Forest and Shade Tree Insect and Disease Conditions for Maine

Summary 2021

Maine Forest Service

MAINE DEPARTMENT OF AGRICULTURE CONSERVATION AND FORESTRY

Augusta, Maine

Forest Health and Monitoring
Summary Report No. 32

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Forest Insect and Disease – Advice and Technical Assistance

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Insect and Disease Laboratory
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Phone: (207) 287-2431
www.maine.gov/foresthealth

The Maine Forest Service, Forest Health and Monitoring (FHM) program maintains a diagnostic laboratory staffed with forest entomologists and a forest pathologist. The staff can provide practical information on various forest and shade tree problems for Maine residents. Our technical knowledge, reference library and insect collection enable the staff to accurately identify most causal agents. Our website is a portal to information sheets and notices of current forest pest issues and other resources. Printed information sheets and brochures are available on many of the more common insect and disease problems. We can also provide you with a variety of other useful publications on topics related to forest insects and diseases.

Submitting Samples – Samples brought or sent in for diagnosis should be accompanied by as much information as possible including: host plant, type of damage (i.e., canker, defoliation, wilting, wood borer, etc.), date, location, and site/land use description along with your name, mailing address and day-time telephone number or e-mail address. Forms are available on our website and in the Annual Summary Report for this purpose. Samples mailed to the laboratory should be accompanied by all necessary information and insects should be in crush-proof containers (such as mailing boxes or tubes). Live insects should be provided with adequate host material for food. Disease samples should be enclosed in paper bags. Mail containers for prompt shipment to ensure they will arrive at the Augusta laboratory or Old Town Office on a weekday. Also on our website you can find our on-line report form for forest health concerns. The online version of the form allows attaching several digital images to accompany contact information and description of the tree issue of concern.

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Forest and Shade Tree – Insect and Disease Conditions for Maine Reports
Sign-Up Form

Sign up on-line at: www.maine.gov/dacf/mfs/publications/condition_reports.html (box at upper right)

The Maine Forest Service (MFS) Forest and Shade Tree Insect and Disease Conditions reports and Annual Summary Report provide information about what is impacting the health of Maine's forest and neighborhood trees. Updates are provided during the growing season and otherwise as conditions dictate. Additionally, our website is useful for special alerts and quarantine information. The MFS Insect and Disease Lab maintains hardcopy information sheets on a variety of pest problems that are also available on our website. Diagnostic services are provided as time and personnel resources permit. We are always interested in what you see affecting your trees – let us know!

E-Mail Address _____

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In an effort to conserve State resources, we are moving toward providing most material electronically. Although we will continue to offer the newsletter in hard copy if specifically requested, our default first option is now as an electronic publication.

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Name _____

Mailing Address_____

_____

Telephone_____ **Date (month/year)**_____/_____

Area of Interest (*only check one*):

☐ Academic Institution
☐ Arborist
☐ Christmas Tree Grower
☐ Forester
☐ Government Agency
☐ Landscaper
☐ Land Trust
☐ Library
☐ Logger
☐ Nursery/Greenhouse
☐ Woodland Owner
☐ Interested Individual
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Comments:_____

Return your completed form to:

Insect and Disease Laboratory
168 Statehouse Station
Augusta, Maine 04333-0168

Phone (207) 287-2431
www.maine.gov/foresthealth

Scan to sign up on-line

Email foresthealth@maine.gov or call (207) 287-2431 for a paper subscription form.

MFS Forest Insect and Disease Diagnostic Request and Report Form

Sample provided? yes no Collection date _____

Please package disease samples in plastic or paper bags and insects in crush-proof containers.

Tree species affected _____

Township _____ County _____

Location in Township: (use area at right to construct map)

Property owner, address, and day-time phone number:

_____

_____

_____

_____

Location of affected plants:

- Forest or Woodlot ☐
- Yard or Landscape ☐
- Street or Driveway ☐
- Barnyard or Pasture ☐
- Tree Plantation ☐

Has the plant been recently transplanted? Yes No

Are there other plants of the same kind nearby? Yes No

Are they similarly affected? Yes No

Has the plant been recently fertilized? Yes No

Has the ground been disturbed? Yes No when/how?_____

Have weed control products/herbicides been used in the vicinity? Yes No what?_____

Approximate size of trees: height _____ diameter _____ Number of trees checked _____

Damage Type: none _____ defoliation _____ wood borer _____ other _____

Damage Location: leaves _____ branches _____ trunk(s) _____ roots _____

Degree of damage: none ____ trace to light (<30%) _____ moderate (≥ 30% to 50%) _____ heavy to severe (>50%)

Number of trees affected: none _____ one _____ many _____ OR Number of acres _____

Describe problem and other additional information (if needed you can continue the description on back):

_____

_____

Collector_____ Day-time Phone Number _____email_____

P.O. Address _____

If we need further information to diagnose this sample who should we contact? _____

Day-time Phone Number _____ email_____

Send sample to: Insect and Disease Laboratory, 168 State House Station, Augusta, ME 04333-0168
(or deliver in person to 201 Deering Building, 90 Blossom Lane) Tel. (207) 287-2431
e-mail: foresthealth@maine.gov

Please send diseased herbaceous material to: Pest Management Office, Plant Disease Diagnostics Lab, 17 Godfrey Drive Orono, ME 04473-3692, http://extension.umaine.edu/ipm/

Acknowledgements

The information in this Annual Summary Report has been assembled and reviewed by Aaron Bergdahl, Michael Parisio, Thomas Schmeelk, Colleen Teerling, Amy Emery, and Allison Kanoti of the Maine Forest Service, Forest Health and Monitoring Division (MFS FHM). Many other individuals and organizations have contributed significantly to the information on forest health presented here, including the rest of the Division.

The Forest Inventory and Analysis Unit (FIA) of our Division provided invaluable assistance in a number of areas including servicing spruce budworm pheromone traps and processing samples, surveying for browntail moth, felling and peeling ash trap trees, and collecting data on hemlock woolly adelgid impact plots.

We extend our thanks to MFS employees Greg Miller, Greg Lord, and Jereme Frank for their assistance with mapping, computer, and statistical tasks. Our survey work was greatly enhanced by the efforts of Joe Bither, Wayne Searles, and Abby Karter. Amy Emery is also thanked for her work in the office, being the first contact for many of the public who reach out to our office, managing day-to-day operations, and serving as dispatch for folks in the field. Jeff Harriman is thanked for his versatility in providing a wide range of support tasks enhancing personnel effectiveness and MFS FHM work environments.

We would like to acknowledge Maine Department of Agriculture, Conservation and Forestry (DACF), Division of Animal and Plant Health staff for their assistance with regulatory issues and appreciate their cooperative efforts towards our overall mission to protect Maine's forest resources through the use of forest pest quarantine rules and regulations. We would especially like to acknowledge the cooperation of Ann Gibbs, Division Director; Gary Fish, State Horticulturist; and Karen Coluzzi, who coordinates pest surveys. Their work in quarantines, survey, and outreach dovetails with and enhances our work.

Thanks are also extended to many other administrative and field staff of the DACF, and to our many contacts in the United States Department of Agriculture (USDA) Forest Service, Northeastern Area – Forest Health and Protection, the USDA Animal and Plant Health Inspection Service, and to our other cooperators in the Northeastern States of the United States and Eastern Provinces of Canada. We also thank the Forest Ecosystem Monitoring Cooperative (FEMC) for their assistance with survey efforts in Maine and helping Maine establish a State Partnership Committee to help steer priority issues that can be addressed jointly by the FEMC and MFS FHM. Thank you to University of Maine's Cooperative Forestry Research Unit (CFRU) for continued partnership in monitoring for spruce budworm in Maine and other efforts.

Our sincere thanks go to those who volunteer in survey and monitoring as well as other tasks. Sharon Whitney and Peter Darling both run daily traps for winter moth each holiday season. Thank you to Nancy Sferra of The Nature Conservancy and Jesse Wheeler of Acadia National Park for running traps for the southern pine beetle survey this year. Thanks also to Tim Bickford with the Maine Army National Guard for coordinating the SPB trap in Hollis. Jesse Wheeler is also gratefully acknowledged for assisting in establishment of beech leaf disease long-term monitoring plots in Acadia with MFS staff and Cameron McIntire of USFS Durham office. Cameron is acknowledged for his overall assistance with beech leaf disease following its detection in Maine in spring 2021. We thank the members of Maine Entomological Society for their continued interest in insects and contributions to our knowledge of them in Maine. We would like to gratefully acknowledge all the landowners in Maine that allow us access to their properties for important activities like girdling trap trees for emerald ash borer detection, biocontrol programs and

placing traps for various forest insects. We would like to acknowledge the support of Dr. Elkinton and his lab at the University of Massachusetts in Amherst in rearing the *Cyzenis* pupae and determining parasitism levels at release sites in Maine. Finally, special thanks go to the vigilant residents of Maine who keep extra eyes on our forest resources and alert us to issues impacting tree and forest health.

Introduction

This annual summary report describes the efforts toward understanding and managing the health issues of importance to Maine's forest resources. Emphasis is placed primarily on insect and disease relationships of forest, shade, and ornamental trees. The myriad of biotic and abiotic agents capable of damaging trees can result in losses to wood production and quality, water quality, recreational opportunities and enjoyment, and in some cases impact human health. Conversely, the great majority of these agents are not simply beneficial, but critical to the productive functioning of forest ecosystems. Therefore, our understanding of the role insect and disease agents play in maintaining a healthy forest is as important as mitigating the damaging effects of the few native and invasive pest species capable of significant disruptions to forest sustainability.

The Forest Health and Monitoring Division has four primary mission responsibilities related to insect and disease conditions of our forest resources: 1) **monitoring and evaluating** the resource for overall health using both aerial and ground survey methods; monitoring is done for both specific agents of concern, and in cooperation with the statewide continuous forest inventory efforts of the Division's Forest Inventory and Analysis group; 2) **providing advice and assistance** on forest health issues to private and public landowners, foresters, industrial and commercial entities, and to the general public; 3) **conducting applied research and demonstration projects** to further the understanding and improve management of specific pests of concern and other forest health issues, and 4) **supervising and managing the forest pest-related quarantines** established by state regulations.

As this report will show, there has been a high level of Division activities conducted on several existing pest problems, along with significant efforts towards anticipating forest pests not yet present in the state. And, considering the pest management challenges of the coming seasons, the efforts outlined in this report will serve to strengthen our response towards more effectively managing our forest resources.

Personnel Updates

In Memorium

Doug Denico passed away on October 22, 2021 in Madison, ME. After years of working in the timber industry, he was appointed to the position of State Forester in 2011. He soon after assumed the responsibility for Maine's Public Lands. Doug valued the years he spent working in this capacity, for the people of Maine, and said they were the most rewarding of his career. Doug will be remembered as a dedicated public servant, an advocate of Maine forests and forestry and as an outdoorsman and animal lover.

New Employees

Former Conservation Aide **Amy Emery** transitioned into a new position in 2021 as the new Office Associate at the Augusta Insect and Disease Lab. Fortunately, Amy's prior experience with us meant she was already up to speed with our day-to-day operations and familiar with many of our insect and disease monitoring programs. If you haven't called already, Amy is the familiar friendly voice on the

phone when you reach out to the MFS Insect and Disease Lab. We are excited to continue to work with Amy in her new role with the Forest Health and Monitoring team.

Former Entomology Technician **Regina Smith** left the Insect and Disease lab this past year for a new position as Research and Outreach Coordinator for the University of Maine's Cooperative Forestry Research Unit. While we miss Regina's contributions to our team, we are glad to know she is doing well in her new role and are fortunate to bump into her from time to time through work events.

New entomology technician **Abby Karter** joined the Insect and Disease Lab in 2021 and filled the vacancy created when Regina left. A native of Winslow, Abby is keenly interested in the natural world and has shown great enthusiasm in learning about her new position and its diverse roles. She has already begun providing excellent assistance to the staff entomologists and pathologist with various tasks and project work including beech leaf disease survey, insect trapping, sorting trap catch and much more. We welcome Abby to the Forest Health Monitoring team and look forward to her first full field season with us.

Insect Conditions

Insects: Softwood Pests

Balsam Gall Midge
Paradiplosis tumifex
Host(s): Balsam Fir (*Abies balsamea*)

MFS received only three inquiries in 2021 regarding balsam gall midge (BGM), one each from Hancock, Washington, and York counties, although this pest is likely active elsewhere in Maine forests. One site visit was made to observe effects of a previous mechanical treatment, which appears to have largely resolved the problem in an isolated pocket of a plantation. We are not aware of chemical treatments for BGM in 2021. BGM inquiries were more common in both 2019 and 2020. Damage from this pest appears to remain sporadic.

Balsam Woolly Adelgid
Adelges piceae
Host(s): Balsam Fir (*Abies balsamea*)

Balsam woolly adelgid (BWA) is known to be established in all Maine counties. BWA symptoms and the presence of the insect, in the case of significant trunk-phase populations, are occasionally recorded from Forest Inventory and Analysis plots when encountered. MFS field staff made no significant observations, and no additional surveys were conducted for this pest between 2019 and 2021. There have been few public reports during the past several years, with just a single report in 2019 and two reports in 2020. There were four general homeowner inquiries regarding minor BWA issues in 2021, reported in Cumberland County (Falmouth and South Portland), Kennebec County (Manchester) and Lincoln County (Damariscotta) which did not require field visits.

Elongate Hemlock Scale
Fiorinia externa
Host(s): Primarily Fir (*Abie*s spp.) and Eastern Hemlock (*Tsuga canadensis*)

Elongate hemlock scale (EHS) is well-established in some forested areas in southern Kittery (York County) but has also been detected on planted trees in several towns throughout York, Cumberland (i.e. Frye Island), Sagadahoc, and Hancock counties. In some cases, EHS has moved from planted trees into the surrounding forest. In fall of 2021, two new infestations were confirmed on planted trees in Falmouth (Cumberland County). In one of these locations, EHS had noticeably spread into the surrounding forest; in the other it had not.

See Appendix A for more information.

Hemlock Woolly Adelgid
Adelges tsugae
Host(s): Eastern Hemlock (*Tsuga canadensis*)

In 2021, hemlock woolly adelgid (HWA) was detected for the first time in forested areas in the towns of Bowdoinham (Sagadahoc County), Waldoboro (Lincoln County), and Rockport (Knox County). Generally, high HWA populations were seen across infested regions following another mild winter with low mortality. In an indication that this was a widespread regional issue, trillions of dead insects washed up on some beaches in southern Maine, staining beachgoers' feet. The insects were sent to USFS researcher Nathan Havill for genetic identification and were identified as sexuparae (winged/alate) HWA. Although alates are not uncommon in the spring-maturing generation, no historical records of region-wide mass-dispersal events on this scale were found.

Stands of hemlock with a long history of infestation continue to decline and mortality has been seen in southern Maine in coastal towns in York, Cumberland, Sagadahoc, and Lincoln Counties. Aerial survey detected almost 40 acres of mortality in Arrowsic, Sagadahoc County. In addition, Forest Policy and Management continues to receive variance requests related to declining hemlock in shoreland areas, particularly in the Midcoast.

A fourth field insectary for the HWA predator, *Laricobius osakensis*, was established in the Waldoboro Town Forest (Lincoln County) in 2021 and the site received its entire complement of 2000 beetles over three releases. There were successful recoveries of both *Sasajiscymnus tsugae* and *L. nigrinus,* and for the first time*, L. osakensis* in various locations in southern Maine.

See Appendix A for more information.

Pine Bark Adelgid
Pineus strobi
Host(s): Eastern White Pine *(Pinus strobus)*

An unusually high population of pine bark adelgid was identified during a harvesting operation in Naples (Cumberland County) in May 2021. A site inspection revealed several individual trees with very high population loads. Since samples were so readily available, large pieces of bark were removed and sent to Dr. Nathan Havill at the USFS Northern Research Station in Hamden, CT to assess for adelgid predators and parasitoids. Dr. Havill reported that he did not recover silver fly larvae or puparia of the genera he was hoping to (*Cremifania* or *Leucopis*), but did recover the following: six *Neoleucopis pinicola* (Chamaemyiidae), two *Syrphus torvus* (Syrphidae), and one *Eupeodes americanus* (Syrphidae).

Pine Leaf Adelgid
Pineus pinifoliae
Host(s): Eastern White Pine (*Pinus strobus)*, Red Spruce (*Picea rubens*), Black Spruce (*P. mariana*)

As indicated in the 2018 Maine Annual Summary Report, pine leaf adelgid was of particular interest in 2019 due to activity in previous years. Despite this heightened alert, no observations were reported by MFS staff, no damage was detected during aerial survey, and no public reports were documented during the 2019, 2020, and now 2021 seasons.

Red Pine Scale
Matsucoccus matsumurae
Host(s): Red Pine (*Pinus resinosa*)

Red pine scale was first detected in 2014 in Mount Desert (Hancock County) and subsequently detected throughout Mount Desert Island in the same year, in Lamoine (Hancock County) in 2017 and Kittery (York County) in 2019. Notable new detections of red pine scale in 2020 included Hancock, Gouldsboro, Sorrento, and Surry in Hancock County and Berwick in York County. The distribution of red pine scale in Hancock County suggests natural, wind-driven dispersal or phoresy on birds. The latest 2021 detection of red pine scale in Steuben (Washington County) is not surprising as it is adjacent to known populations in neighboring Hancock County. However this does represent the first official Washington County detection. In Hancock County, some red pine scale related mortality was reported on public lands at Donnell Pond Public Reserve Land.

Southern Pine Beetle
Dendroctonus frontalis
Hosts**:** Pitch Pine (*Pinus rigida*), Red Pine (*P. resinosa*), Jack pine (*P. banksiana*), and other conifers

Southern pine beetle (SPB) is an aggressive bark beetle native to the southeastern U.S. It has been expanding its range from southern states northward. The preferred hosts of SPB are “hard pines” like pitch pine (*Pinus rigida*) and red pine (*P. resinosa*). It has been known to attack eastern white pine (*P. strobus*) and Norway spruce (*Picea abies*) in areas with high infestations.

SPB attacks healthy trees and uses pheromones to attract other beetles to mass attack and overcome host tree defenses. Often the most noticeable signs of a fresh attack are pitch tubes that resemble bits of popcorn on the trunk. SPB can overwinter in all life stages and can have multiple generations in a year. Generally, infestations start in a small area and then spread out as the population increases, with many beetles attacking the same tree.

Between October 4 and November 3, 2021 13 specimens of SPB were collected from Lindgren funnel traps that were deployed by Caroline Kanaskie, a PHD student in the Garnas lab at the University of New Hampshire. This new detection was made at the Waterboro pine barrens in Waterboro, Maine which is owned and managed by The Nature Conservancy (TNC). On November 3rd, 2021 an informal survey was performed by staff from the Maine Forest Service, TNC, Maine Inland Fisheries and Wildlife as well as Caroline from UNH. No infested trees were detected during this survey, which is to be expected for such low numbers of beetles. MFS trapping during the spring dispersal period was conducted at 10 sites with 11 traps total throughout Hancock, Lincoln, Sagadahoc, and York Counties (Great Wass was not included due to personnel shortages). Sites were chosen based on the locations of Maine’s hard pine resources.

The trapping was conducted with the help of TNC and the National Parks Service. Out of the 38 samples collected, all were found to be negative for the target.

SPB is a major threat to Maine's hard pine resources (pitch, jack, and red pine) that inhabit Maine's rocky coastline and also the globally rare inland pine barrens ecosystem. The 2022 trapping schedule will be modified to capture the fall dispersal in an effort to better understand where SPB occurs.

