever recorded affected approximately 673,000 acres (272,000 ha) in British Columbia from 1990 to 1994 in an area stretching from northwest of McBride to northeast of Vernon.

Evidence of Infestation

Western hemlock looper defoliation typically occurs in mature and over-mature stands that have a high percentage of western hemlock or stands predominated by western hemlock and western redcedar. Severe outbreaks can develop in multi-canopy forests dominated by old-growth western hemlock near the Pacific Coast and on the west slopes of the Cascade Mountains. However, some recent outbreaks have affected much younger, vigorous 50 to

Figure 4. Young stand of defoliated western hemlock in northwest Washington State.

100-year-old stands (Figure 4). Outbreaks in interior forests on the west slopes of the Rocky Mountains can develop in forests dominated by western hemlock, true firs, or Douglas-fir. Interior western hemlock is considered less tolerant of defoliation than coastal western hemlock and therefore, more susceptible to mortality during and after outbreaks. Severity of damage is often patchy across the landscape with distinct centers of heavy defoliation. Areas with defoliation are more often observed in valley bottoms and mid-slope locations between 1,500 and 4,500 feet (460 and 1,370 meters) in elevation. Changes in stand composition and harvesting have moved some historically defoliated stands away from habitat suitable for future outbreaks.

Early instar larvae begin feeding on new foliage in the tops of trees between May and June. As larvae grow, the later larval stages (instars) begin to feed voraciously on new and old foliage throughout the crown. As a result, mortality of severely defoliated trees can occur in a single season. Between July and October defoliation becomes quite noticeable. The larvae are messy feeders, leaving needles chewed off near the base or partially consumed needles that turn red and drop off by late fall or remain suspended in abundant silk webbing produced by larvae. Green half-eaten needles and frass also accumulate beneath infested trees, especially during severe outbreaks. Between September and October, large numbers of moths can be seen flying or resting on trunks of trees or other objects. Flying moths may be so numerous, they can give the impression of a summer snowstorm. During outbreaks, large numbers of dead adults may be seen floating in pools of water.

Description of Life Stages

Western hemlock looper adults are fairly delicate moths and are not powerful flyers. The wingspread is 1 1/3 inches (35 mm) and the body is 1/2 inch (12 mm) long. Males and females are similar in size and pattern, but males have broad, feather-like antennae. Wings are mottled light tan to gray, with two dark, wavy stripes outlined with yellow across the forewings and one similar stripe on the hindwings (Figure 1). There is one small, dark spot near the front edge of each forewing between the two stripes. The wings are laid flat at rest with forewings partially overlapping hindwings, typical of geometrid adults.

Eggs are approximately 0.03-0.04 inches (0.75-1 mm) long, ovoid and opalescent gray-green when laid. Non-viable eggs remain light green, whereas viable eggs turn light bronze,

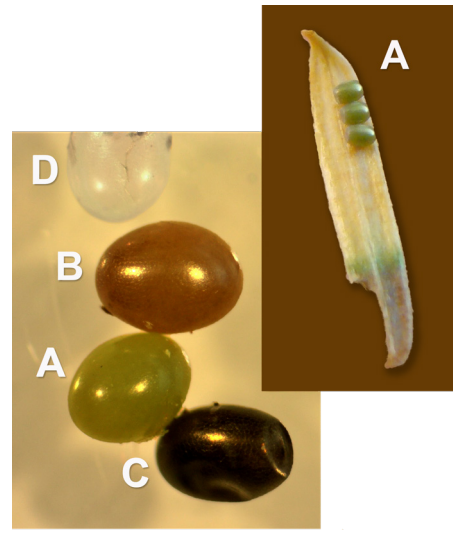

Figure 5. All western hemlock looper eggs start out green (A), then viable eggs turn bronze (B) as they mature. Parasitized eggs turn black (C). Previous years' eggshells are clear (D).

and parasitized eggs turn black. Last year's eggs can also be found as clear shells (Figure 5).

Larvae have five or six instars which range from 1/8 to 1 1/3 inches (3-33 mm) in length. The total number of instars likely depends on the length of the growing season and health of individual larvae. Descriptions from British Columbia report either five or six instars, but in

its southern range in Washington and Oregon only six instars has been reported.