Table 1. Locations of southern pine beetle traps in 2021

Town	County	Location	Target Tree Species	Latitude	Longitude	Install Date	End Date
Bar Harbor	Hancock	Acadia National Park	pitch pine	44.3582	-68.2375	5/7/2021	6/16/2021
Phippsburg	Sagadahoc	Bates–Morse Mountain Conserv. Area	pitch pine	43.7396	-69.8240	5/4/2021	6/23/2021
Phippsburg	Sagadahoc	TNC Basin Preserve	pitch pine	43.8084	-69.84228	5/6/2021	7/1/2021
Phippsburg	Sagadahoc	Popham Beach	pitch pine	43.7373	-69.79943	5/4/2021	7/2/2021
Hollis	York	Hollis Barrens	pitch pine	43.66058	-70.66363	5/4/2021	7/1/2021
Kennebunk	York	Kennebunk Plains "A" WMA	pitch pine	43.40516	-70.62125	5/4/2021	7/1/2021
Kennebunk	York	Kennebunk Plains "B" WMA	pitch pine	43.3835	-70.65108	5/4/2021	7/1/2021
Saco	York	Ferry Beach State Park	pitch pine	43.47415	-70.38594	5/4/2021	7/1/2021
Shapleigh	York	Vernon Walker WMA	pitch pine	43.62286	-70.84677	5/42021	7/1/2021
Wells	York	TNC Wells Barrens Preserve	pitch pine	43.3778	-70.6456	5/6/2021	7/1/2021

Spruce Budworm
Choristoneura fumiferana
Host(s): Balsam Fir (*Abies balsamea*), White Spruce (*Picea glauca*), Red Spruce (*P. rubens*), Black Spruce (*P. mariana*), Eastern Hemlock (*Tsuga canadensis*)

As spruce budworm (SBW) populations continue to fluctuate throughout Maine in recent years, the MFS, University of Maine Cooperative Forestry Research Unit (CFRU), and our extensive cooperator network have continued SBW monitoring in 2021 using a combination of pheromone trapping, light trapping, overwintering larval (L2) sampling, and ground and aerial survey.

A total of 351 pheromone trap sites were operated in spruce-fir forests throughout western and northern Maine in 2021 and usable samples were ultimately collected from 328 sites. The average number of SBW moths per pheromone trap fell for the second season in a row to 16, compared to 36 in

2020 and 67 in 2019. Perhaps due to drought conditions and food scarcity, bear mischief was responsible for destroying traps at 15 sites, with samples from eight other sites lost for other reasons.

The overall range for trap captures was much less as well in 2021, ranging from zero to 174 versus zero to 397 moths per trap in 2020. Massive migration flights like those experienced in 2019, which helped explain high trap captures that year, did not occur in 2020 or 2021. Instead, this marked decrease for the second season in a row might be best explained by weather events. Though we do not have the fine scale weather data available in neighboring New Brunswick, it is believed that abnormal spring weather there may have caused major declines in SBW numbers in areas like the New Brunswick panhandle. Larvae prematurely induced into spring development by very early warm spells are likely to have starved and died as weather patterns returned to normal, bringing with them the cold temperatures more typical for that time of year. Given the close proximity of these observations to Maine, it is likely these weather patterns affected Maine SBW populations as well.

As noted in 2020, mature SBW larvae were once again abundant across northern Maine, accompanied by visible defoliation in several locations in 2021. Last year marked the first time SBW larvae were able to be found so easily since the late 1980s or early 1990s. In response to that apparent increase in SBW populations, a mid-season defoliation survey was performed in 2020 at 60 sites in Aroostook County and repeated in 2021. Fortunately, changes in defoliations levels at these sites were minimal, with the largest increase at any site reaching just 5.5% and all sites remaining within the trace, light, or moderate damage categories.

This most recent population increase also led to the first aerial applications of pesticides for SBW since the last great outbreak. Overwintering larval sampling indicated an area near Cross Lake had reached the treatment threshold set by the Early Intervention Strategy for spruce budworm of seven larvae per branch sample at a site. Subsequent survey confirmed elevated populations in the area and resulted in the landowner treating several thousand acres of forest with two applications of Btk to augment natural mortality of larvae. In addition to this, 2021 was remarkable in that around 850 acres of SBW defoliation damage were visible during aerial survey, making this the first time it has been mapped from the air since the last outbreak as well.

After a dramatic drop to just 107 SBW moths collected from light traps statewide in 2020, catches fell even further in 2021 with only nine SBW moths collected from light traps statewide. In previous seasons, light traps recovered 502 moths statewide in 2019 and 202 moths in 2018.

Additional information on the coming 2022 SBW situation in Maine will be provided byoverwintering (L2) larval sampling results. In exciting news, UMaine CFRU was able to establish a new lab dedicated to this portion of Maine's SBW monitoring program. Maine had been sending branch samples to Canada for processing at the Canadian Forest Service lab in Fredericton, NB. With the establishment of the new lab, we expect UMaine CFRU will release additional material on L2 sampling results, and the full Spruce Budworm in Maine 2021 Annual Report from MFS is still in progress with anticipated availability in spring 2022.

For the complete 2021 Maine Spruce Budworm Report, see Appendix D.

Insects: Hardwood Pests

Anoplophora macularia
Host(s): Likely Maples (*Acer* spp.) and other hardwoods (potential host range of thie insect has not been fully determined)

An intensive follow-up ground survey on August 12, 2021 did not reveal any specimens or damage directly attributable to *Anoplophora macularia*. This survey was performed in response to a single pinned male specimen of *Anoplophora macularia* that was brought to the attention of the Maine Forest Service in spring of 2019. The specimen was reported to have been collected in North Berwick, Maine between 2014 and 2017. MFS will continue to survey for this species in the coming years to determine if there is an established population or whether this is an isolated incident.

Browntail Moth
Euproctis chrysorrhoea
Host(s): Northern Red Oak (*Quercus rubra*), Apple (*Malus* spp.), other Rosaceae family trees and shrubs, and other deciduous trees and shrubs

Browntail moth populations are continuing an upward population trend that began in 2015. Another year of drought in spring and early summer was not conducive to a large-scale outbreak of the fungus *Entomophaga aulicae* that attacks browntail moth caterpillars. Through our monitoring efforts, we detected isolated pockets of the fungus and virus throughout the infested region including in Blue Hill which is considered part of the leading edge. Intense defoliation over the past several years, sometimes by multiple agents and coupled with dry growing seasons, has led to scattered oak mortality and decline throughout the region hardest hit by browntail moth. Mapped acres of defoliation for the both spring and fall aerial surveys increased to near 200,000 acres statewide an increase of 47,000 acres compared to 2020.

A more comprehensive report on browntail moth can be found in Appendix C.

Emerald Ash Borer
Agrilus planipennis
Host(s): Ashes (*Fraxinus* spp.)

Emerald ash borer (EAB) continued to spread rapidly in southern Maine during 2021, while in northern Maine expansion still appears to be much slower. This is likely due partly to the cooler climate in northern Maine, where EAB appears to maintain a two-year life cycle, while in southern Maine, the life cycle can be completed in one year in areas with high population density. In southern Maine, EAB is widely scattered throughout York County, there have been several detections in southern Cumberland County, and it is starting to move into the southern areas of Oxford County. In 2021 there were detections in two new towns in York County, five in Cumberland and two in Oxford County. 2021 also marked the first year of detection in Oxford County. There is both an Emergency Order Area and a Quarantine Area for this pest in Southern Maine. In northern Maine, EAB was not detected in any new towns in northern Maine in 2021. However, the northern Maine quarantine area was expanded due to 2020 detections and feedback from the public on firewood restrictions.

See Appendix B for more information on EAB detections in Maine and 2021 EAB survey efforts.

Spongy Moth (formerly gypsy moth)
Lymantria dispar
Host(s): Apple (*Malus* spp.), Aspen (*Populus* spp.), Basswood (*Tilia americana*), Birch (*Betula* spp.), Larch (*Larix laricina*), Oak (*Quercus* spp.), and others (>300 trees and shrubs)

The current spongy moth situation in Maine began in 2020 with abundant reports of mature larvae from almost all counties in 2020. Despite the increase observed in 2020, defoliation remained limited and was not observed during aerial survey except in one area previously identified from the ground. Informal egg mass surveys in usual areas during the winter of 2020/2021 also did not reveal exceptionally high egg mass densities. Late summer 2021 revealed the true nature of the population increase when the public reports from western Maine came pouring in. Early site visits showed extensive damage in southern Oxford County, where larvae completely consumed vegetation on both hardwood and less-preferred conifer hosts.

Aerial survey documented roughly 55 thousand acres of defoliation damage. Damage was mostly confined to core areas in western Maine in Oxford and Franklin Counties. This core area was contiguous with another 36 thousand acres or so of defoliation across the border in New Hampshire. A few other notable defoliation pockets were identified in Millinocket (Penobscot County) and T3 ND (Hancock County). We expect low-level defoliation occurred statewide, though these were the most severely affected areas visible from the air.

We no longer have a formal spongy moth pheromone trapping survey now that all of Maine has been included in the federal quarantine area. Male moths made their presence known in other ways, however, by inundating our traps used for various other insect surveys. We expect defoliation to continue and expand in 2022.

Oak Leaf Shothole Leafminer
Agromyza viridula
Host(s): Oaks (*Quercus* spp.)

The Insect and Disease Lab received a large number of reports in 2019 due to damage caused oak leaf shothole leafminer. While it is not uncommon to document minimal damage in a few locations each year, damage was without a doubt much more severe and widespread than usual in 2019. In addition to statewide reports in Maine, forest health colleagues in other New England and mid-Atlantic states reported a similar regional increase in damage from this insect as well in 2019. Interestingly, evidence of this periodic pest all but vanished in 2020 and remained virtually absent throughout the 2021 season.

Oak Leafrolling Weevil
Synolabus bipustulatus
Host(s): Oaks (*Quercus* spp.)

Several reports of oak leafrolling weevil were received in 2021 including one notable area of defoliation damage in Arrowsic (Sagadahoc County). Other Maine counties where beetles were observed in large numbers in 2021 include Cumberland (Brunswick, Westbrook) and York (Biddeford, Buxton). We are also aware of significant populations reported in southeast New Hampshire. The last reports of damage caused by this insect in Maine date back to 2005 in Camden Hills State Park (Knox County), however populations appeared to collapse after a single season of defoliation.

In Arrowsic, the damage was reported at the Holt Research Forest which had undergone a harvest the prior winter. Weevil activity may not have been readily apparent before the harvest, although the next generation would have been overwintering in the leaf litter at the time of harvest and subsequently emerging weevils could have been concentrated on the remaining oak trees. Areas adjacent to the harvest appeared to have much lower levels of impact.

Spotted Lanternfly
Lycorma delicatula
Host(s): Tree-of-Heaven (*Ailanthus altissima*, preferred host), Apple (*Malus* spp.), Cherry (*Prunus* spp.), Grape (*Vitis* spp.), Maple (*Acer* spp.), Pine (*Pinus* spp.), and others

The first documented interception of spotted lanternfly (SLF) life stages in Maine occurred in 2020 as the result of shipments of red maple nursery stock bearing SLF egg masses imported from Pennsylvania. Affected nursery stock was out planted in the communities of Boothbay, Freeport, Northeast Harbor, and Yarmouth. It is believed that the egg masses found on trees in Boothbay and Northeast harbor hatched prior to importation into Maine. It is possible that the egg masses found in Freeport and Yarmouth hatched in Maine, however no nymphs or other life stages were observed during follow-up survey work in 2020. No life stages were observed during follow-up survey work in these areas during 2021.

A single SLF interception was recorded on November 3, 2021 in Wells (York County). A single dead adult was discovered inside of a food warehouse by a commercial pesticide applicator performing a treatment and reported it to DACF. Given the poor condition of the specimen, it is unknown whether the adult was brought to the facility alive or dead. Follow-up surveys were performed by the DACF horticulture program.

Winter Moth
Operophtera brumata
Host(s): Oaks (*Quercus* spp.), Maples (*Acer* spp.), Apple (*Malus* spp.), Ashes (*Fraxinus* spp.), Birches (*Betula* spp.) and other trees and shrubs

Maine Forest Service staff continued its winter moth survey using pheromone traps from December 2020 through January 2021 in order to determine where populations were highest and to delineate the outer extents of the infestation area. The survey covered coastal areas of York, Cumberland, Sagadahoc, Lincoln, Knox, and Waldo Counties as well as inland areas of Hancock, Androscoggin, and Kennebec Counties. Traps were deployed at 72 locations along the coast and along a transect progressing inland from known infested areas. These traps captured 25,452 winter moths in total. In areas with large catches the numbers were calculated by weight. The towns with a notably high trap catch in 2021 included Boothbay Harbor (501), Friendship (609), Thomaston (756), Southport (877), South Portland (1,057), Bath (2,260), Harpswell (3,629), Phippsburg (3,975) and Kittery (9,571).

Reports of winter moth defoliation came in from the Boothbay Harbor region (Lincoln County), Kittery (York County), a few of the islands off the coast of Portland including Cushing, Peaks, the Diamonds and Chebeague Island (Cumberland County) as well as Bristol (Lincoln County) and Mount Desert (Hancock County).

The annual release of *Cyzenis albicans* flies, the biocontrol agent for winter moth, took place on May 17 in East Boothbay Harbor. This year's host homeowners, who allowed the cage of fly puparia to be buried

on their property for overwintering, looked after the flies as they emerged and even fashioned a homemade sign to deter disturbance of the cage. Such care is warranted as much effort goes into rearing each fly and only 150 were available for release from 2020 collection efforts.

On May 25, MFS staff collected winter moth caterpillars to further our biocontrol program. Caterpillars were collected at some of our previous release sites including Fort McClary State Park, Two Lights State Park, Harpswell, South Portland, and Bath. A portion of these caterpillars are infected with the parasitoid fly *C. albicans* (the proportion of parasitism varies by location), which is the most effective and specific biocontrol for winter moth. Caterpillars were harder to come by, as has been the case for the past couple of years. The collected caterpillars were sent to our collaborators at the University of Massachusetts at Amherst, Elkinton Lab, to determine the percentage of parasitism and prepare the parasitoids for overwintering.

From these 2021 larval collections, the parasitism rates were found to be 5.71% in Bath, 35.75% at Fort McClary State Park, 0.85% in Harpswell, 0.84% in South Portland and 10.95% at Two Lights State Park. The recoveries in Bath were the first at that site and were quite encouraging because it was the first site where we had fewer than 1,000 flies to release (only 500, released in 2020). The 329 puparia for next year's release were reared by cooperators from the Elkinton Lab and delivered in November 2021 to be overwintered in South Bristol, Maine.

Table 2. Release and recovery of parasitic flies, *Cyzenis albicans*, in Maine.

Town	County	Dates	Number of *Cyzenis albicans* Released	Comments
Harpswell	Cumberland	1-May-13	2,000	Survival not good
Cape Elizabeth	Cumberland	1-May-13	2,000	First recovery 2016; 27.4% parasitism in 2020
Kittery	York	16 & 23-May-14	1,200	First recovery 2016; 35.75% parasitism in 2021
Harpswell	Cumberland	16 & 22-May-14	1,200	
Vinalhaven	Knox	21-May-14	2,000	First recovery in 2018
Portland	Cumberland	15-May-15	2,000	First recovery in 2018, 4.7% parasitism in 2020
Cape Elizabeth	Cumberland	15-May-15	1,000	In 2021 parasitism rates at 10.95%
Harpswell	Cumberland	15-Nov-16	2,000	First recovery 2020 0.85% parasitism in 2021
South Portland	Cumberland	29-Nov-17	3,000	0.84% parasitism in 2021
Bath	Sagadahoc	21-May- 2020	500	Few flies emerged, cage was tampered with. 5.71% parasitism in 2021 (first recovery)
Boothbay Harbor	Lincoln	29-April-2020	500	Great emergence
East Boothbay Harbor	Lincoln	17-May-2021	150	Good emergence
South Bristol	Lincoln	Cage set, 1-Nov-21	329	Release to be made in 2022

Winter moth is another invasive defoliator, and unlike browntail moth, it has an introduced biological control with an excellent track record of bringing populations down to endemic levels. There has been a lapse in funding for winter moth biocontrol efforts in recent years due to success in management of winter moth in Southern New England. We are hopeful that a funding proposal recently submitted by our cooperators in Massachusetts and supported by Maine Forest Service, Maine land trusts, and federal land managers in Maine will be accepted so that more resources can be put towards collection of parasitized caterpillars and introduction of the biological control agent along the leading edge of winter moth populations in Maine.

Diseases and Other Injuries

Overview: The Forest Pathology program travels the state of Maine, conducting site visits, providing technical assistance and doing forest disease surveys to gain a better understanding of the state's forest health conditions. Seven presentations by the pathologist were given on various forest and shade tree pathology and forest health topics and contributions were made to a further four presentations given by other forest health staff. In 2021, assistance was provided to approximately 383 landowners, homeowners, foresters, partners and others. An additional 37 on-site visits occurred involving tree and forest disease diagnostic assistance. Contributions were made to seven issues of the *Forest and Shade Tree Insect and Disease Conditions for Maine* newsletter, which, in addition to this Annual Summary Report, is coordinated by the staff forest pathologist.

Aerial survey of pathological forest health issues was limited in 2021. Following the detection of beech leaf disease (BLD) in Midcoast Maine, this area was surveyed using on-the-ground methods. BLD detection led to increased survey efforts and the establishment of seven long-term monitoring plots in the state in cooperation with the US Forest Service Pathologists in Durham, NH. Since the detection of BLD in Maine, the staff forest pathologist has regularly participated in monthly BLD Research Group meetings. Again in 2021, the pathology program assisted the USFS in assessing white pine crowns in Bethel as part of a long-term white pine health project. Also in 2021, MFS cooperated with Michigan State University to do spore trapping as part of an epidemiological study to reveal the sporulation period of the fungus causing Caliciopsis canker of eastern white pine. Maine Forest Service's pathology program continues to participate in a national white pine health group and efforts within Maine to better understand eastern white pine health and management. The pathologist did not attend any in-person meetings or workshops in 2021 due to the COVID-19 pandemic but did participate in several meetings and workshops online.

Finally, findings from the USDA Forest Service-funded multi-state Evaluation and Monitoring (EM) effort aimed at enhanced monitoring of the white pine needle damage disease complex and overall white pine health were published (2022) in the in general technical report, Forest Health Monitoring: National Status, Trends, and Analysis 2021. This concludes work associated with the white pine decline grant from 2018.

Diseases and Injuries: Native

Anthracnose Diseases of Hardwoods
Various species, depending on the host species
Host(s): Ashes (*Fraxinus* spp.), Birches, (*Betula* spp.), Maples (*Acer* spp.), Oaks (*Quercus* spp.), Sycamore (*Platanus occidentalis*)

Anthracnose diseases were encountered more frequently than expected in 2021. Due to the dry spring and low occurrence of these diseases in 2020 and the rainless months of May and June in 2021, anthracnose infection levels were expected to be trace in 2021. However, this was not the case, with unusually high and widespread reports of maple anthracnose in the southern quarter of Maine and a handful of birch and oak anthracnose reports. One particularly interesting report of severe oak anthracnose came from Sedgwick (Hancock County) where several mature backyard oaks were severely impacted, with deformed leaves from top to bottom. However, while one tree was severely impacted, some neighboring trees were unaffected or had only small lesions that occurred on fully expanded leaves. This perhaps demonstrates the importance of the relationship between tree phenology and timing of weather conditions conducive to disease. Trees that flushed earlier were minimally impacted,

while later-flushing leaves formed lesions on expanding leaf tissue, leading to severe deformation of leaves and heavy defoliation. This is of interest due to the increasing unpredictability of seasonal weather patterns and temperature fluctuations and their potential impacts on foliar diseases.

Armillaria Root Rot
***Armillaria* spp.**
Host(s): Trees, shrubs, and several other plant species.

The Armillaria root rot fungus is present throughout the environment and several species are thought to occur in Maine. Armillaria root rot was seen in all Maine Counties in 2021 parasitizing stressed trees. The fungus appears to be a significant factor contributing to tree mortality, however significant predisposing stressors are often easily identified in affected areas. The Armillaria root rot disease complex remains a concern due to the widespread stress to pines in Maine, especially white pine, that have suffered several years of heavy defoliation due to the fungi causing white pine needle damage. Red pine under pressure from Diplodia tip blight and Sirococcus shoot blight (these issues are discussed in their own section in this report) are also being monitored for stress-related increases in Armillaria. Additionally, increased incidence of *Armillaria* spp. has been seen in areas impacted by drought and summer flooding. The fungus is also readily found in areas impacted by the 1998 ice storm. The drought periods of 2020 and 2021 throughout much of Maine may lead to an increase of mortality caused by this ubiquitous, stress-related secondary pest.

Caliciopsis Canker of White Pine
Caliciopsis pinea
Host(s): Eastern White Pine (*Pinus strobus*)

Caliciopsis canker of white pine (*Caliciopsis pinea*) was commonly seen in 2021 during visits to white pine stands. Caliciopsis canker was seen affecting the health of codominant and suppressed white pine trees and seems to be responsible for mortality among white pine seedlings and saplings in the understory of infected stands. Caliciopsis canker is thought to be associated with overstocked stands and poor soils, but this relationship in Maine is only anecdotal. Drought stress from consecutive periods of drier-than-normal weather may favor further *Caliciopsis* disease development and impact. In 2021, the MFS cooperated with Michigan State University to do spore trapping as part of an epidemiological study to reveal the sporulation period of the fungus causing Caliciopsis canker. We hope results of this study will provide important knowledge to inform future white pine management decisions. This spore trapping effort will continue in 2022.

Bot Canker
Diplodia corticola
Host(s): Oaks, primarily Northern Red Oak (*Quercus rubra*) in Maine.

Bot canker was reported in several locations in York County in early summer 2021. The disease was also seen impacting red oaks in additional locations in Androscoggin, Cumberland, Kennebec, Hancock, Knox and Waldo counties. On a trip to visit a homeowner with flagging oak branches in Wells (York County), Bot canker was noticed all along route 109 and in some cases the damage was severe and widespread in the crown, with infected seedlings in the understory. As bot canker seems to infest stressed oaks more extensively, perhaps the oak trees in this area, characterized by sandy, drought-prone soils, have suffered drought stress due to the long periods of dry weather in the previous growing seasons. The Wells homeowner's oak tree was in steep decline due to heavy bot canker infestation, despite regular

watering via an irrigation system. However, the source of stress likely leading to high infestation was identified as the recent landscaping work done in close proximity to the tree. It may be important to note that a majority of the oak trees assessed for bot canker also had noticeable populations of Kermes scale (*Allokermes* spp.). This has been noted in earlier years as well. Oak anthracnose was also seen co-infecting some trees. Oak twig pruner (*Anelaphus parallelus*) was also recorded at several bot canker sites.

Fire Blight
Erwinia amylovora
Host(s): Trees and shrubs in the Rosaceae family (Apple, Pear, Cherries, and Mountain-Ash account for most instances of fire blight in Maine).

Fire blight was observed on several Rosaceous hosts throughout Maine in 2021 and is likely present at various levels throughout the state. Most infections occur earlier in the season, spread to blossoms by pollinating insects that become infested with the bacteria. Occurrence of fire blight is favored by extended periods of moist weather, since free moisture is a key element to bacterial colonization of host material via entry points such as the nectaries of flowers and wounds. The number of reports and observations of fire blight was consistent with previous years despite the abnormally dry weather in the months of May and June in 2021, a key time period for fire blight spread. Where fire blight is present, it has the ability to spread quickly and cause high levels of damage, especially when plants are injured via pruning, insect damage and extreme weather events. Hail events are known to increase the incidence of fire blight infection. Contrary to expectations, there were no reports of fire blight in 2021 in the areas of Sanford that experienced severe hail in 2020.

Fir Needle Casts
Lirula nervata*, *L. mirabilis*, *Isthmiella faullii*, *Rhizosphaera pini
Host(s): Balsam Fir (*Abies balsamea*), Fraser Fir (*A. fraseri*)

Fir needle disease incidence appeared to be light, with only a few observations of fungi in the genera *Lirula* and *Rhizosphaera* causing minor damage in Christmas tree plantations and only one report of larger-scale heavy damage in Waldoboro. Although not the case in Waldoboro where affected trees were in a higher and drier area, in most cases the degree of needle cast infection seems to be largely dependent on where and how trees are planted: trees planted in low-lying areas with poor air circulation and trees planted too close together and/or with inadequate vegetation management under and around the trees are most susceptible to needle diseases. Fir needle diseases can be managed by well-timed fungicide applications as part of an integrated pest management strategy. However, this may be challenging, for example, due to limited knowledge on spore dispersal of fir needle casts.

Hemlock Shoot Blight
Sirococcus tsugae
Host: Eastern Hemlock (*Tsuga canadensis)*

Hemlock shoot blight especially affects hemlock regeneration in forest habitats, typically closer to bodies of water. Once abundant in southern and southwestern areas of Maine, hemlock shoot blight was not reported by the public in 2021. During hemlock survey, forest health staff saw this tip blight only a few times. Hemlock rust, on the other hand (it was not possible to determine if the rust was *Thekospora hydrangea* or *Pucciniastrum vaccinii*), was reported in Hancock County and observed by forest health staff in Oxford County.

Phomopsis Galls on Oak
***Phomopsis* spp.**
Host(s): Oaks (*Quercus* spp.), occasionally other hardwoods

Reports of Phomopsis galls on oaks are typically received in spring before leaf-out and again when oaks lose their leaves in late fall/early winter when the unusual looking and often numerous galls are easily seen on the branches and the main stem of individual oak trees. Annually, the number of reports is consistent and the pea-sized up to softball-sized (or sometimes larger) galls seldom represent more than an aesthetic issue. Trees with many galls and on larger branches may show dieback in the crown, but this is rarely a disease that by itself results in tree mortality. However, the stress from heavy Phomopsis infection may lead to attack by secondary pests, hastening decline. As susceptibility to Phomopsis gall disease is thought to be genetically based, management recommendations are not given to landowners, unless to cut down the impacted trees to encourage the growth of unaffected neighboring trees or to improve landscape aesthetics.

Red Pine Decline
Diplodia pinea, Sirococcus conigenus
Host(s): Red Pine (*Pinus resinosa*), Scots Pine (*P. sylvestris*), and Austrian Pine (*P. nigra*)

Red pine plantings throughout Maine are commonly infected by Diplodia tip blight (*Diplodia pinea*) and Sirococcus shoot blight (*Sirococcus conigenus*) is also commonly seen, although not nearly as often as *D. pinea*. Data from an informal survey of red pine stands that began in 2019 showed that nearly all stands had active Diplodia tip blight infections and all stands had lower crown mortality. About one third of plantations had Sirococcus shoot blight, and those same stands also had Diplodia tip blight. The diseases are also found in native red pine stands. Infection potential is largely driven by cool, wet springs and prolonged periods of wet weather in summer. While these weather conditions have been common in most of the Northeast for a majority of the past 15 years, the long dry periods of the spring and summer of 2020 and 2021 may mean lower disease pressure in the coming years, although this cannot be certain. Perhaps just enough moisture and the concentration of suitable host material (plantations) will result in continued steady decline of Maine's red pine resources. No red pine stands were surveyed in 2021; we hope to resume this survey in 2022.

Red Ring Rot of White Pine
***Porodaedalea pini* (formerly *Phellinus pini* and including other related *Phellinus* species)**
Host(s): Eastern White Pine (*Pinus strobus*), also other Pines (*Pinus* spp.), Spruces (*Picea* spp.), Larches (*Larix* spp.), and several other conifers

Red rot is considered the most economically significant disease of mature white pine and other conifers because it causes the highest wood volume losses. The decay fungus *Porodaedalea pini* is often associated with over-mature trees, and with trees growing poorly in understory conditions or on poor sites. This pathogen may go unnoticed due to the habit of the fungus to produce a fruiting body only after advanced decay in large trees. *P. pini* is regularly seen in mature pine stands throughout Maine and reported a few times each year by foresters and landowners.

Eastern Dwarf Mistletoe
Arceuthobium pusillum
Host(s): White Spruce (*Picea glauca*), Black Spruce (*P. mariana*), Red Spruce (*P. rubens*), Balsam Fir (*Abies balsamea*) and Larch (*Larix* spp.)

In coastal areas of Maine where spruce is present, one does not have to look too far to find examples of damage to spruce trees by the obligate plant parasite, eastern dwarf mistletoe. In 2021, this disease was frequently seen in inland areas of Maine as well and occasionally on other species such as fir. On a trip to Islesboro in 2021, eastern dwarf mistletoe was seen severely impacting spruce trees, especially near the southern end of the main island. Observations of severe mistletoe were also made on coastal peninsulas in Sagadahoc, Knox, and Waldo Counties.

Spruce Needle Casts
Rhizosphaera kalkhoffii, Stigmina lautii
Host(s): White Spruce (*Picea glauca*) and Colorado Blue Spruce (*P. pungens*), Norway Spruce (*P. abies*) is typically more resistant, but is also affected.

Spruce needle cast diseases reports were consistent with previous years and the diseases continued at moderate to high levels across the state, wherever the spruce hosts occur. It has been especially damaging to ornamental plantings of mostly blue spruce, but also less frequently white spruce, in suburban settings, in public parks, and along community streets. Severe damage to trees from the needle casts has resulted in some mortality, but more often the aesthetic impacts associated with the diseases, like needle loss and lower branch dieback, lead to a significant number of removals. The spruce needle cast disease survey has continued in 2021 based on samples received at the lab and a few field collections. This will continue in 2022.

Tar Spot of Maple
Rhytisma acerinum
Host(s): Norway Maple (*Acer platanoides*); occasionally other Maples (*Acer* spp.)

Reports of tar spot of maple occur in average abundance each autumn in Maine. Most reports come from urban centers, but also less frequently in more rural settings where Norway maple has been planted as an ornamental. Dry spring weather in 2020 may have decreased disease pressure in 2021 and the further dry weather in May and June of 2021 may lead to a further reduction in severity – although we can still expect calls from concerned citizens about this conspicuous disease of Norway maples. The increasingly invasive Norway maple tree has few serious pests and is not significantly harmed by the tar spot fungus. This is a rare case when foresters and pathologists may wish for this disease to be more virulent to combat the spread and success of *A. platanoides*, especially in urban and riparian forest areas. There are several tar spot fungi in the genus *Rhytisma* that can occur in Maine and affect a variety of deciduous hosts. Tar spot of blueberry (*Rhytisma vaccinum*) was seen in Kennebec and York Counties in 2021 and appeared to be widespread near water bodies in several areas.

White Pine Needle Diseases
Mycosphaerella dearnessii (= Lecanosticta acicola), Lophophacidium dooksii* (formerly *Canavirgella banfieldii*), *Bifusella linearis and Septorioides strobi
Host(s): Eastern White Pine (*Pinus strobus*)

The white pine needle disease (WPND) complex that has been impacting regional white pine trees, for the better part of two decades, has continued to result in extensive premature needle shedding. This disease-related summer needle drop typically occurs in late May through early July wherever white pines grow across Maine. Heavy needle losses resulted in a moderate number of disease clinic requests for assistance. The number of calls is not a reliable indication of disease conditions, since people have become used to summer needle discoloration and premature needle shedding, much like the natural needle shedding that occurs in fall. WPND remains widespread, but is most severe throughout central, western, and southern Maine. Impacts on white pine seemed to be especially severe in southeastern Maine in 2021.

Due to the nature of the infection cycles of the needle diseases that comprise the WPND complex, disease severity projections are based on the frequency and length of moisture events during the spore dispersal periods of the previous spring. However, predicting the severity of this disease complex in recent years has been less straightforward. Heavy infection levels in 2018 and several prolonged periods of wet weather in spring 2019 led to predictions of severe discoloration and defoliation in 2020. However, observations from around the state did not indicate that 2020 damage was more severe than in previous years, and in fact seemed to be average. On the other hand, due to the very dry weather of spring and early summer 2020, WPND severity for 2021 was forecasted to be low. This was also predicted by USFS WPND impact models. However, this was not true and in some cases damage from WPND seemed to be worse than ever. This could have been in part due to stress from the drought conditions in May and June 2021 worsening needle discoloration. Further, these dry conditions in spring/summer 2021 could lead some to predict WPND severity will be lower in 2022, but based on the conditions this year, one cannot be sure of such predictions.

Overall, due to the mostly consistent WPND damage levels over the past years, combined with environmental stressors like the back-to-back droughts during the growing seasons of 2020 and 2021, the near-future implications of this chronic disease remain a concern. Continued monitoring of white pine health will be prioritized for early detection of any emerging insect or disease agents that could serve as further factors leading to white pine decline and mortality.

Lastly, the final report concluding the multi-state USFS-funded project “Monitoring eastern white pine decline and its causes in New England and New York through enhanced survey methods” will be published in 2022 in the USDA Forest Service’s Forest Health Monitoring Program General Technical Report (GTR), Forest Health Monitoring: National Status, Trends, and Analysis 2021.

Diseases: Non-Native

Beech Leaf Disease
Litylenchus crenatae mccannii
Host(s): American beech (*Fagus grandifolia)* and non-native and ornamental varieties of *Fagus* spp.

Beech leaf disease (BLD) was confirmed for the first time in Maine in 2021. Extensive symptoms of beech leaf disease were reported in a forest in Lincolnville (Waldo County) and confirmed by MFS and USFS Durham Field Office forest pathology staff in late May. Affected leaf samples were sent to Dr. Robert Marra of Connecticut Agricultural Experiment Station and presence of the suspected causal agent, the nematode *Litylenchus crenatae mccannii*, was confirmed via molecular methods. The diseased trees were brought to the attention of the Maine Forest Service Pathologist by the landowners,

who pay close attention to changes to the trees on their property during their frequent walks through their forest. Symptoms of the disease have since been confirmed, in order of detection, in Waldo, Knox, Lincoln, and Penobscot counties (see Appendix E). The disease is currently widespread in Waldo and Knox counties, while the distribution in Lincoln and Penobscot counties is not fully known. BLD is likely to be found elsewhere in Maine and further survey efforts are planned for 2022.

The BLD detection was communicated to the public through various forms of media and in monthly Maine Forest Service Conditions Report bulletins throughout the summer and fall. This public outreach proved to be very effective as many reports of BLD came from landowners, recreationalists, and foresters in the form of calls, text messages and emails with pictures. Prompt BLD training for MFS staff and other Department of Agriculture, Conservation and Forestry cooperators also led to numerous confirmed reports of BLD. We will continue to engage the public in 2022 and ask for their help in identifying additional areas impacted by beech leaf disease.

In cooperation with the USFS Durham Office Forest Pathologists, seven BLD long-term monitoring plots were established; one in each of the following locations: Cumberland, Hancock, Kennebec, Knox, Oxford, Penobscot and Waldo counties. These plots will be monitored for approximately the next five years to assess the progression of beech leaf disease in Maine and the combined impacts of other health threats to beech like beech bark disease.

See Appendix E for a map of the current known distribution of BLD in Maine.

Butternut canker
Ophiognomonia clavigignenti-juglandacearum* (formerly *Sirococcus clavigignenti-juglandacearum)
Host: Butternut (*Juglans cinerea*)

The health of butternut trees continues a steady decline across Maine wherever butternut trees grow. Informal survey of the disease continues with butternut canker consistently found on butternut trees. On one assistance call to a home in rural Newport (Penobscot County), the staff pathologist was called to check extensive leaf damage to a butternut tree (which turned out to be mite damage). The expansive, multi-stemmed mature tree appeared to be a native butternut, was canker-free and held a large crop of nuts. Occasionally, trees that resemble butternut are found without disease. It is thought that these disease-free trees are hybridized with Japanese walnut, a species shown to have resistance to butternut canker.

Dutch Elm Disease
Ophiostoma ulmi; O. novo-ulmi
Host(s): Elms (*Ulmus* spp.)

Overall, the level of Dutch elm disease (DED) remains consistent in younger elms in mixed forest and roadside stands. Several notable large elms in Knox and Lincoln Counties were lost to DED in 2021. Landowner requests for assistance have been steady compared to previous years, with some landowners willing to try to manage DED via pruning and therapeutic treatments (even after being informed that these efforts are not likely to be effective). These effectiveness of these efforts will be informally monitored.

European Larch Canker
Lachnellula willkommii
Host(s): Native and Non-native Larch (*Larix* spp.)

In the fall of 2007, European larch canker (ELC) was found on several non-native larch trees planted decades earlier on a golf course in Brunswick initiating a spot eradication effort for infected trees in 2008 and 2009. These efforts continue at present with annual monitoring and sanitation measures. Since 2009, the main factor limiting eradication efforts has been the golf course's available funding for tree pruning and removal. In 2020, the ownership was able to secure funding for removal of several trees. This enabled MFS to facilitate and contribute to increased eradication efforts in spring 2021. For the past two years, MFS have been actively assisting with pruning work (just under 100 cankers removed in 2020). In early April 2021, MFS staff pruned a further 43 cankers among roughly 70 remaining larch trees on the course grounds. The most positive development in this cooperative effort has been the landowner's removal of larch trees based on MFS recommendations from yearly survey work. In the past year, roughly 40 infected and hazard larch trees have been removed, a steep increase from previous years' removal numbers. Pruned material and removed trees were chipped and burned on site as directed by MFS Forest Health staff. More larch tree removals are planned for spring 2022 based on the 2021 survey. Cooperative work to eradicate ELC in this area will continue.

The MFS conducts annual surveys for ELC near and within quarantine areas, focusing on towns next to those where the disease has been confirmed. Thus far, surveys have shown that the regulated area has remained stable. All ELC-related efforts will continue in 2022 with an increased focus on winter survey.

Oak Wilt
Bretziella fagacearum
Host(s): Oak (*Quercus* spp.); Red Oak-group Oaks (highly susceptible), White Oak-group Oaks (moderately susceptible)

Oak wilt has not been found in Maine. In previous years, MFS has surveyed for this destructive disease, supported by an emerging pest grant from the US Forest Service. Survey in 2021 was done by general observation and investigating all reports of flagging/wilting oak branches from the public. No suspicious cases of oak wilt were encountered. Instead, Bot canker (*Diplodia corticola*), mechanical damage, oak twig pruner (*Anelaphus parallelus*), oak anthracnose (*Apiognomonia errabunda*), Kermes scale (*Allokermes* spp.) and browntail moth (*Euproctis chrysorrhoea*) damage were found to be the causal agents for oak wilt-like symptoms. Informal survey for oak wilt will continue in 2022.

White Pine Blister Rust
Cronartium ribicola
Host(s): Eastern White Pine (*Pinus strobus*), Currants and Gooseberries (*Ribes* spp.)

White pine blister rust (WPBR) remains a significant threat, especially to white pine regeneration and sapling-sized trees throughout the white pine resource in Maine. This disease was seen impacting white pine regeneration in Androscoggin, Cumberland Kennebec and Knox counties in 2021, although white pine blister rust can typically be found wherever white pine and the rust's alternate hosts grow in Maine. In 2021, there were some inquiries about the commercial cultivation of currants in Maine. Due to the European black currant being a highly effective alternate host crucial to the disease cycle of WPBR, and the rust fungus' documented ability to break the resistance in varieties marketed as resistant

to the disease, existing regulations will continue to be enforced to protect Maine's valuable white pine resource.

Abiotic/Weather Events

Drought
Host(s): All Species

May and June of 2021 saw very low amounts of precipitation across Maine. This followed a dry growing season throughout Maine in 2020; one that saw the USDA declare Aroostook County an official Drought Disaster Area. By July 6, 2021, all of Maine was at least abnormally dry, with large portions of the state classified as being in moderate to severe drought. The impacts on some trees in some areas were more immediate, while some symptoms thought to be attributable to drought appeared later in the season. These included early and more extensive senescence of fir foliage, increased fall needle drop of pines, and premature leaf loss from some hardwoods before their typical colorful fall foliage display. The fact that some drought symptoms appeared after record rainfall later in July made explaining delayed drought stress to the public more challenging. It is expected that drought impacts from 2020 and 2021 will continue to be seen in the coming years.

Also related to drought conditions in 2021, Maine experienced another very active wildfire season. A total of 629 wildfires were documented in 2021, burning a total of 372.6 acres.

Frost Damage
Host(s): All Species

A July report from the forest industry described sporadic pockets of wilting beech, yellow birch and white birch leaves throughout a large acreage in the Squaretown Township and Indian Stream areas in Somerset County. A site visit revealed wilting of newly emerged foliage, especially of beech, only in open harvested areas and on edges (there was no damage on the canopies of trees growing within stands of regeneration). Further observations revealed similar damage to alder and raspberry. With these symptoms and no clear signs of disease and no recent history of herbicide use, it was concluded that the damage was likely caused by a late-may frost event (possibly May 28, when temperatures at regional weather stations recorded below freezing temperatures). Wilted and dried out leaves remained on the impacted species. As these locations were also impacted by the severe lack of rain in May and June, trees were struggling to flush new sets of full-sized leaves, making crowns appear very thin. By the time of the site visit, some trees had recovered quite well, while others did not. Soon after this site visit, a similar report came from a forest health technician in T7 R18 WELS, Somerset County. Another report followed from a forester in T3 R3 WELS, Aroostook County. At this site, wilted new growth of fir in the lower half of the crown also supported a similar potential for frost damage. Samples were collected at each location and observed at the Augusta lab. No clear evidence of a pathogen as the primary agent for these symptoms was visible.