Unlike most other caterpillars, geometrid larvae only have two pairs of prolegs at the rear of the abdomen. The 'inchworm' or 'looper' style of movement results from looping the body to attach these prolegs to the surface just behind the thoracic legs, then standing up and stretching the body so thoracic legs can reach forward to the next purchase. First instar larvae have black heads and a black and light gray banding pattern on the abdomen (Figure 6). The second and third instar larvae have yellow-brown, mottled bodies and black and brown head capsules with no pairs of spots on the head. The third instar is the first to have paired spots on body segments. Fourth through sixth instar larvae are yellow-brown to gray-brown, have two pairs of dark spots on the top of the head capsule and each abdominal segment, and a variegated pattern of lines that give the general impression of longitudinal stripes (Figure 7).

Figure 6. First instar western hemlock looper larva.

Pupae are 1/8 to 5/8 inches (11-15 mm) long, unprotected by a cocoon, mottled tan to greenish-brown, covered in dark spots, and tapered from the head to sharp point at the end of the abdomen (Figure 8).

Life History and Habits

Eggs are laid singly or in groups from September to early October and are typically attached to the underside of needles, moss and lichen on bark, twigs, woody debris, understory shrubs, and moss on the forest floor. A single female can lay approximately 50 to 100 eggs. Eggs are the overwintering stage.

Figure 7. Late instar western hemlock looper larva.

Figure 8. Western hemlock looper pupa on a Douglas-fir twig.

They begin hatching in May and early June at the time of budburst and shoot elongation of western hemlock. Many first and second instar larvae may be found on understory shrubs before they crawl up trees to feed on newly expanding foliage in May, June and early July. Damage from early instar feeding is primarily in the upper crowns. Later instars move to the lower crown and cause the most noticeable damage after feeding on both new and old foliage from mid-July through September. From late August through September, later instar larvae can easily be spotted on trunks, branches, and shrubs, or dropping on silk strands to the ground. In late-August or early September, final instar larvae begin wandering to seek out protected sites, such as bark crevices, moss, lichens, or woody debris, to pupate. Adult moths emerge from September to early October, approximately 10 to 14 days after the pupae are formed, with peak flight occurring in September in Washington. Adults are nocturnal; however, large numbers flutter about tree trunks during the day, becoming more active at dusk. After dusk, females release pheromones to attract males. Mating typically occurs at night after temperatures dip below 68 degrees F (20 degrees C). During an outbreak, bodies of adults that die shortly after mating can accumulate in massive numbers on the ground, in streams, and on the leeward shore of ponds and lakes. A report of the northern Idaho outbreak in fall 1937 (Evenden 1938) describes the accumulation "in some areas the ground was actually white with their dead bodies, and small streams were even clogged and dammed."

Ecological Impacts

Western hemlock looper is considered one of the most destructive defoliators in the Northwest because it can cause mortality within one to two years. Tree mortality is species dependent and also appears to depend on stand composition. Stands that sustain the most damage often have a high percentage of dominant, large diameter western hemlocks with exposed crowns. Western hemlocks that sustain greater than 50% crown defoliation are the most likely to die. Outright mortality of other host species from western hemlock looper feeding often requires 80-100% crown defoliation. Western hemlock was the most frequently killed host in many past outbreaks, but other conifer hosts reportedly killed were Douglas-fir, western redcedar, white spruce, Engelmann spruce, subalpine fir, Pacific silver fir, and grand fir. Severe outbreaks in interior British Columbia have shown that 40-69% of a stand can be killed, and that up to 35% of remaining live trees are top-killed. Tree mortality occurs rapidly in the first two years after an outbreak begins. Many partially defoliated trees die from a combination of defoliation and other factors. Cumulative factors include bark beetles, other defoliating insects, drought, pathogenic infections, and temperature extremes. These factors increase overall tree mortality for several years after an outbreak. Surviving trees have reduced radial growth for at least two years. A study linking aerial survey of defoliated areas in British Columbia to tree ring data noted average growth losses of 10%. Trees that have been killed by western hemlock looper have been found to decay at a rate of approximately 10% a year for the first two years after death.