Hail Injury
Host(s): All Species

A 2020 hail event in the Sanford area, York County, caused serious damage to trees in a roughly 2000-acre area centered along Rte. 109, west of the airport, also including several peripheral areas. Aerial

survey in 2021 indicated that the forests of this area looked to be in poor condition. Groundtruthing revealed that the trees were not recovering vigorously from the previous year's damage. Crowns were heavily damaged and branches and younger thin-barked trees were riddled with wounds, some healing and some that likely led to branch dieback. Surprisingly, no diseases that would regularly be associated with this type of widespread damage were noticed. However, many of these trees could have been exposed to canker fungi and decay organisms, the impacts of which may be seen in the coming years. The white pine in this area was also impacted by WPND, further contributing to the appearance of poor forest health in this area.

Herbicide Injury
Host(s): All Species

Reports of herbicide damage to trees in residential areas were steady in 2021 compared to previous years. Harm to non-target trees and shrubs due to improper application of broad-spectrum and selective herbicides used for vegetation control was seen in several cases, mostly in residential settings and rights of way. Instances of nefarious use of herbicide to kill trees continue to occur yearly in Maine and are referred to the Board of Pesticide Control.

Winter Injury
Host(s): Evergreen Trees and Shrubs

Evergreens continue to be impacted by de-icing salts applied to roads in winter. As symptoms develop in late winter along many of Maine's roads, reports from the public become increasingly common. Salt damage symptom were mostly reported along major roadways and overall the damage seemed to be worse than in previous years. Winter burn continues to be frequently encountered and reported in late-winter to spring, especially among varieties of arborvitae planted in urban and horticultural settings.

Division Activities

Partnership with the Forest Ecosystem Monitoring Cooperative
In 2021 the Maine Forest Service began a partnership with the Forest Ecosystem Monitoring Cooperative (FEMC, formerly the Vermont Monitoring Cooperative) based out of the University of Vermont through a cooperative agreement with the USDA Forest Service. The organization's mission is to evaluate long-term trends in the health of the forests of the Northeastern United States and to benefit natural resource management, education, and increase public interest. The FEMC produces accessible products to communicate the rich data they have access to, such as the forest health indicators dashboard which provides snapshots of the status of Maine's forests and the biotic and abiotic factors influencing them.

As part of the Maine Forest Service's involvement in this partnership, 35 plots were established throughout Maine across a diversity of forest types. With planned annual survey of these plots, it is hoped that not only long-term changes will be tracked, but also short-term changes in Maine's forests will be detected, such as insect, disease, or environmental agents, or combinations thereof, causing rapid changes. The plot network will also serve as a foundation for other projects aimed at evaluating forest health.

In addition to longer-term projects, FEMC also does short-term "Sprint Projects" which can focus on regional, but also Maine-specific forest ecosystem issues. Examples of Sprint Projects done in other states include looking at deer browse impacts on forest regeneration; an analysis of the rate, extent and timing of all timber clearing in a state (NH) over an 18-year period in order to better understand patterns of silviculture and forest conversion; detailed analysis of carbon storage and sequestration rates between managed and unmanaged forest (NH). The topics of sprint projects are determined each year during various FEMC meetings. Longer-term projects are also annually reviewed at these meetings.

Work to form a steering committee of Maine stakeholders was initiated in 2021 to work with Maine Forest Service and the FEMC to determine appropriate projects for the state and other ways to move forward the relationship with FEMC.

Insect Collection

The Maine Forest Service Insect Collection contains over 73,000 specimens in the reference portion of the collection. Additionally, there are more than 5,000 ant specimens stored in alcohol, more than 60,000 spider records, and in excess of 10,000 bark beetle and woodborer specimens. Most of the specimens are stored at the MFS Entomology Lab located in the Deering building. We are still awaiting verification of our pro-tem Syrphidae collection by John Klymko (Atlantic Canada Conservation Data Centre, Sackville, NB Canada) as well as identification of our pro-tem Ichneumonidae by Dr. Istvan Miko (UNH) lab. We hope to add more species to our understanding of Maine's insect communities through these identifications.

Quarantine Administration

The most significant change in forest pest regulations came in the form of federal deregulation of emerald ash borer in January 2021. Maine has continued to enforce the State regulations in place at the time of federal deregulation and has adopted additional regulations to take the place of those previously enforced through federal regulations. All out-of-state areas previously designated as infested under federal regulations have been incorporated into Maine's designated regulated areas, thus continuing to prohibit importation of regulated ash items into non-regulated areas of Maine from other states. Deregulation of wood chips that may contain ash marks the most significant change to the list of regulated ash items. Maine continues to strictly enforce a ban of all non-heat-treated firewood from out-of-state,regardless of tree species. Limited movement of regulated items continues to be permitted under State-issued compliance agreements. At present, in addition to quarantine areas, there exists an emergency order area for a portion of southern Oxford County. Current boundaries of regulated areas can be found at www.maine.gov/eab.

Other notable changes to quarantine regulations in 2021 include the removal of State regulations pertaining to pine shoot beetle, following the removal of Federal regulations in late 2020. Otherwise, regulated area boundaries and regulations for European larch canker, *Lymantria dispar*, hemlock woolly adelgid, and white pine blister rust (*Ribes* spp.) remain the same since the 2020 annual summary report.

Regulations surrounding all of the forest pests mentioned here are subject to change and up-to-date information can be found by visiting the DACF website, www.maine.gov/foresthealth. Specific questions about forestry-related quarantines and moving regulated material and requests for compliance agreements can be directed to Michael Parisio: michael.parisio@maine.gov; phone: (207) 287-7094; mailing address: Maine Forest Service, 168 State House Station, Augusta, ME 04333.

Light Trap Survey

The Maine Forest Service has been monitoring forest insect pest populations with an array of light traps across the State for over 70 years. Fifteen traps were run in 2021 in locations from South Berwick to Ashland to Topsfield (Table 3). Rothamstead light traps are used in most locations with a blacklight (BL) trap at the remaining site. The Rothamstead traps have a 150W light bulb inside a protective casing with an entrance for moths. The moths fall down a funnel into a can where they die. Blacklight traps have metal fins that the moths hit as they fly toward the light and then fall into a collecting can. Trap operators collect the catch daily and send it in weekly to be processed. Traps run for either 30 or 45 days depending on the location and flight season of the moths of interest. The results are used in predicting forest pest outbreaks. A heartfelt thank you goes out to current trap operators. We are actively looking for replacement volunteers since some of our long-term light trappers who have been helping us for decades have decided to retire from the activity. Logistical complications from Covid-19 meant that certain operators were not able to operate their light trap due to not coming to Maine this summer or border checkpoints that were closed due to border closures.

A checklist of significant insect defoliators is used in sorting the moth catch material. Trap catch records for some of these insects are available for over 30 years' worth of trapping. Other insects that are trapped and occur in unusual numbers or have not been seen before are noted in the light trap records. A portion of the moth catch is saved for use in outreach programs during the remainder of the year. Pest populations of significance are reported in the appropriate section of this report. These traps are also used to monitor for invasive species coming into the State. The older portions of this long-term dataset have been digitized up to year 2020, so they are in an easy-to-share format for use by researchers and for our own use. Additions were made to help track population trends of some species over time. Additions included Luna moth (*Actias luna*), Io moth (*Automeris io*), Cecropia moth (*Hyalophora cecropia*), Saint Lawrence tiger moth (*Arctia parthenos*), giant leopard moth (*Hypercompe scribonia*) and a category called "other saturniids" Some targets that were removed from the list were the eastern black-headed budworm *Acleris variana* and the Siberian silkworm *Dendrolimus sibiricus*.

Table 3. 2021 Light trap locations

Trap Location	County	Start Date	End Date	No. Nights	Trap
Allagash	Aroostook	7/1/2021	7/31/2021	30	Rothamstead
Ashland	Aroostook	7/1/2021	7/31/2021	30	Rothamstead
Garfield (6 mile check point)	Aroostook	*Data for this site was accidentally combined with Ashland*		30	Rothamstead
Clayton Lake Twp	Aroostook	7/1/2021	7/31/2021	30	Rothamstead
New Sweden	Aroostook	7/1/2021	7/31/2021	30	Rothamstead
Big 20 TWP (Estcourt)	Aroostook	7/1/2021	7/31/2021	30	Rothamstead
Cape Elizabeth	Cumberland	6/16/2021	7/31/2021	45	Rothamstead
Rangeley	Franklin	6/16/2021	7/31/2021	45	Rothamstead
Salem Twp	Franklin	7/1/2021	7/31/2021	30	Rothamstead
Exeter	Penobscot	6/16/2021	7/31/2021	45	Rothamstead
Bowerbank	Piscataquis	6/16/2021	7/31/2021	45	Rothamstead
Monson	Piscataquis	6/16/2021	7/31/2021	45	Rothamstead
Madison	Somerset	6/16/2021	7/31/2021	45	Rothamstead
Calais	Washington	6/16/2021	7/31/2021	45	BL-110V
Topsfield	Washington	6/16/2021	7/31/2021	45	Rothamstead
South Berwick	York	6/16/2021	7/31/2021	45	Rothamstead

Exotic Woodborer and Bark Beetle Survey
Host(s): Spruces (*Picea* spp.), Pines (*Pinus* spp.), other conifers, and Oaks (*Quercus* spp.) and other hardwoods

The Maine Forest Service continued its participation in a Plant Protection Act Section 7721-funded pest detection survey for exotic woodborers and bark beetles (known as EWBB) for early interception of potentially destructive exotic pests. This survey focuses primarily on spruce resources in northern Maine and pine and oak resources in southern Maine (Table 4)**.** Pathways of potential spread for these insects could include industrial forest products such as logs, camp firewood, and solid wood packing material. Depending on the species, insects are targeted for trapping by using either funnel traps or cross vane traps baited with specific chemical attractants. Depending on the target species, certain samples are identified by MFS staff, while others are sent away to a taxonomic expert at the Carnegie Institute. *Agrilus biguttatus* is surveyed for by monitoring colonies of *Cerceris fumipennis*, a predatory wasp that specifically hunts metallic wood boring beetles, and those beetle captures are screened by MFS staff. Fortunately, none of the target beetles of concern were recovered from samples collected during the 2021 season.

Table 4. Exotic woodborer and bark beetle target species included in 2021 EWBB survey in Maine

Scientific Name	Common Name
Agrilus biguttatus	Oak splendor beetle
Ips sexdentatus	Six-toothed bark beetle
Ips typographus	European spruce bark beetle
Hylobius abietus	Large pine weevil
Monochamus alternatus	Japanese pine sawyer
Monochamus urussovii	Black fir sawyer
Platypus quercivorus	Oak ambrosia beetle
Tetropium castaneum	Black spruce beetle
Tetropium fuscum	Brown spruce longhorned beetle
Thrichoferus campestris	Velvet longhorned beetle

Early Detection and Rapid Response Survey

A vacant spot allowed Maine to participate in the national Early Detection and Rapid Response (EDRR) survey in 2021, which it has not been done since 2009. Maine was also one of 22 states to take part in the pilot project when this nationwide detection survey was launched in 2001. EDRR focuses on non-native bark and ambrosia beetles that pose a serious threat to U.S. forests. A typical EDRR monitoring site consists of three funnel traps baited with specific pheromones and attractants to determine whether any of the target bark and ambrosia beetle species are present in high-risk areas. Maine operated 12 trap sites in 2021, which were installed in early April to potentially capture any of the earliest flying species on the target species list. Traps were operated for a 12-week period and the overall trapping area included high-risk sites located in Androscoggin, Kennebec, and Oxford counties. Samples were sent to US Forest Service identifiers and results have recently become available.

Overall, 24,097 beetles of interest were collected, belonging to 58 different species. Fortunately, none of the species recovered in Maine in 2021 are considered forest pests of significant concern. Many of the species documented were also documented in 2009 when we last participated in this program.

However, four new state records for Maine in 2021 illustrate how species can expand their ranges or be transported and become established in just a short period. These include *Cyclorhipidion bodoanum*, *Hylesinus pruinosus*, *Ips avulsus* (small southern pine engraver), and *Xylosandrus crassiusculus* (granulate ambrosia beetle). One of these species, granulate ambrosia beetle*,* does have the potential to cause significant pest problems in orchard and nursery settings. Interestingly, this species was also detected for the first time in New Hampshire in 2021, a state that also resumed participation in the EDRR program just this year.

Maine Forest Service Technical Report Series

DEPARTMENT OF AGRICULTURE, CONSERVATION and FORESTRY
INSECT and DISEASE MANAGEMENT PUBLICATIONS

No. Title

1. LaBonte, G.A. The Saddled Prominent Outbreak of 1970-1971 and Its Damages. March 1978. 20 pp.
2. Dearborn, R.G., H. Trial, Jr., D. Struble and M. Devine. The Saddled Prominent Complex in Maine with Special Consideration of Eastern Maine Conditions. March 1978. 20 pp.
3. Maine Forest Service, Entomology Division. Spruce Budworm in Maine: 1977. March 1978. 80 pp.
4. Devine, M.E., H. Trial, Jr. and N.M. Kotchian. Assessment of Spruce Budworm Damage in the Moosehorn National Wildlife Refuge. August 1978. 32 pp.
5. Struble, D., H. Trial, Jr. and R. Ford. Comparison of Two Rates of Sevin-4-Oil for Spruce Budworm Control in Maine: 1976. August 1978. 28 pp.
6. Morrison, T.A. and J.B. Dimond. Field Trials for Control of Spruce Budworm in Maine: A History and Bibliography. September 1978. 13 pp.
7. Bradbury, R. Spruce Budworm Parasitic Survey in Maine with Special Reference to the 1978 Season. December 1978. **Unpublished**.
8. Trial, Jr., H. and A. Thurston. Spruce Budworm in Maine: 1978. December 1978. 109 pp.
9. Trial, Jr., H., W. Kemp and D. Struble. Evaluation of Split Application and Reduced Dosages of Sevin-4-Oil for Spruce Budworm Control in Maine: 1978. November 1979. 30 pp.
10. Struble, D., W. Kemp and H. Trial, Jr. Evaluation of a Reduced Dosage of Orthene for Spruce Budworm Control in Maine: 1977 and 1978. December 1979. **Unpublished**.
11. Dimond, J.B., M. Kittredge, D. Schaufler and D. Pratt. *Bacillus thuringiensis*: Operational Project - Spruce Budworm Control in Maine 1978. 1978. 36 pp.
12. Kemp, W.P., H. Trial, Jr. and D. Struble. Sampling and Analysis Design for Departmental Insecticide Monitoring. February 1979. 32 pp.
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14. Trial, Jr., H. and A. Thurston. Spruce Budworm in Maine: 1979. March 1980. 111 pp.
15. Bradbury, R.L. and G.A. LaBonte. Winter Mortality of Gypsy Moth Egg Masses in Maine. November 1980. 4 pp.
16. Devine, M.E. and J.Y. Connor. Resurvey of Spruce Budworm Damage in the Moosehorn National Wildlife Refuge. February 1981. 21 pp.
17. Trial, Jr., H. and M.E. Devine. Spruce Budworm in Maine: Biological Conditions in 1980 and Expected Infestation Conditions for 1981. February 1981. 64 pp.
18. Trial, Jr., H. and M.E. Devine. Spruce Budworm in Maine: Results of the 1981 Project, Biological Conditions in 1981, and Expected Infestation Conditions for 1982. April 1982. 83 pp.

19. Trial, Jr., H. and M.E. Devine. Spruce Budworm in Maine: Results of the 1982 Project, Biological Conditions in 1982, and Expected Infestation Conditions for 1983. March 1983. 76 pp.

20. Trial, Jr., H. and M.E. Devine. Spruce Budworm in Maine: Results of the 1983 Project, Biological Conditions in 1983, and Expected Infestation Conditions for 1984. May 1984. 75 pp.

21. LaBonte, G.A. Control of the Red Oak Leaf-Mining Sawfly. August 1984. 7 pp.

22. Dearborn, R.G., R. Bradbury and G. Russell. The Forest Insect Survey of Maine -Order Hymenoptera. May 1983. 101 pp.

23. Trial, Jr., H. and M.E. Devine. Spruce Budworm in Maine: Results of the 1984 Project, Biological Conditions in 1984, and Expected Infestation Conditions for 1985. April 1985. 75 pp.

24. Trial, Jr., H. and M.E. Devine. Spruce Budworm in Maine, Results of the 1985 Project, Biological Conditions in 1985 and Expected Infestation Conditions for 1986. August 1986. 71 pp.

25. Bradbury, R.L. Efficacy of Selected Insecticides Against the White Pine Weevil (Coleoptera: Curculionidae). November 1986. 8 pp.

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27. Bradbury, R.L. An Economic Assessment of the White Pine Blister Rust Control Program in Maine. January 1989. 17 pp.

28. Trial, Jr., H. Spruce Budworm in Maine: The End of the Outbreak, Biological Conditions in 1986, 1987, and 1988, and a Look at the Future. October 1989. 50 pp.

29. Granger, C.A. Forest Health Research and Monitoring Activity in Maine 1989-90. April 1990. 30 pp.

30. Trial, Jr., H. and J.G. Trial. The Distribution of Eastern Hemlock Looper (*Lambdina fiscellaria* (Gn.)) Eggs on Eastern Hemlock {*Tsuga canadensis* (L.) Carr} and Development of an Egg Sampling Method on Hemlock. February 1991. 12 pp.

31. Trial, Jr., H. and J.G. Trial. A Method to Predict Defoliation of Eastern Hemlock (*Tsuga canadensis* (L.) Carr) by Eastern Hemlock Looper (*Lambdina fiscellaria* (Gn.)) using Egg Sampling. September, 1992. 12 pp.

32. Dearborn, R.G. and C.P. Donahue. The Forest Insect Survey of Maine - Order Coleoptera (Beetles). December, 1993.
101 pp.

33. Trial, Jr., H. and M.E. Devine. Forest Health Monitoring Evaluation: Brown Ash**.** (*Fraxinus nigra*) in Maine - A Survey of Occurrence and Health. May 1994. 37 pp.

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35. Bradbury, R.L. Efficacy Trials of Foray 48B Against Early Larval Instars of the Browntail Moth, *Euproctis chrysorrhoea* (L.). May, 1995. 7 pp.

36. Trial, Jr., H. and M.E. Devine. The Impact of the Hemlock Loopers, *Lambdina fiscellaria* (Guenée), and *L. athasaria* (Walker) on Eastern Hemlock and Balsam Fir in New England. November 1995. 24 pp.

37. Trial, Jr., H. and M.E. Devine. Forest Health Monitoring Evaluation: Brown Ash**.** (*Fraxinus nigra*) in Maine - A 1995 Resurvey of Brown Ash Decline Plots Established in 1993. August 1996. 12 pp.

38. Bradbury, R.L. The Browntail Moth**.**, *Euproctis chrysorrhoea*, Summary of Maine Forest Service Activities For 1995. March 1998. 12 pp.

39. Donahue, C. and K. Murray. Maine's Forest Insect and Disease Historical Database: Database Development and Analyses of 16 Years (1980-1995) of General Survey Data. February 1999. 17 pp.

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41. Foss, K.A. Variations in Ground Beetle (Coleoptera: Carabidae) Populations Across Ecological Habitats for the Stetson Brook Watershed in Lewiston, Maine. October 2001. 2- pp. + i-ii.

42. Foss, K.A and R.G. Dearborn. Preliminary Faunistic Survey of Mosquito Species (Diptera: Culicidae) with a Focus on Population Densities and Potential Breeding sites in Greater Portland, Maine. November 2001. 35 pp. Revised May 2002 including 3 additional pages of larval data.

43. Maine Mosquito Surveillance Program – Report of the 2001 Working Group (MeDOC/FHM, MMCRI, Coop. Extension serv. PMO, DHS-HETL). November 2001. Revised 2004. 134 pp.

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45. Jennings, D.T., C.D. Dondale, J.H. Redner. An Annotated Checklist of the Spiders (Arachnida: Araneae) of Mount Katahdin, Baxter State Park, Maine, USA. October 2012. 30pp.

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Appendix A
Hemlock Woolly Adelgid and Elongate Hemlock Scale in Maine 2021

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Hemlock woolly adelgid (HWA, *Adelges tsugae*) was first detected in Maine forests in August 2003. Currently, it is found in the forest in towns from Kittery to Mount Desert with an additional cluster of HWA in the area of Sebago Lake (Figure 1). Most known infestations are close to the coast or other significant bodies of water. In 2021, hemlock woolly adelgid (HWA) was newly detected in forested areas in the towns of Bowdoinham (Sagadahoc County), Waldoboro (Lincoln County), and Rockport (Knox County).

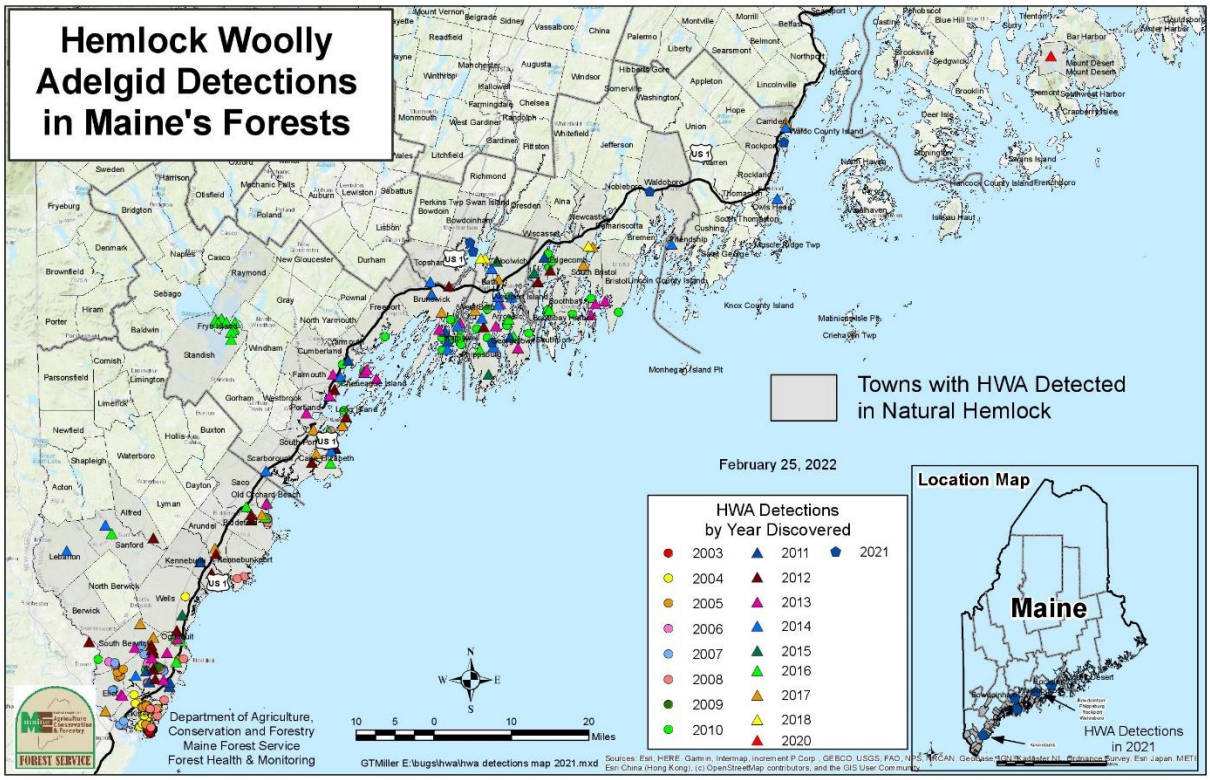

Figure 1. Hemlock woolly adelgid detections in Maine's forests.

Elongate hemlock scale (EHS, *Fiorinia externa*) is a slowly spreading invasive forest insect pest in Maine, first recognized in the state in 2009 on planted hemlocks. EHS was detected in the forest for the first time on Gerrish Island (Kittery, York County) in fall of 2010, and subsequently in mainland Kittery. In 2019, it was discovered on forest trees on Frye Island in Sebago Lake (Cumberland County). Detections on ornamental trees have been reported, scattered from Kittery to Mount Desert, and in some cases have moved into the forest (Figure 2). In 2021, two new infestations were confirmed on planted trees in Falmouth in Cumberland County. In one of these sites, EHS has moved into the surrounding forest. However, it is also likely to have moved into the forest at undetected levels in other areas where it is currently only known on planted trees (Table 5).

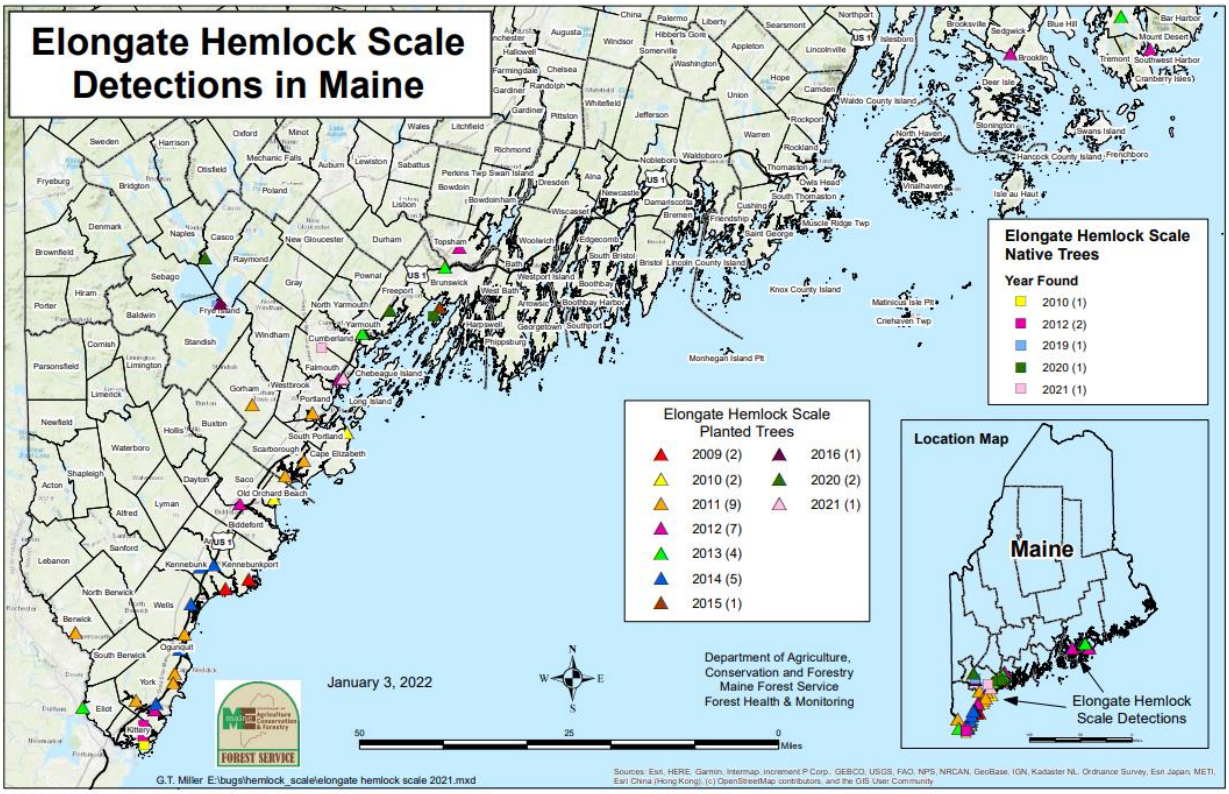

Figure 2. Locations of elongate hemlock scale on forest and planted trees in Maine.

Table 5. Known infestations of elongate hemlock scale in Maine

County	Town	EHS Status
Cumberland	Cape Elizabeth, Casco, Freeport, Portland, Scarborough, Yarmouth	known on planted trees
Cumberland	Brunswick, Frye Island, Gorham, Falmouth	moved from planted trees, now established in forest
Hancock	Mount Desert	moved from planted trees, now established in forest
Hancock	Sedgwick	known on planted trees
Sagadahoc	Bath, Topsham	known on planted trees
York	Kittery	widely established in forest
York	Berwick, Kennebunk, Kennebunkport, Ogunquit, Old Orchard Beach, Saco, Wells, York	known on planted trees

The beetle, *Cybocephalus nipponicus*, a generalist scale predator, was discovered feeding on EHS at multiple sites on Gerrish Island in Kittery, York County. Its identity was confirmed in Jan 2018. No further recoveries of *C. nipponicus* occurred in 2021. There are reports of this predator being released in Massachusetts decades ago for control of San Jose scale on *Euonymus.* It appears that it has naturally followed populations of EHS. In Pennsylvania, *C. nipponicus* has been released as a control measure for EHS and may have contributed to the decline of EHS populations there.

The bulk of the field work for these projects was conducted by Wayne Searles, Regina Smith, Abby Karter and Amy Emery with assistance from Melanie Duffy (MFS-FIA) and others. A summary of 2021 activities related to these two pests follows.

Hemlock monitoring plots were established in Maine to assess hemlock crown health and presence of three stressors (HWA, EHS and hemlock tip blight (*Sirococcus tsugae*)). Five sites were established in 2011 in infested areas of Maine, and one in 2015 in Hallowell, outside the infested area. Crown indicators and damage agent information were collected on each of the plots in December 2021. Crown classification measures follow those established for USDA Forest Service, Forest Inventory and Analysis plots. Infestation status (infested or not) of individual trees is based on what observers can see from the ground.

An ongoing detection survey is conducted both in towns outside the HWA quarantine and inside the quarantine zone where HWA has not yet been found. In 2021, 49 sites were surveyed in nineteen towns in eight counties. At each site, 200 branches were inspected in hemlock stands in areas of high risk for HWA and EHS transmission. All surveys were negative for EHS and all but three were negative for HWA. HWA was found in the new towns of Rockport, (Knox County), Waldoboro (Lincoln County), and Bowdoinham (Sagadahoc County).

Table 6. Detection survey for hemlock woolly adelgid and elongate hemlock scale

County	Town	# sites surveyed	Town regulated?	HWA found?	EHS found?
Cumberland	Bridgton	6	no	no	no
Kennebec	Augusta	4	no	no	no
Kennebec	Chelsea	4	no	no	no
Kennebec	China	1	no	no	no
Kennebec	Gardiner	1	no	no	no
Kennebec	Hallowell	3	no	no	no
Kennebec	Monmouth	2	no	no	no
Kennebec	West Gardiner	1	no	no	no
Kennebec	Windsor	1	no	no	no
Knox	Rockport	1	yes	yes	no
Lincoln	Waldoboro	1	yes	yes	no
Oxford	Denmark	5	no	no	no
Oxford	Hiram	6	no	no	no
Oxford	Porter	3	no	no	no
Sagadahoc	Bowdoinham	1	yes	yes	no
Waldo	Knox	4	no	no	no
Waldo	Montville	1	no	no	no
Waldo	Palermo	3	no	no	no
York	Cornish	1	no	no	no

Winter Mortality Survey

Maine Forest Service monitors winter mortality in six sites throughout the State. Adelgid-infested branches were collected from these sites, held in buckets of water in a cool room for about two weeks to make it easier to differentiate between living and dead adelgids, and then mortality was measured under a dissecting microscope. This year, mortality ranged from 56–69%, and averaged 62%. This is the third year in a row with mild winters and low HWA winter mortality (Table 7 and Figure 3).

Table 7. Hemlock woolly adelgid overwintering mortality (Winter 2020–2021)

Town	County	# HWA alive	# HWA dead	% mortality
Cape Elizabeth	Cumberland	196	305	60.8
Freeport	Cumberland	95	207	68.5
Standish	Cumberland	171	319	65.1
Bath	Sagadahoc	196	250	56
South Berwick	York	227	384	62.8
York	York	151	236	61
total		**1036**	**1701**	**62.1**

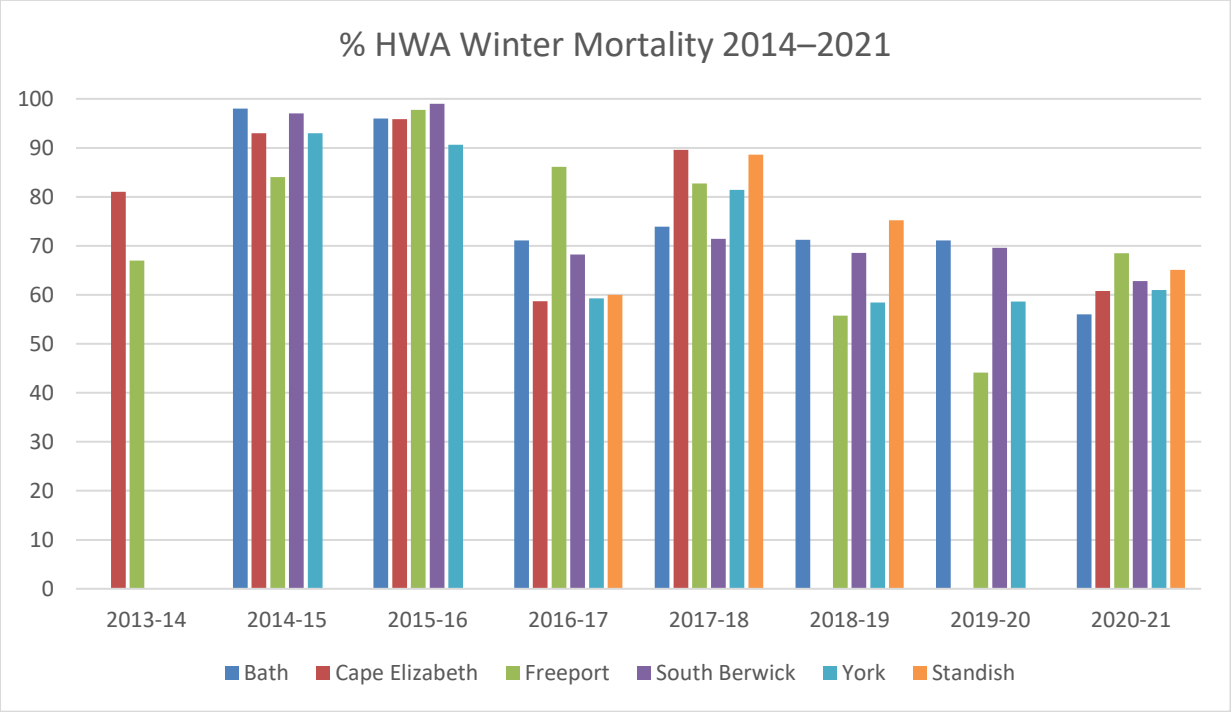

Figure 3. Overwintering mortality of hemlock woolly adelgid in Maine 2014–2021.

Biological Control

Maine's fourth field insectary for the HWA predator, *Laricobius osakensis*, was established in the Waldoboro Town Forest (Lincoln County) in 2021 and received its full complement of 2,000 beetles.

Since the initial detection of HWA in Maine's forests, the MFS has facilitated the release of over 100,000 *Sasajiscymnus tsugae* beetles and over 5,000 *L. nigrinus* beetles. The release of 2,000 *L. osakensis* at the field insectary in Waldoboro in 2021 brings the number released to almost 6,000 (Table 8). These biocontrol release sites range along much of the known distribution of HWA (Figure 4).

Table 8. Hemlock woolly adelgid biological control releases 2004–2021

County/Town	***Laricobius nigrinus* Released**	***Laricobius osakensis* Released**	***Sasajiscymnus tsugae* Released**
Cumberland		**1,950**	**24,803**
Cape Elizabeth			5,000
Freeport			10,500
Frye Island		1,950	
Harpswell			8,000
Portland			1,303
Lincoln		**2,000**	**6,500**
Waldoboro		2,000	
Wiscasset			6,500
Sagadahoc			**16,469**
Bath			4,500
West Bath			4,000
Woolwich			7,969
York	**5,272**	**2,000**	**53,218**
Kittery	900	1,500	17,734
Saco	500		4,500
Sanford			5,000
South Berwick		500	14,037
Wells			650
York	3,872		11,297
Grand Total	**5,272**	**5,950**	**100,990**

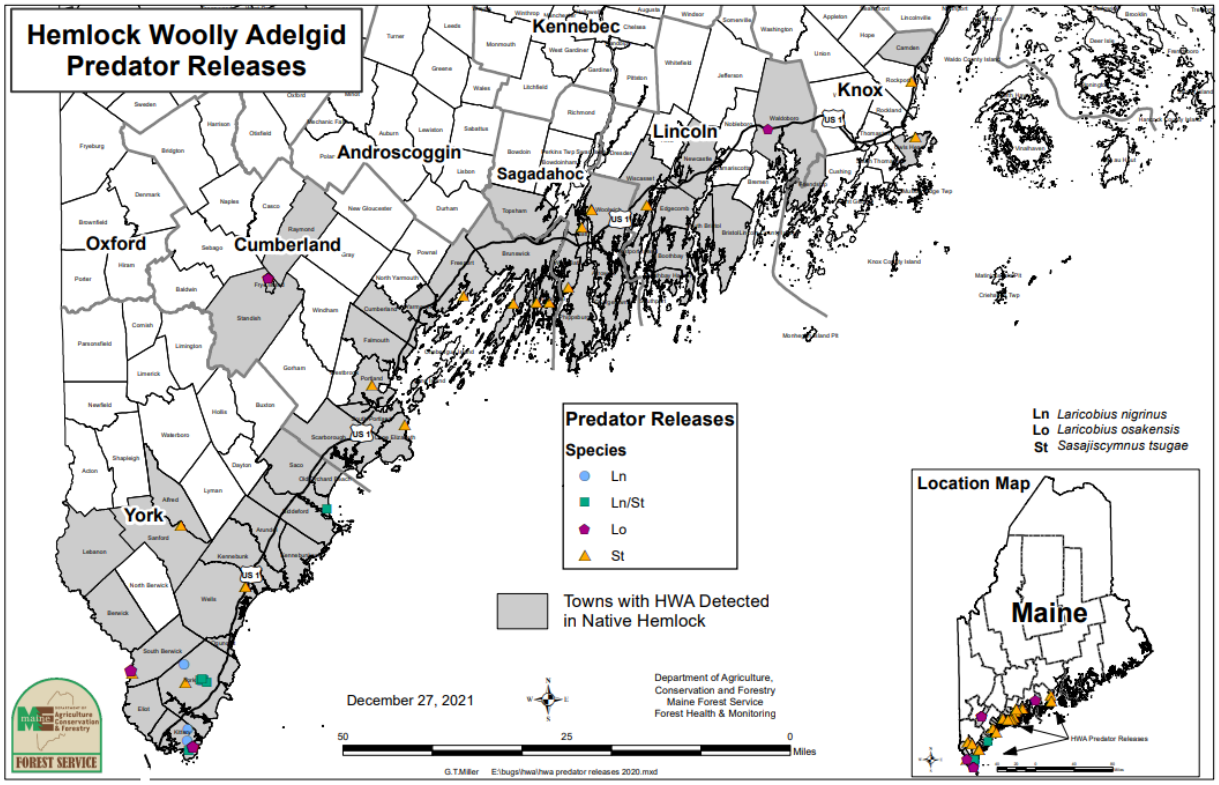

Figure 4. *Sasajiscymnus tsugae, Laricobius osakensis,* and *L. nigrinus* release sites in Maine 2002–2021.

In the fall, release sites are sampled to determine how well predator beetles have become established. However, in 2021, predator monitoring was additionally conducted in the spring in cooperation with Ryan Crandall from the lab of Joe Elkinton at the University of Massachusetts. There were successful spring recoveries of adult *S. tsugae*, *L. nigrinus* and *L. rubidus* (feeding on HWA). Fourteen *L. nigrinus* were collected from two sites in Kittery, and an additional 16 from two sites in York, including four from a site approximately three miles from the nearest release point.

A few weeks later, larvae were sampled both by beating branches and collecting twigs for larval rearing. It should be noted that both *L. nigrinus* and *L. osakensis* had been released at the Kittery site, but only *L. nigrinus* had been released at York, and *L. osakensis* at Frye Island. Since it is not possible to identify *Laricobius* larvae to species, a subsample of larvae from each site was genetically identified (data courtesy of Ryan Crandall, Tables 9 & 10).

Laricobius nigrinus was released in Maine from 2006–2008, then halted due to concerns about hybridization with the native *L. rubidus*, a predator on pine. However, these results indicate that it may be more well-established in southern York County than previously thought (Tables 11 & 12).