Western hemlock looper can be an important

stand disturbance agent depending on survival rates of defoliated trees. Stand structure and species composition are likely to change following severe outbreaks. Heterogeneity across stands is likely to increase due to the patchy nature of damage. Nitrogen and other nutrients lost from tree crowns during defoliation accumulate on the forest floor as droppings and uneaten needles. Studies of defoliation have shown that only minor amounts of nitrogen are lost from the forest floor due to leaching, so most will be available for future forest growth and recovery.

Dead and dying trees and trees with dead tops can have dramatic, aesthetic impacts on the public and cause safety risks in popular recreation areas, trailheads, and lakes. In large outbreaks, larvae and droppings falling from the canopy can be a nuisance in campgrounds and other recreation areas. Decaying adult moths can clog small streams and ponds, rendering the water unfit to drink and giving off a foul odor.

Natural Controls

During the last century, the time between western hemlock looper outbreaks has been highly variable, fluctuating across its range between a 4- to 17-year return interval. Development and collapse of outbreaks depend on a number of environmental factors, but natural enemies likely play an important role in regulation of populations. Rapid spread of a nucleopolyhedrosis virus (NPV) disease through populations of western hemlock looper larvae is typically the primary driver of outbreak collapse. NPV is often the most important factor, since it kills some larvae that contain parasites, lessening their effectiveness. NPVs are characterized by the development of polyhedral inclusion bodies in the nuclei of certain cells. The NPVs are dissolved in the alkaline mid-gut of the insect, causing viral particles to rupture and cause infection. Infected larvae stop eating, become lethargic, swollen, and eventually hang upside down from their prolegs and die (Figure 9). Larval corpses then burst, spreading the NPV onto foliage and infecting more larvae.

Figure 9. NPV infected western hemlock looper larva.

Extreme heat, cold, or heavy rain during the flight period can hasten outbreak collapse. During severe outbreaks, a lack of food may become the limiting factor that causes an outbreak to collapse. In addition to NPV and abiotic factors, a number of parasites, predators, and disease-causing fungi are known to cause western hemlock looper mortality, but their relative contribution to population reduction is not well understood.

A total of 47 species of parasites have been found in the life stages of western hemlock looper. However, parasitism in the egg and larval stages appears to have the most impact. Tiny wasps, *Telenomus dalmani* (Ratz.) (Platygastridae) and *Trichogramma minutum*

Riley (Trichogrammatidae), are the most common parasitoids of western hemlock looper eggs. Common Hymenopteran larval parasitoids include *Apanteles* sp. (Brachonidae) and *Hyposoter* sp. (Ichneumonidae) that overwinter in pupae and emerge to attack first instar larvae, and one *Hyposoter* sp. that destroys larvae before they pupate. Seven species of tachinid flies in the genera *Winthemia, Chaetophlepsis, Omotoma* and *Hyphantrophaga* are also known to parasitize western hemlock looper larvae, primarily in the fourth and fifth instars. *Winthemia* species have been associated with western hemlock looper population collapse. Several species of ichneumonid wasps are important parasitoids of western hemlock looper pupae, including *Aoplus cestus* (Cresson), *Aoplus velox* (Harrington), *Apechthis ontario* (Cresson), *Pimpla* spp., and *Itoplectis quadricingulatus* (Provancher). In the 2010-2012 outbreak near Baker Lake in Washington State, many of the pupae collected were parasitized by *A. cestus* and *I. quadricingulatus*.

There are numerous generalist predators that will readily consume western hemlock looper larvae and pupae, including various songbird and insect species. However, predation on epidemic populations is thought to be minimal. Some important generalist predators include the ground beetle *Scaphinotus angusticollis* (Mannerheim) (Carabidae), which feeds on larvae and pupae, and a Hemipteran, *Euschistus* sp., that feeds on pupae.

Known fungal pathogens of western hemlock looper include *Empusa rhizospora* Thaxter, *Sporotrichum globuliferum* Speg., *Beauveria bassiana* (Bals.) Vuill., and *Entomophthora* sp.

Management

There are several sampling techniques that can be used to help predict outbreaks of western hemlock looper the following year. These include egg sampling, larval sampling, pupal sampling, and pheromone trapping. The most operational egg sampling method uses samples in the lower third of the crown to estimate population, and involves rinsing l00 grams of lichens in hot water to loosen eggs which are examined and counted. Alternately if the objective is to determine live parasite numbers, lichens could be rinsed in a 2-5% bleach solution to preserve the parasites within the eggs. Larval sampling using beating sheets, or pupal sampling using burlap traps in the lower crown can also be used. Trapping of adult males with pheromone lures, developed in Canada, is also employed to predict populations. However, to most accurately predict incipient outbreaks, more than one method should be used. More informally, observing numerous adults in flight or resting in a small area may indicate an approaching outbreak or nearby defoliation.