Table 9. Results of spring larval *Laricobius* sp. sampling

Town	*Laricobius* larvae (beating)	*Laricobius* larvae (reared)
Kittery	209	207
York	204	110
Frye Island	131	14

Table 10. Genetically identified subset of spring larval *Laricobius* sampling

Town	*L. nigrinus*	*L. osakensis*	*L. rubidus*
Kittery	35	4	3
York	39	0	0
Frye Island	0	26	4

Table 11. *Laricobius nigrinus* recoveries of adults in Maine (2007–2021)

Year	**Kittery**	**York**	**Saco**
2006	Release Year		
2007	0	Release Year	
2008	0	0	Release Year
2009	0	**1**	0
2010	**2**	**7**	**1**
2011	**2**	0	0
2012	0	0	0
2013	0	0	0
2014	0	**12**	0
2015	0	0	0
2016	0	0	0
2017	0	0	0
2019	0	-	-
2020	**17**	0	-
2021	**14** (spring)	**16** (spring)	-

Table 12. *Sasajiscymnus tsugae* recoveries in Maine (2005–2021)

Year	**Kittery**	**York**	**Harpswell**	**Saco**	**West Bath**	**Freeport**	**Wiscasset**	**Bath**	**Woolwich**
2004	Release								
2005	0								
2006	**17**								
2007	**13**	Release							
2008	**18**	**1**							
2009	**28**	0							
2010	**55**	**1**	Release	Release **1**					
2011	**37**	0	**3**	0	Release **1**	Release			
2012	0	0	**2**	0	0	0			
2013	0	0	0	0	0	0	Release		
2014	**6**	0	**1**	0	0	**1**	**0**	Release	
2015	0	0	0	0	0	0	0	0	Release
2016	**26**	0	**5**	0	0	**1**	**5**	0	0
2017	0	0	0	0	**12**	**20**	**33**	**19**	**2**
2019	0	-	-	-	0	0	0	0	-
2020	**9**	0	0	-	0	0	**2**	0	0
2021	**4** (spring)	0 (spring)	0 (fall)	**-**	**4** (fall)	**3**(fall)	**3** (fall)	**3** (fall)	0 (fall)

Appendix B
Emerald Ash Borer in Maine 2021

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In 2021, the known range of emerald ash borer (EAB) again expanded significantly in southern Maine. However, no noticeable expansion was observed in northern Maine. In addition to the state quarantine of EAB in southern Maine, an Emergency Order was issued in August 2021 restricting the movement of ash products in an extended area of southern Oxford County (Figure 5).

Much of the field work involved in monitoring for EAB was conducted by Wayne Searles, Regina Smith, Abby Karter, and Amy Emery with some assistance from MFS-FIA personnel. In addition, much work was carried out by volunteers. We thank the many volunteers who assisted with monitoring for EAB by girdling a trap tree on their property or servicing a green funnel trap. Their assistance has been invaluable and has led to a more complete understanding of the status of EAB in Maine. A summary of 2021 activities related to emerald ash borer follows.

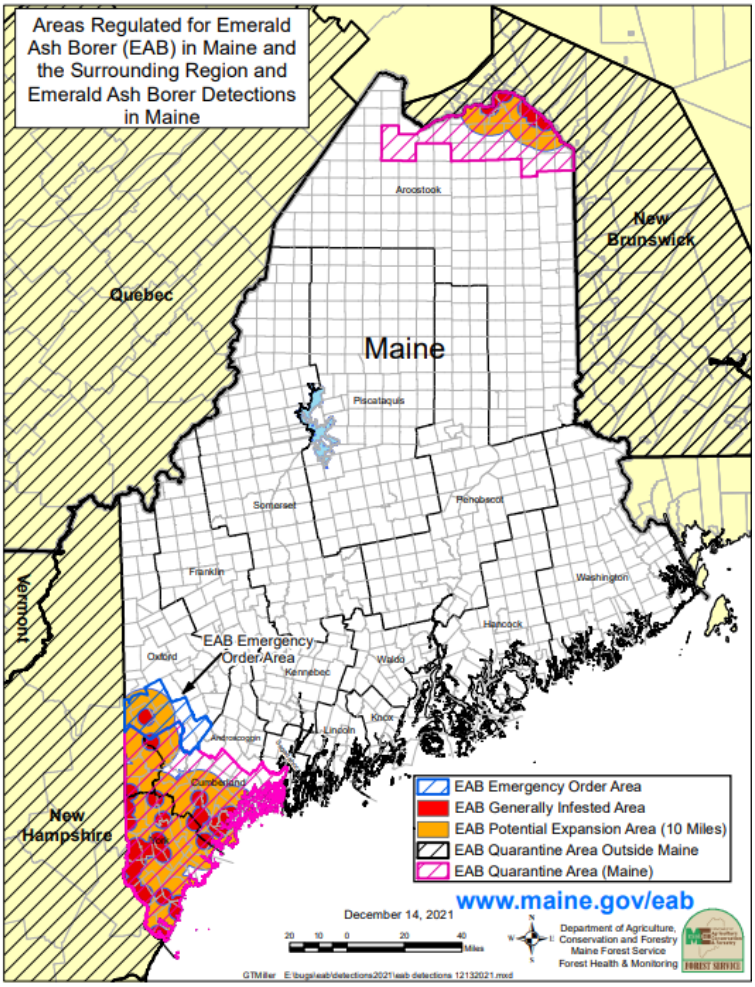

Figure 5. EAB infestations and regulated areas in Maine.

Purple Prism and Green Funnel Trap Survey

In 2021, 171 purple prism traps were deployed in non-regulated areas to detect new infestations. Nine native Buprestids in the genus *Agrilus* were collected and none were EAB.

Ten green funnel traps were deployed within the overall regulated area in locations where EAB had not yet been detected. In Cumberland County, adult EAB were captured in green funnel traps in Gorham (second detection) and Lovell (first detection). In York County, EAB was captured in Buxton (first detection).

Girdled Trap Tree Survey

In the spring of 2021, 52 ash trees throughout the state of Maine were girdled by department staff and volunteers as trap trees for EAB. Some of these trees were strategically placed in large ash stands near known infestations in an effort to locate candidate sites for biological control releases. Several trap trees were girdled within the quarantine zones to attempt to delimit infestations, while many more were located throughout the state as in previous years to monitor for outlier infestations (Figure 6). All trees were felled and peeled in the fall except one which will be peeled in the spring. Within the regulated area in Aroostook County, EAB was found in one tree in Frenchville. In the regulated area in southern Maine, EAB was found for the first time in Falmouth in Cumberland County. No EAB were found in any girdled trap trees outside the regulated area.

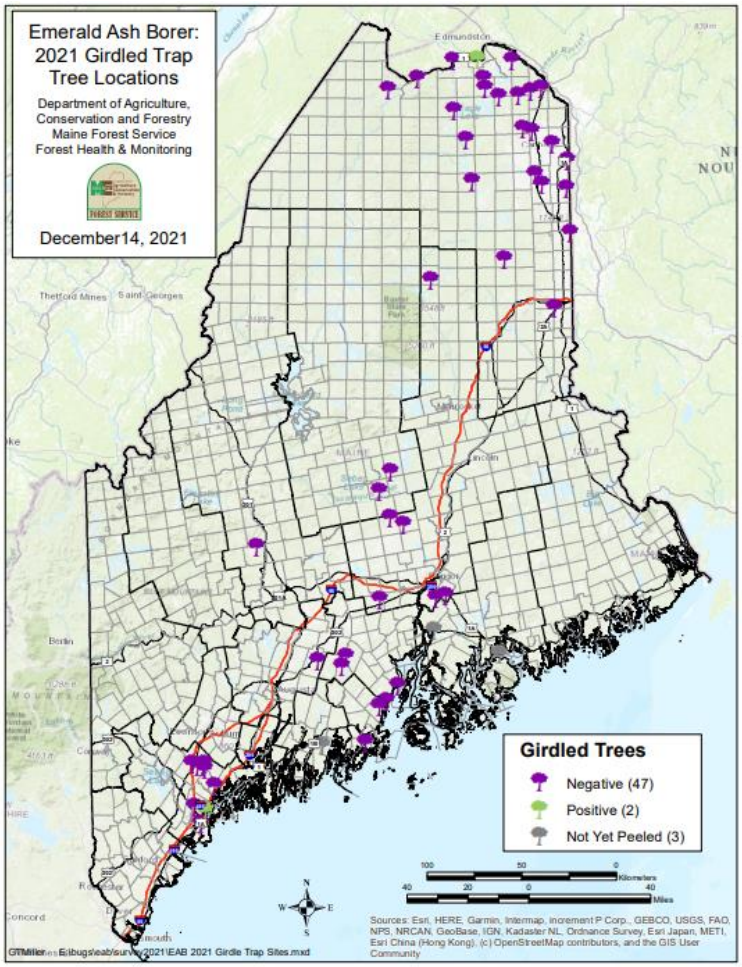

Figure 6. Girdled trap tree survey 2021.

Biosurveillance

Biosurveillance with the hunting wasp, *Cerceris fumipennis*, was also employed to monitor for EAB. As always, biosurveillance occurred in southern and western Maine, since *C. fumipennis* is not found in the eastern and northern parts of the state. (Figure 7). In 2021, biosurveillance was carried out in areas outside the quarantine zone, at 13 sites in eleven towns in Androscoggin, Hancock, Kennebec, and Lincoln counties. One hundred and fifty-two beetles were collected at 10 of the sites. No EAB was collected.

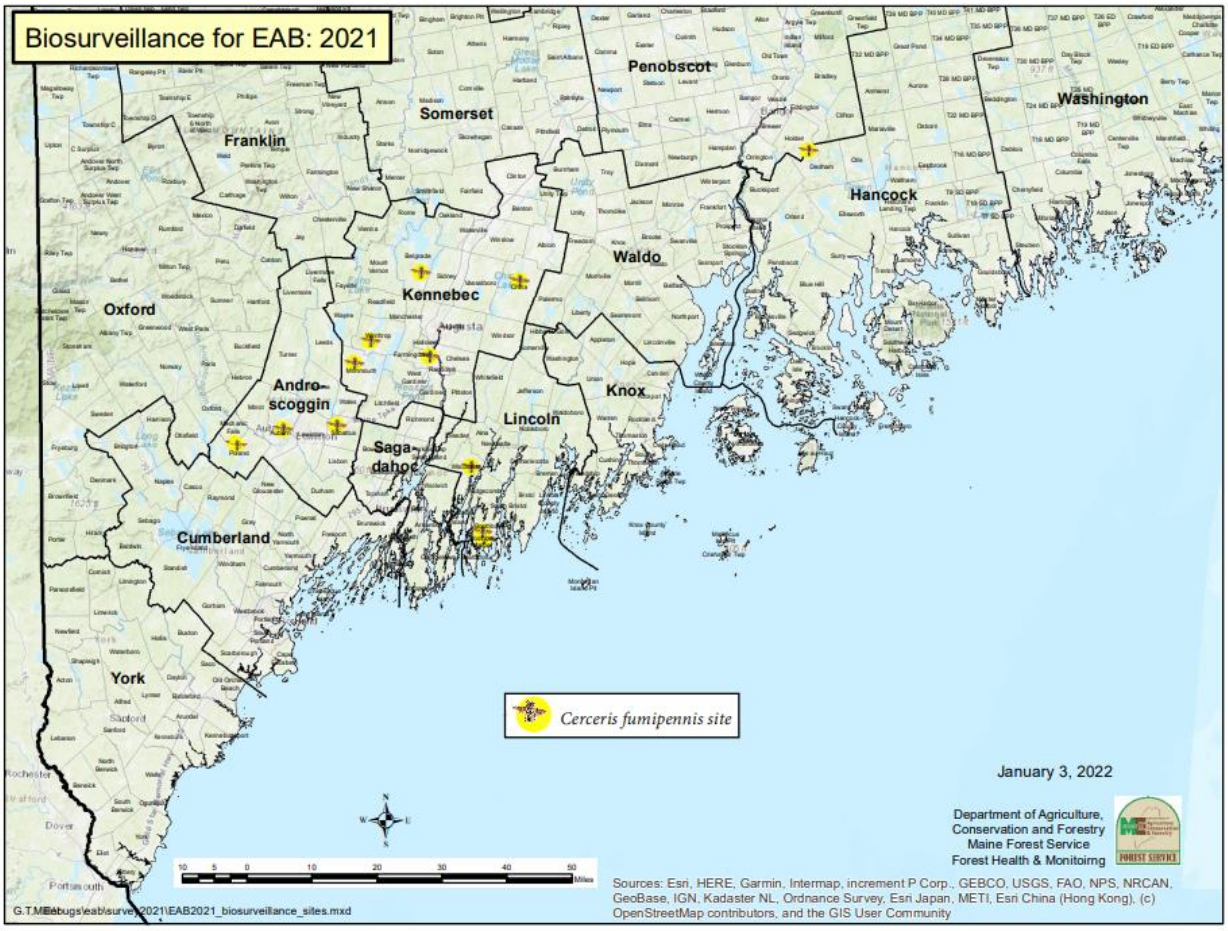

Figure 7. Biosurveillance for emerald ash borer with *Cerceris fumipennis* 2021.

Biological Control

Three species of parasitoids, *Tetrastichus planipennisi*, *Spathius galinae*, and *Oobius agrili*, were released at seven sites in York County (Acton (two sites), Alfred, Berwick, Limington, Newfield, Shapleigh) and one in Cumberland County (Gorham). Across all sites combined, a total of 9,000 *Oobius*, 9,209 *Spathius*, and 20,277 *Tetrastichus* were released (Figure 8).

In the two retired sites in Madawaska (Aroostook County), a first attempt was made at parasitoid recovery. Methods used included peeling of trees (*Spathius* and *Tetrastichus*), rearing of bark samples (*Oobius*), sifting and visual examination of bark samples for parasitized eggs (*Oobius*), and yellow pan traps (all three species). To date, some possible *Spathius* and *Tetrastichus* species were recovered in yellow pan traps and have been sent to experts for identification.

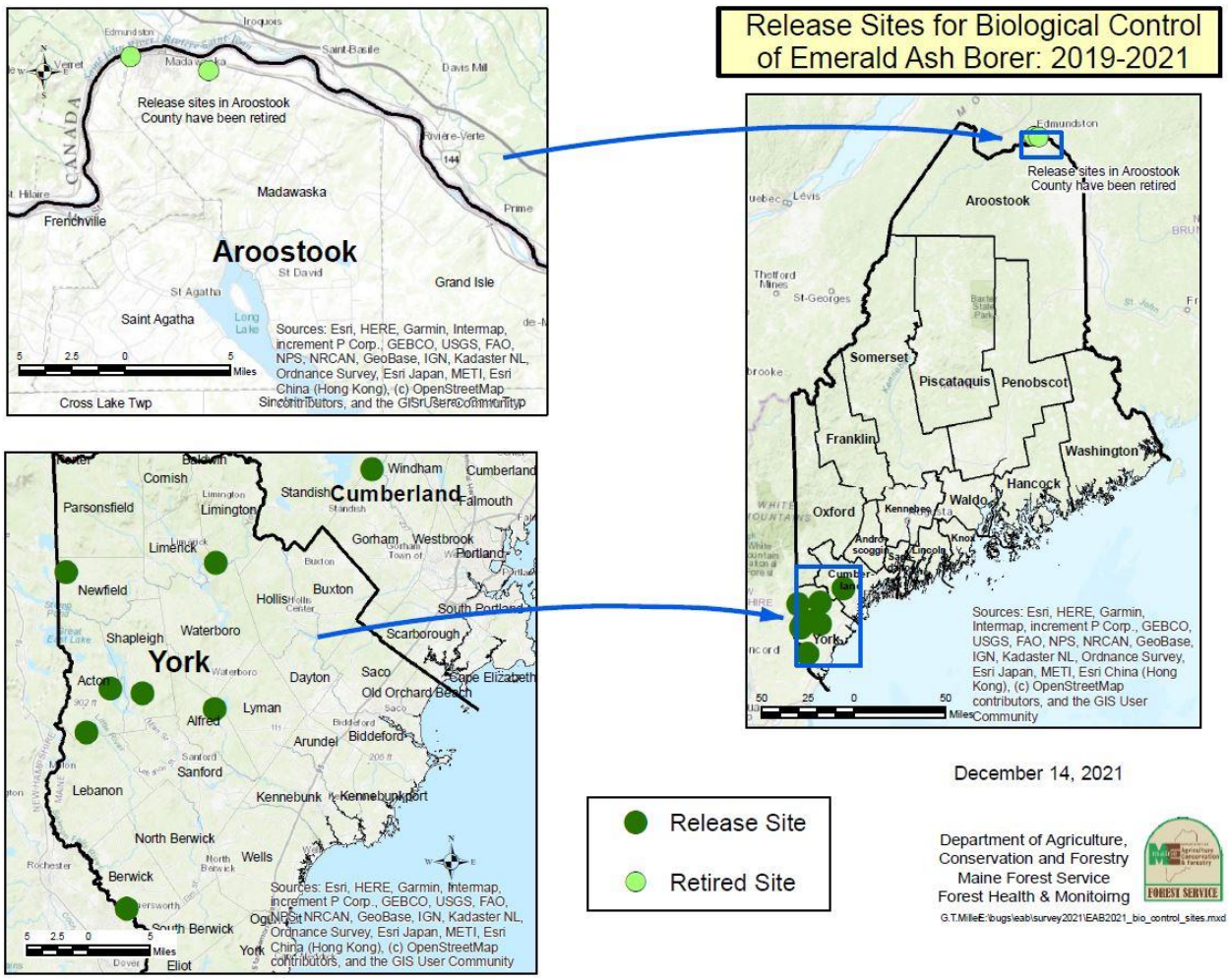

Figure 8. Release sites for biological control of emerald ash borer 2019–2021.

Detection Summary

There is no 'silver bullet' to use when monitoring for EAB. A variety of survey methods have been used in Maine over the past years. All have demonstrated some success in delimiting known infestations or detecting new ones. In 2021, EAB was found in six new towns visually, in two new towns with green funnel traps, and in one new town with a girdled trap tree (Table 12).

Table 13. Method of first and subsequent EAB detections in Maine towns

County/Town	**Year of 1st Detection**	**Method 1st Detection**	**Subsequent Finds: Year (Method)**
Aroostook	**2018**	**Visual**	
Frenchville	2018	purple trap	2020 (girdled tree)
Grand Isle	2018	purple trap	2020 (girdled tree)
Madawaska	2018	visual	2018 (trap, visual, girdled tree)
Van Buren	2020	girdled tree	
Cumberland	**2019**	**Trap**	
Bridgton	2021	visual	
Falmouth	2021	girdled tree	
Gorham	2020	girdled tree	2021 (green funnel trap)
Portland	2019	purple trap	2020 (girdled tree)
Saco	2021	visual	
South Portland	2021	visual	
Westbrook	2021	visual	
Oxford	**2021**	**Visual**	
Lovell	2021	green funnel trap	
Porter	2021	visual	
York	**2018**	**Trap**	
Acton	2018	purple trap	2019 (branch, girdled tree)
Alfred	2019	girdled tree	2020 (visual)
Berwick	2019	branch	2019 (girdled tree)
Buxton	2021	green funnel trap	
Cornish	2021	visual	
Kittery	2019	girdled tree	2020 (biosurveillance)
Lebanon	2018	purple trap	2019 (branch, girdled tree)
Limington	2019	girdled tree	
Newfield	2020	visual	
Ogunquit	2020	visual	
Parsonsfield	2020	visual	
Shapleigh	2020	visual	
South Berwick	2020	girdled tree	
Waterboro	2020	visual	
York	2020	visual	

Appendix C
Browntail Moth in Maine 2021

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Originally introduced from Europe to Massachusetts in the 1890s, browntail moth (BTM) has been established in Maine since 1904. It is currently only known to exist in North America in Maine and Cape Cod. Browntail moth is primarily a human health nuisance, causing skin rashes or breathing problems when people come into contact with or breathe-in the hairs. The caterpillars' barbed hairs contain a toxin that is stable in the environment for one to three years. The severity of individuals' reactions to the hairs varies. It is a difficult insect to work with because of the health effects; little work has been done to rigorously study this insect in past decades and Maine Forest Service (MFS) has been working with researchers in the northeast in recent years to add to the understanding of this pest.

This year we saw continued growth in the outbreak of BTM. Call activity was very high, with well over 500 BTM calls and a similar amount of emails received by the MFS from mid-May to August. This was in addition to calls fielded by the 211 hotline (287 calls) and other agencies such as Maine Center for Disease Control (CDC), Maine Board of Pesticide Control (BPC) and Cooperative Extension. As we did last year, regular BTM developmental updates were provided to the public and our cooperators to keep everyone up to date on BTM developments.

When warranted, two rounds of aerial survey occur each year to monitor for BTM: one in late spring/early summer to detect defoliation from the mature caterpillars and another in late summer/early fall to capture the skeletonization damage from the newly hatched caterpillars. The spring survey revealed 172,870.5 acres of defoliation while the fall surveys produced an additional 26,849.5 acres. This brings the grand total for 2021 to 199,720 acres (Figure 9). There was some overlap in areas mapped between the two surveys, so the total of unique acres mapped is 198,773, which is again a marked increase from 2020 where the total aerial defoliation was 153,680 acres. In 2021, damage was mapped in Oxford and Hancock Counties for the first time in this outbreak (prior to this, only winter webs had been observed and reported in these counties).

The annual winter web survey wrapped up in late March. This year MFS moved away from the "risk map" format in favor of a new way to share the information related to our monitoring surveys. This is, in part, due to the broad extent of detections. The new format displays the raw winter web survey data points along with the aerial defoliation and damage polygons. In the winter of 2021, field staff detected webs in Aroostook County (Fort Fairfield, Monticello, and Smyrna) for the first time since the early 1900s outbreak. This speaks to the ability of this species' caterpillars, pupae, and adults to hitch-hike on vehicles furthering distribution.

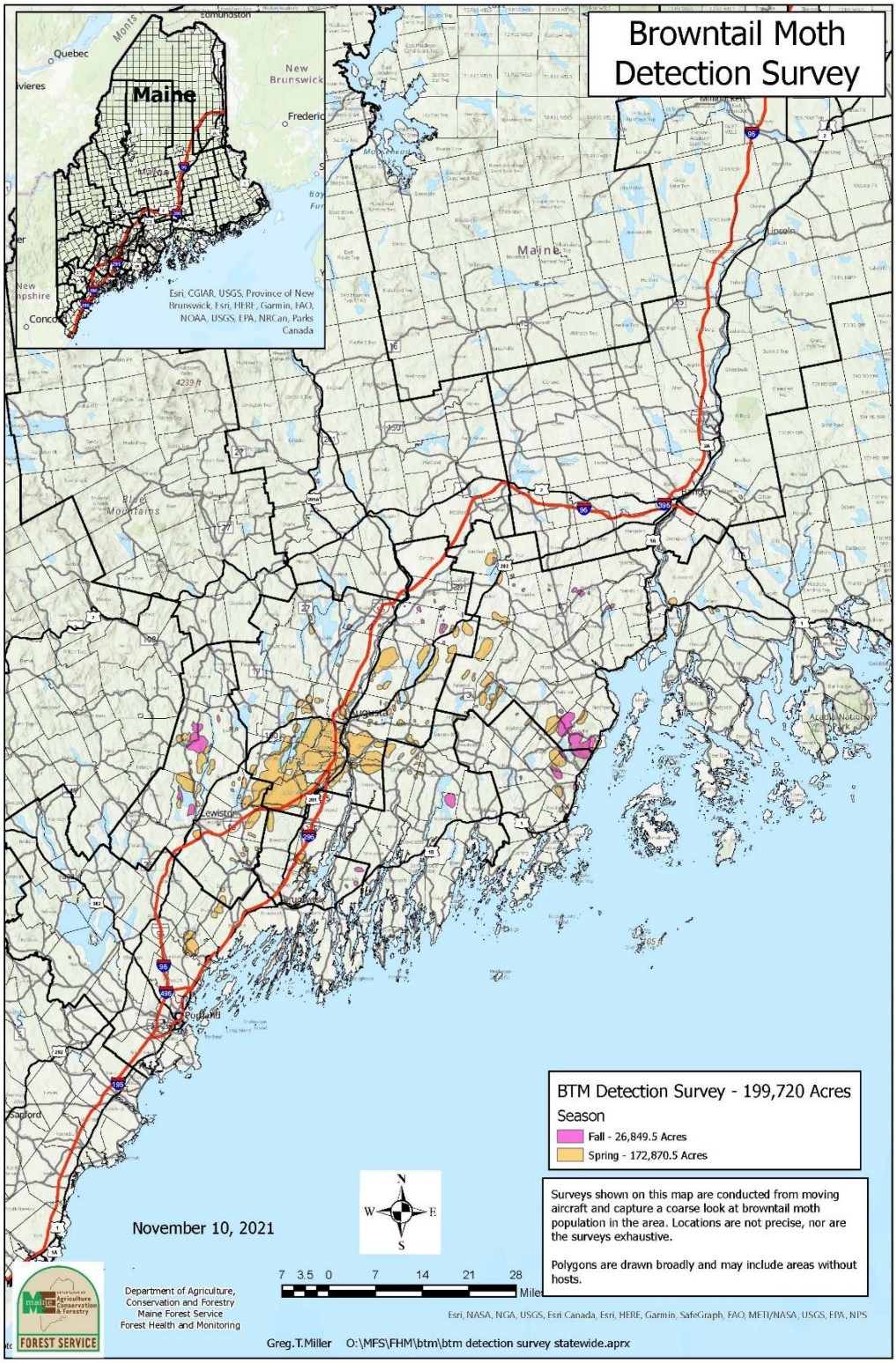

Figure 9. Spring and fall aerial survey data mapping browntail caterpillar defoliation and skeletonization.

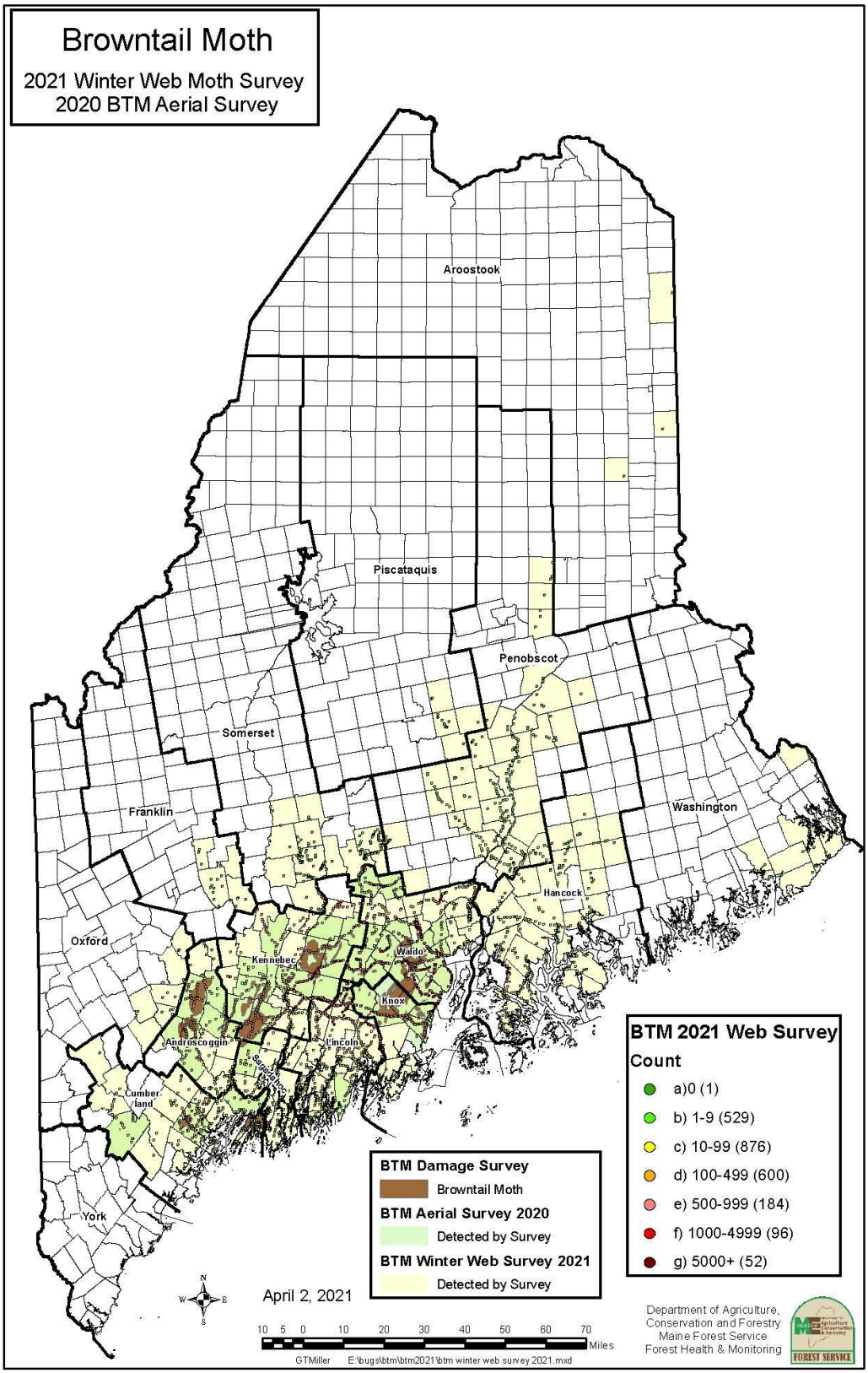

Figure 10. Data points from the 2021 winter web survey.

By the second week of April, BTM caterpillars had emerged from their winter webs in Southern Maine to feed on the buds and newly emerging leaves of host trees. By the second week of May, many of the monitoring sites had fourth instar caterpillars, which are distinguished by their white tufts on each body segment. This was 2 weeks earlier than in previous years. One explanation for this is that the mild, early spring may have coaxed the caterpillars to emerge and therefore begin feeding earlier. There was notable variability in caterpillar size even within a single nest with some caterpillars being as large as 17 mm while others that were 7 mm looked as if they had not molted since they emerged in April. During the second week of May, we began receiving reports of wandering caterpillars, which usually does not occur until the end of May. This might be explained by caterpillars stripping the host plants on which they emerged and their need to find better quality food. During the second week of June, MFS staff made observations of the first caterpillars pupating at all our monitoring sites. Again, this was a couple of weeks earlier than has been seen in the past (June 26 in 2020). Beginning during the week of June 27, we began observing emergence of adult BTM. During the period of adult activity, we received many photos as well as witnessed firsthand the sheer number of adult moths that were attracted to gas station lights as well as any other bright outdoor light. In many areas it looked as is if it had snowed around the lights. We began seeing the first egg masses hatch during the week of August 1, and by the third week of August we observed caterpillars starting to create the web in which they will spend the winter. In late August, we began observing feeding damage from young BTM caterpillars becoming very apparent in many areas, especially in Kennebec County.

As a silver lining to the season, in spite of another year of drought, we observed a few very small and isolated pockets of a BTM-pathogenic fungus and what looks to be the baculovirus associated with BTM in Blue Hill (Hancock County), Readfield (Kennebec County), Dresden and Jefferson (Lincoln County), and Belfast and Liberty (Waldo County); the pathogens are likely found in many places in between. This indicates that the fungus and virus are widespread, but in order for these pathogens to spread more and make a significant impact on populations, wet weather is needed in May and June. In collecting some of the diseased caterpillars at our monitoring sites for use in future assisted disease dispersal work, we found both parasitoid wasp larvae as well as some fly puparia within the collecting containers. Using the collections of infected caterpillars, we performed some assisted disease dispersal inoculations in Old Town (Penobscot County) as well as Little Deer Isle (Hancock County) since these locations are on the approximate leading edge of heavier populations and these BTM populations did not show signs of disease infections.

One observation of note in September was deceased immature browntail moth caterpillars on the outside of some webs. This may be due to a pathogen, although we cannot say for sure. Symptomatic caterpillars were fairly widespread on the State office complex in Augusta with most trees that were inspected having at least some webs with deceased caterpillars on them. During this visual inspection we also noticed some flies in the family Tachinidae investigating the webs. The larvae of this family of flies are exclusively parasitic on arthropods of all shapes and sizes. There are a few species of tachinid fly that use browntail caterpillars as a host, representing another element of biological control.

Finally, evidence of BTM populations was well documented using the light trapping program. In July, 219 BTM were collected from light traps at eight sites throughout the state – this is a drop from last year's numbers as we lost the participation of one light trap operator in Northport, an area with some of the heaviest infestations along the coast.

Part of the MFS work on BTM was funded through an Emerging Pest award through the USDA Forest Service (20-DG-11094200-079).

Appendix D
Spruce Budworm in Maine 2021

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Introduction

The Maine Forest Service (MFS), University of Maine Cooperative Forestry Research Unit (CFRU), and our cooperator network continue to monitor the spruce budworm situation in Maine carefully as populations still show clear signs of instability. 2021 marked the first year of the current spruce budworm population build-up where aerial surveys were able to detect larval feeding damage and the second year that appreciable feeding damage was detectable during ground surveys. Despite this, average spruce budworm moth capture across Maine has dropped for the second consecutive monitoring season. Results of the CFRU-led L2 survey are forthcoming and will help to shed additional light on Maine's spruce budworm situation heading into 2022.

A comprehensive spruce budworm (SBW) monitoring program requires a multi-pronged approach. It relies on using methods such as pheromone trapping, light trapping, overwintering L2 larval sampling, and both ground and aerial survey. At the core of the MFS monitoring program lies the extensive pheromone trap network throughout western and northern Maine's spruce-fir forests. A permanent pheromone trap network was first established in 1992 and was made up of around 80 sites operated by MFS, J.D. Irving Ltd, Penobscot Nation Department of Natural Resources, and the USDA Forest Service. The program expanded in 2014, and now with the support of a large team of dedicated cooperators, our modern pheromone trap network consists of hundreds of sites statewide.

SBW is a native insect whose outbreaks cover vast regions and spread through massive dispersal flights as moths undergo atmospheric transport from impacted areas to new ones. In northeastern North America, SBW outbreaks tend to return on a roughly 30–60 year interval, with the last major SBW outbreak to directly affect Maine occurring during the 1970s–80s. Historical data tells us that Maine is due for another SBW outbreak and monitoring efforts have provided a glimpse of population increase, as both pheromone trap and light trap catches remain above those numbers expected during a typical endemic period. This has been accompanied by regular observations of mature larvae feeding throughout the forests of northern Aroostook County in recent years. Millions of acres of ongoing SBW defoliation in neighboring Canada has crept nearer to the Maine border over the years and Maine's forests are now being impacted by moths migrating from those areas. Since 2013, several significant in-flights of moths into northern Maine have been suggested by pheromone and light trap captures, as well as through flight models and weather data, where moth flights have even been documented on radar. Significant atmospheric transport events were not apparent in 2020, meaning the majority of the moths recovered during that monitoring seasons likely completed their entire life cycle here in Maine's forests. Moth migration into Maine did occur in some degree in 2021, however the extent of any influx is still difficult to determine from flight models alone.

Pheromone Trapping

Spruce Budworm Pheromone Trap Survey Cooperator Network

American Forest Management	***Maine Bureau of Public Lands***
Appalachian Mountain Club	***Maine Forest Service***
Baskahegan Company	***Passamaquoddy Tribal Forestry Department***
Baxter State Park	***Penobscot Indian Nation***
Forest Society of Maine	***Prentiss & Carlisle***
Hilton Timberlands, LLC	***Rangeley Lakes Heritage Trust***
Houlton Band of Maliseet Indians	***Seven Islands Land Company***
J.M. Huber Corporation	***The Nature Conservancy***
J. D. Irving Ltd.	***USDA Forest Service***
Katahdin Forest Management, LLC	***Wagner Forest Management, Ltd.***
LandVest	***Weyerhaeuser***

Pheromone trapping methods follow a standardized protocol used by both Canadians and Americans since 1986 (http://phero.net/iobc/montpellier/sanders.html). Pheromone trapping efforts are concentrated in northern and western Maine, where the spruce-fir resource is greatest. Cooperators are asked to locate pheromone trap sites in spruce-fir-dominated stands greater than 25 acres at a density of one site per township or roughly every six miles along forest roads. Stands vary in tree size and degree of management, but as a minimum requirement, at least half the trees should be pole-sized or larger. Once established, cooperators tend to reuse sites annually, but sites are occasionally dropped or established due to management activities, changes in access, or other reasons.

In 2021, the trap network employed reusable Multipher traps baited with SBW pheromone lures made by ISCA Technologies and distributed by Solida and equipped with Vaportape II insecticide strips (1" x 4", 10% DDVP) made by Hercon Environmental. These high-capacity traps can monitor SBW moth numbers over a wide range of population densities ranging from 0–20 at low population densities to over l,000 per trap at high densities. Each site consists of three traps arranged in a triangle with ~130 feet between traps. Traps are deployed during the first three weeks of June and retrieved in mid-August or later. Once collected, the bulk of these samples are typically processed at the MFS Insect and Disease lab in Augusta.

Due to the peak numbers experienced during the 2019 monitoring season, numbers will be presented here from 2019 to 2021 to better illustrate the most recent downward trend. In 2019, a total of 383 usable SBW pheromone trap samples were collected throughout Maine (Figure 11). In 2020, a reduced target of 350 pheromone trap sites yielded a total of 345 usable samples from roughly the same geographic area, with fewer sites operated in western Maine (Figure 11). In 2021, 328 usable samples were collected from 351 sites statewide (Figure 12). Overall, the statewide average pheromone trap catch has fallen substantially from 67 in 2019, to 36 in 2020, to 16 in 2021 (Figure 13). The maximum average for any site also fell from 534 in 2019 to 397 in 2020, and the maximum average in 2021 was 174 moths per trap. Over this three-year period, the number of sites recording more than 50 moths per trap has also dropped substantially (Figure 14). Generally speaking, the monitoring sites in northern Maine with high captures still correspond well with those areas that were most affected by the moth

migrations of 2019. The results of the 2021 pheromone trap monitoring program indicate more clearly now that the greatest population densities appear to remain in one concentrated area in northeastern Aroostook County and one concentrated area in northwestern Aroostook County. Not surprisingly, these sites also correspond with the areas where defoliation was visible during aerial survey in 2021 and an area that received pesticide treatments in 2021 due to average L2 counts exceeding the early the intervention strategy threshold of seven larvae per branch at the end of the 2020 monitoring season.

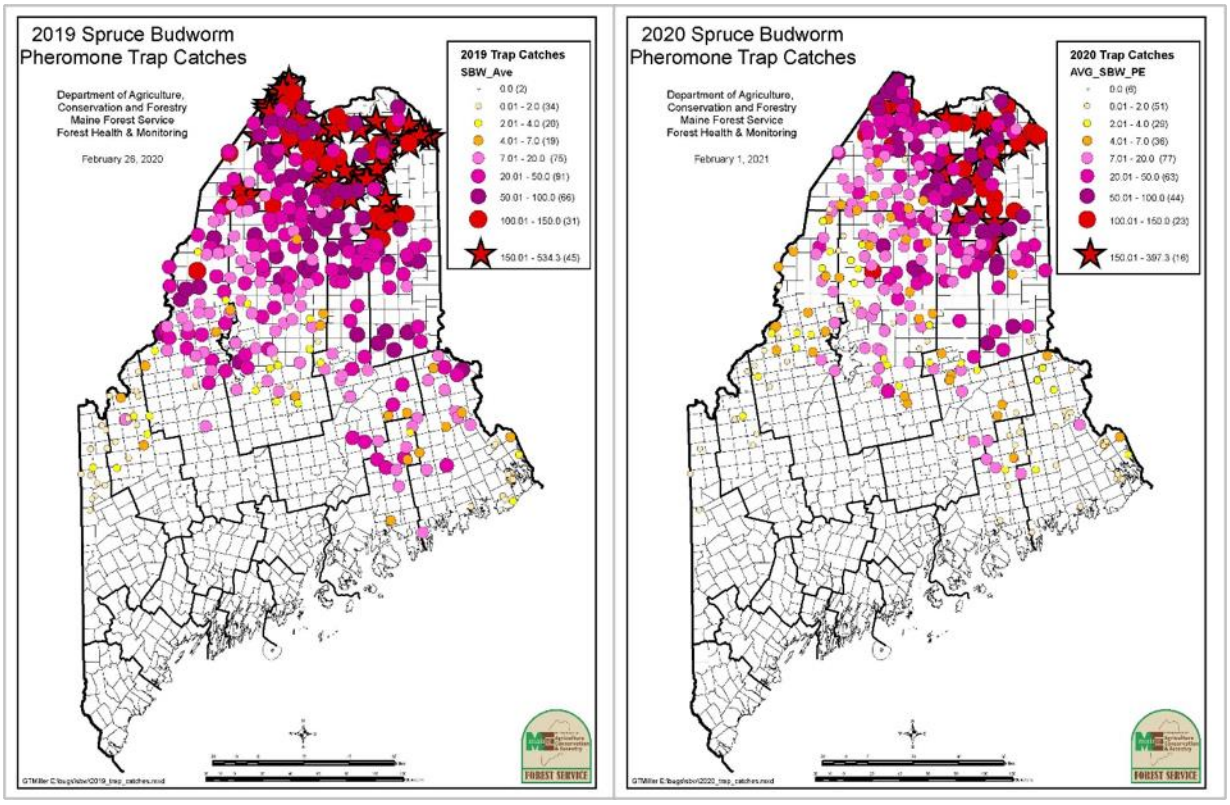

Figure 11. Statewide spruce budworm pheromone trap average catches in 2019 (left) and 2020 (right).