Models have been developed that can assess percent mortality in a stand based on percent defoliation, host species involved and elevation. Mortality prediction models should be used at the end of the outbreak cycle since many trees may recover from short term defoliation. Results can be used to determine survivorship and plan salvage logging boundaries if needed. Salvage should be completed within one to two years of mortality to avoid damage by secondary insects such as wood borers and decay. Mortality due to defoliation and post-outbreak effects may be delayed up to three years, so repeat observations may be needed to evaluate survivorship.

Hazard rating systems which identify stands at risk of defoliation by western hemlock looper have been developed by Canadian researchers (Borecky and Otvos 2001, Borecky 2003). Factors incorporated into the hazard rating

system include proximity to past outbreaks, location of mature hemlock, biogeoclimatic zones[3], climate factors, and elevation. Historic outbreaks of many forest Lepidoptera, including western hemlock looper, have been tied to below normal precipitation and higher than normal temperatures during larval growing seasons. Given a changing climate, western hemlock looper outbreaks in the future may be larger, more frequent, and more synchronous. Trees stressed by drought or competition are more likely to die as a result of defoliation or secondary factors. Having well-spaced, even aged, mixed species stands should lessen the effect of western hemlock looper defoliation. In areas where western hemlock is the primary host, promoting mixed species stands, composed of less than 50% western hemlock, will decrease susceptibility.

Suppression of western hemlock looper populations using insecticides is rarely done in the United States on a stand scale, primarily due to challenges with early detection of outbreaks before severe defoliation occurs. To be effective, insecticides need to be applied early in the outbreak cycle before natural collapse is imminent. Due to the severity of western hemlock looper defoliation and likelihood of mortality, use of insecticides may be warranted to protect high value trees. Large forested areas can be aerially sprayed for short-term protection, and individual trees can be sprayed using ground equipment. Several chemical insecticides and the biological insecticide *Bacillus thuringiensis* var. *kurstaki* (B.t.k.) are effective against loopers if applied at the correct time. In 2003 and 2012, British Columbia conducted large-scale western hemlock looper suppression projects using B.t.k. If spraying is considered, State or Federal insect management specialists should be consulted for treatment timing, formulations, dosages, and the most current information on registered insecticides.

Associated Species

There are two other recognized sub-species of *L. fiscellaria* in North America. The hemlock looper, *Lambdina fiscellaria fiscellaria* (Guenee), occurs in eastern North America from Newfoundland south to Georgia and west to Manitoba and Minnesota, where preferred hosts are eastern hemlock (*Tsuga canadensis*), balsam fir (*Abies balsamea*), and white spruce (*Picea glauca*). The western oak looper, *Lambdina fiscellaria somniaria* (Hulst), occurs from Oregon into British Columbia where the preferred host is Oregon white oak (*Quercus garryana*). The sub-species designations of *L. fiscellaria* are largely based on host tree preferences and geographic range. Early records of western hemlock looper and its activity have been published under several former scientific names including *Ellopia somniaria, E. fiscellaria, E. fervidaria,* and *Therina fervidaria*.

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[3] *A biogeoclimatic zone is a geographical area (large ecosystem) with a relatively uniform macroclimate, characterized by a mosaic of vegetation and soils reflecting that climate.*

Figure credits:

Figure 3 - Aleksandar Dozic, Washington Department of Natural Resources (DNR); Figure 4 - Washington DNR; Figures 6 and 8 - Lorraine Maclauchlan, BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development; Figure 7 - Natural Resources Canada, Canadian Forest Service, Figure 9 - Canadian Forest Service, Victoria, BC. All other photos taken by Darci Dickinson, USDA Forest Service.

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The Forest Insect and Disease Leaflet (FIDL) series provides information about insects and diseases affecting forest trees in the United States. FIDLs are produced through coordinated efforts of the US Forest Service's Forest Health Protection staff and its partners from state forestry, academic and research organizations.

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