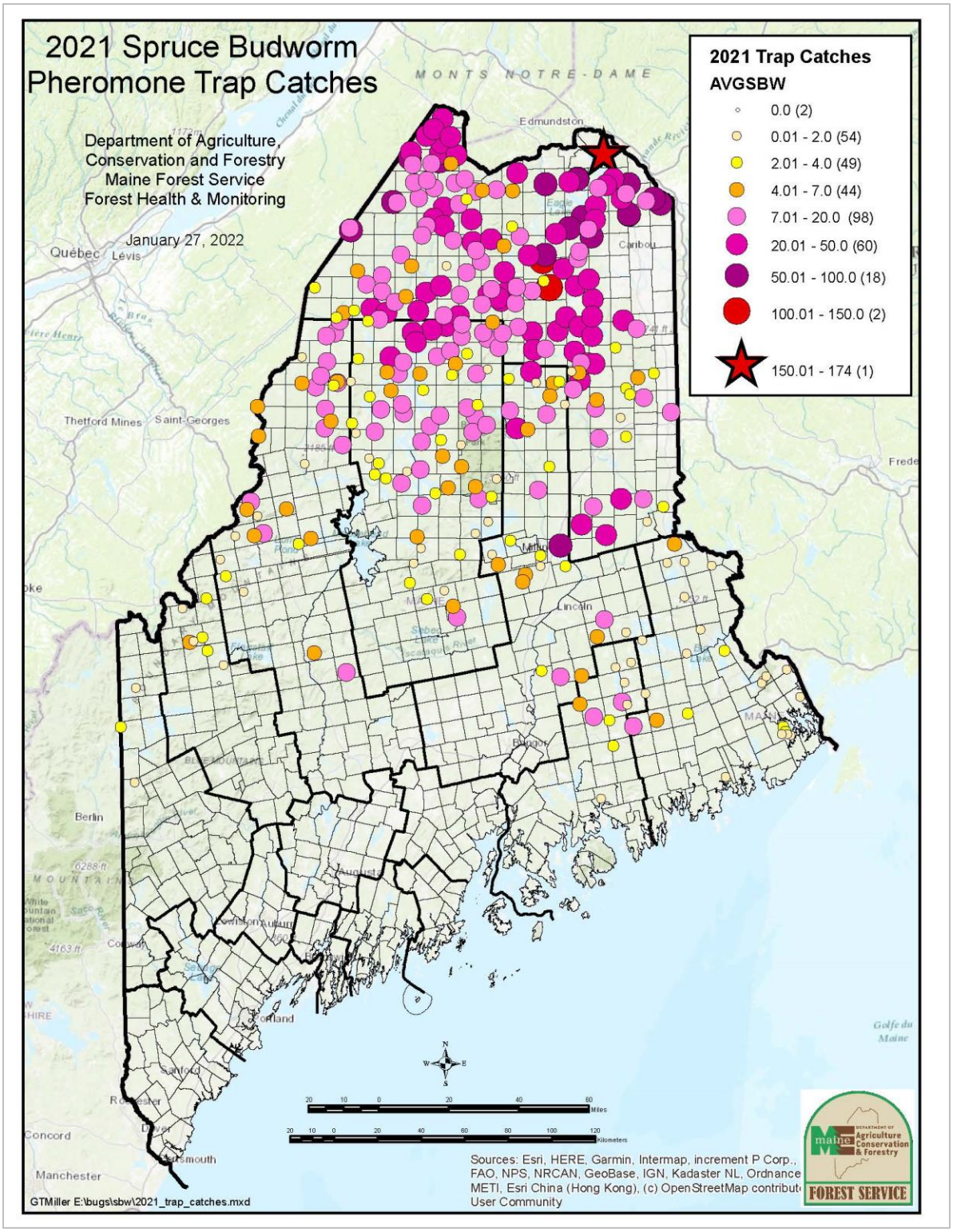

Figure 12. Statewide spruce budworm pheromone trap average catches in 2021.

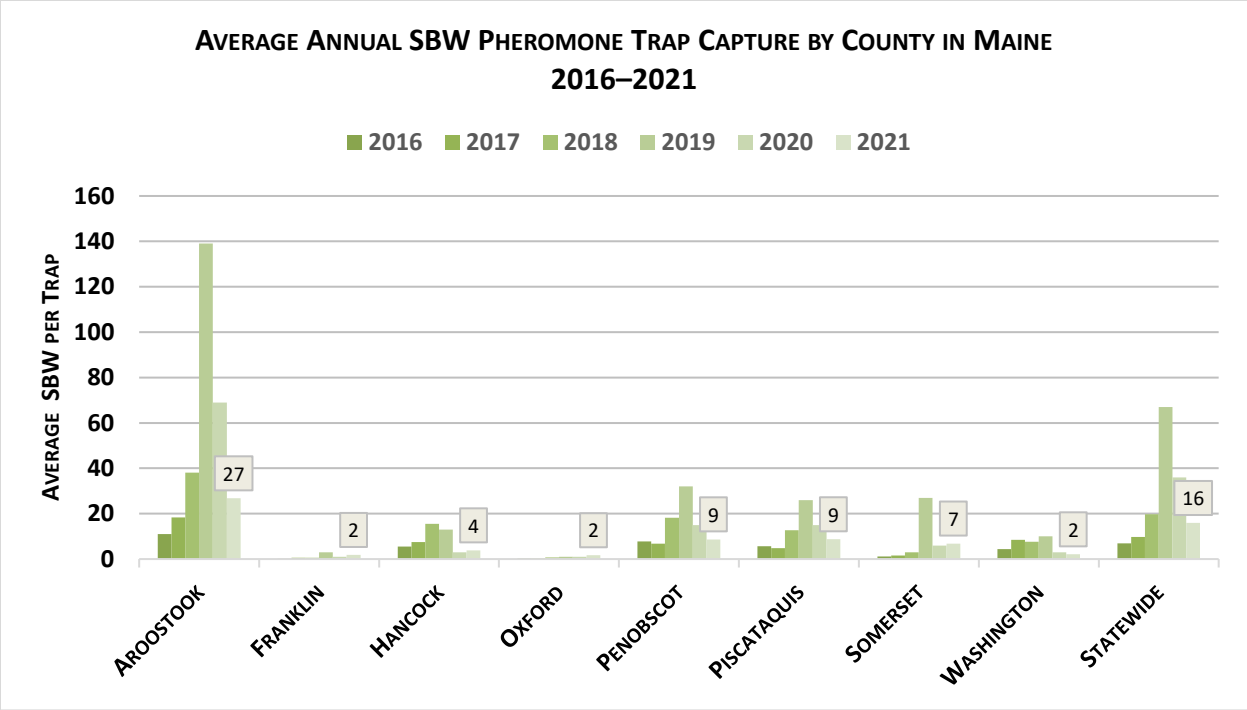

Figure 13. Average SBW pheromone trap capture by county in Maine, 2016–2021.

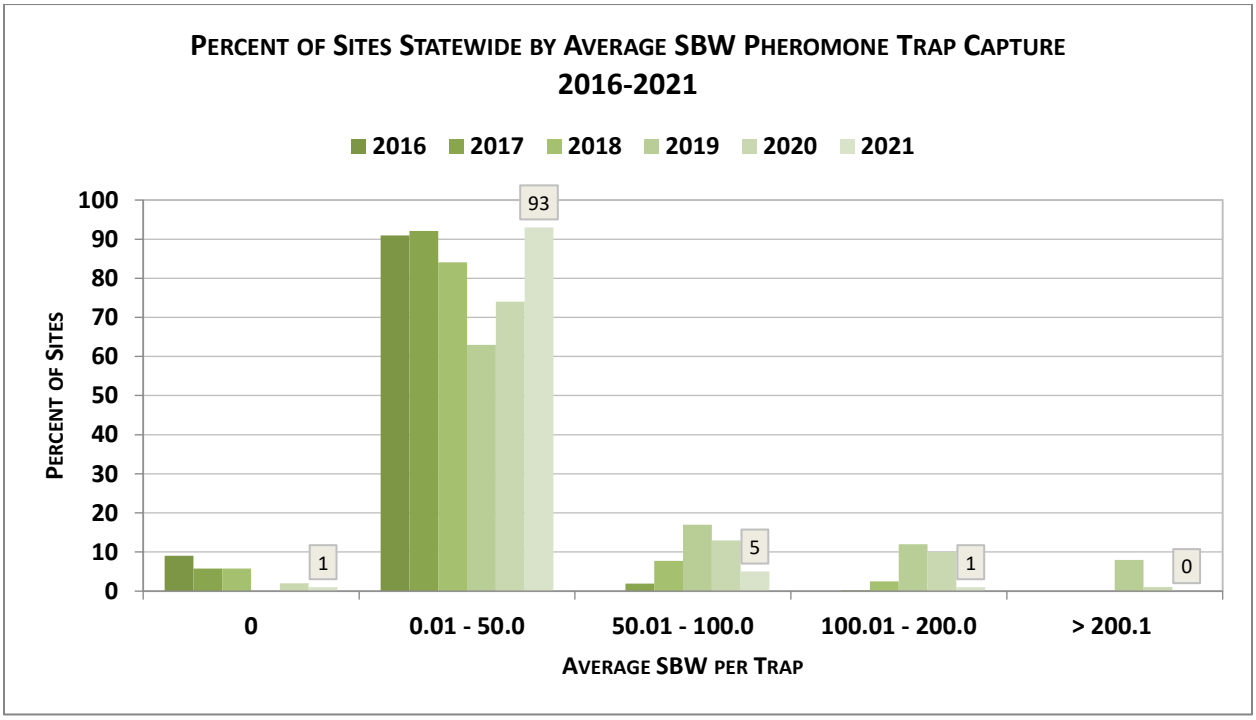

Figure 14. Percent of monitoring sites by average SBW pheromone trap capture, 2016–2021.

As noted earlier, MFS and cooperators have been monitoring a core set of long-term pheromone trap sites since 1992 (Figure 15). Across these long-term sites, from 1992 to 2012, the average number of moths per trap remained well below 10. That average jumped to 18 in 2013, followed by further increases in 2014 and 2015 to more than 20 moths per trap. Average catches fell to just seven moths per trap in 2016 and 2017, but once again returned to double digits in 2018 with an increase to 15 moths per trap. In 2019, we observed a dramatic increase as the average grew to about 55 moths per trap. We suspect this 2019 statistic was largely influenced by mass migrations of SBW moths from outbreak areas in Canada. In 2020, the number remained elevated but fell to an average of 30 versus 55 in 2019. Now in 2021, the number has returned to 12.

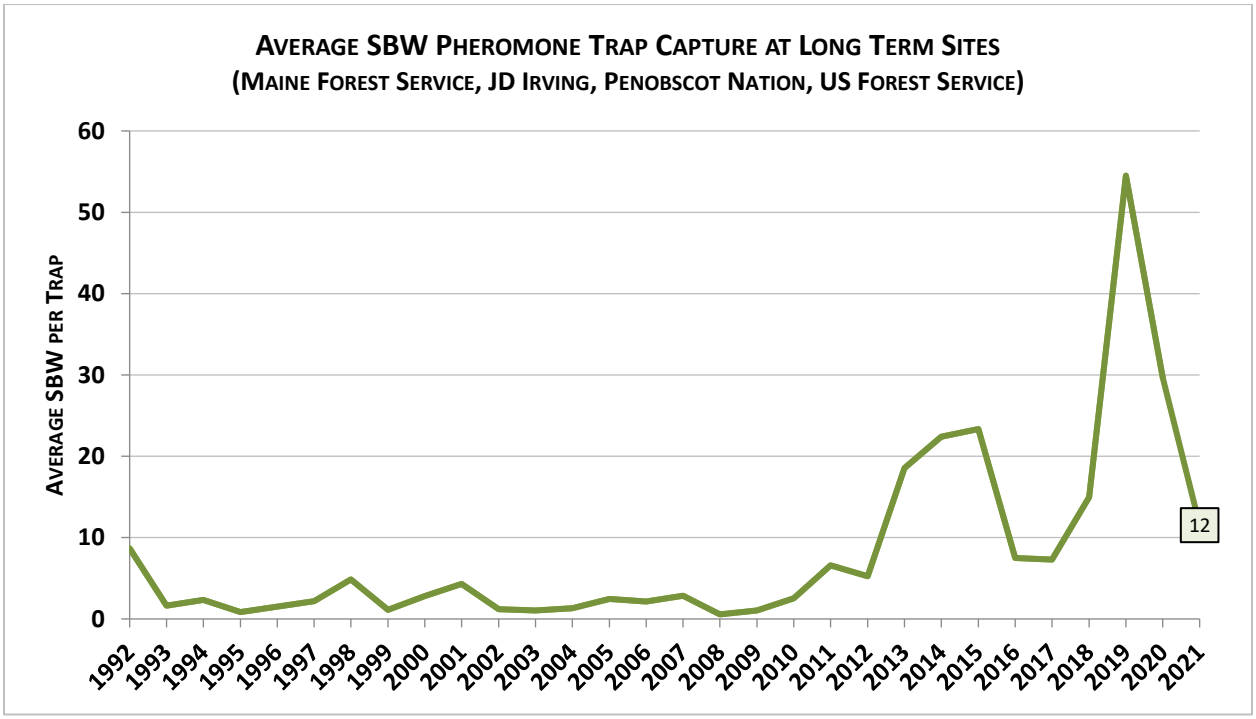

Figure 15. Average SBW pheromone trap capture at long term sites operated since 1992 by the Maine Forest Service, J.D. Irving Ltd., Penobscot Nation DNR, and USDA Forest Service.

Automated Pheromone Trapping

New in 2021 was Maine's participation in a larger network of automated pheromone traps operated by Natural Resources Canada throughout Quebec and the maritime provinces. Maine was provided with two traps that were deployed in the towns of New Canada and Stockholm in Aroostook County. These solar-powered camera traps contain a rotating roll of adhesive paper that is photographed and transmitted to a server each day, where SBW moth capture is counted using software. Understanding SBW activity on a daily basis enables us to calibrate flight periods throughout the season and most importantly provides us with a better start date for SBW flight season in Maine. These traps captured the first flights of SBW occurred on the night of June 21 and morning of June 22, reinforcing the current practice of deploying traps by mid-June (Figure 16). These data also help to inform flight models.

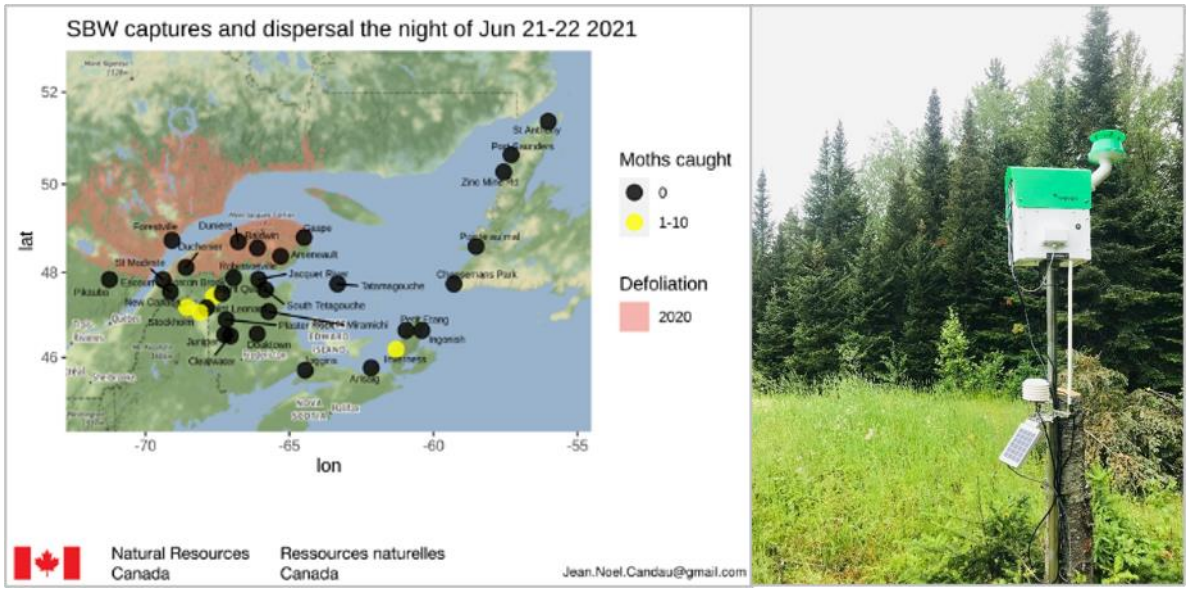

Figure 16. (left) Map of automated SBW pheromone trap locations throughout Canada and Maine and first flight dates for Maine during 2021 monitoring season; (right) Example of automated SBW pheromone trap operated in New Canada, Aroostook County during 2021.

Light Trapping

Light trapping has been used in Maine for more than seven decades to monitor forest defoliators and remains a useful tool for monitoring SBW moths. In 2019, 17 light traps were operated statewide, and we witnessed a dramatic increase in SBW light trap catches, with 507 moths captured at 14 sites. In 2019, most moths were recovered from just five sites in Aroostook County (135 in Garfield Plt, 127 in Crystal, 89 in St. Pamphile (T15 R15 WELS), 65 in Clayton Lake Twp, 44 in Allagash, and 27 in New Sweden). Overall, there was a substantial decrease in capture to just 107 moths from all 18 light traps operated statewide in 2020. Unfortunately, several of the locations that proved to be the biggest producers in 2019, such as Crystal and St. Pamphile (T15 R15 WELS), were unable to be operated in 2020. We believe many of the moths captured in 2019 were Canadian-origin and those captured in 2020 to be primarily moths that completed their entire life cycles in Maine. Regardless, notable decreases were still observed however in Allagash, Clayton Lake Twp, and Garfield Plt. 2021 witnessed another substantial drop and just nine moths were recovered statewide (Table 13, Figure 17). Interestingly, the most productive light trap in 2020 located in Garfield Plt, recovered no moths in 2021, which appears to be somewhat supported by low pheromone trap catches in surrounding areas. Other productive light traps in previous seasons recovered similarly low numbers in 2021.

Table 14. Spruce budworm moth capture in light traps from 2015-2021

TOWN	COUNTY	2015	2016	2017	2018	2019	2020	2021
Allagash	Aroostook	3	25	N/A	23	44	9	2
Ashland	Aroostook	0	3	0	29	N/A	N/A	N/A
Big Twenty Twp	Aroostook	N/A	N/A	N/A	54	N/A	0	1
Bowerbank	Piscataquis	1	0	0	2	1	0	1
Calais	Washington	2	0	6	2	1	1	0
Cape Elizabeth	Cumberland	0	0	0	1	0	4	0
Clayton Lake Twp	Aroostook	N/A	N/A	N/A	10	65	2	0
Crystal	Aroostook	5	53	7	42	127	N/A	N/A
Exeter	Penobscot	0	0	0	2	0	0	0
Garfield (6-Mile CP)	Aroostook	N/A	N/A	N/A	N/A	135	82	0
Jackman	Somerset	N/A	0	0	0	0	N/A	N/A
Madison	Somerset	N/A	N/A	N/A	N/A	N/A	0	1
Millinocket	Penobscot	1	1	0	0	8	0	N/A
Monson	Piscataquis	N/A	N/A	N/A	0	3	0	3
Mount Desert	Hancock	N/A	4	N/A	0	N/A	0	N/A
New Sweden	Aroostook	2	3	0	12	27	7	0
Northport	Waldo	N/A	N/A	N/A	N/A	N/A	0	N/A
Rangeley	Franklin	1	0	0	0	1	1	1
Salem	Franklin	N/A	N/A	0	0	4	0	0
South Berwick	York	0	0	0	0	1	1	0
Topsfield	Washington	0	44	18	22	1	0	0
T3 R11 WELS	Aroostook	2	13	0	0	N/A	N/A	N/A
T15 R15 WELS	Aroostook	17	0	10	3	89	N/A	N/A
TOTAL NUMBER OF SBW MOTHS		**34**	**146**	**41**	**202**	**507**	**107**	**9**

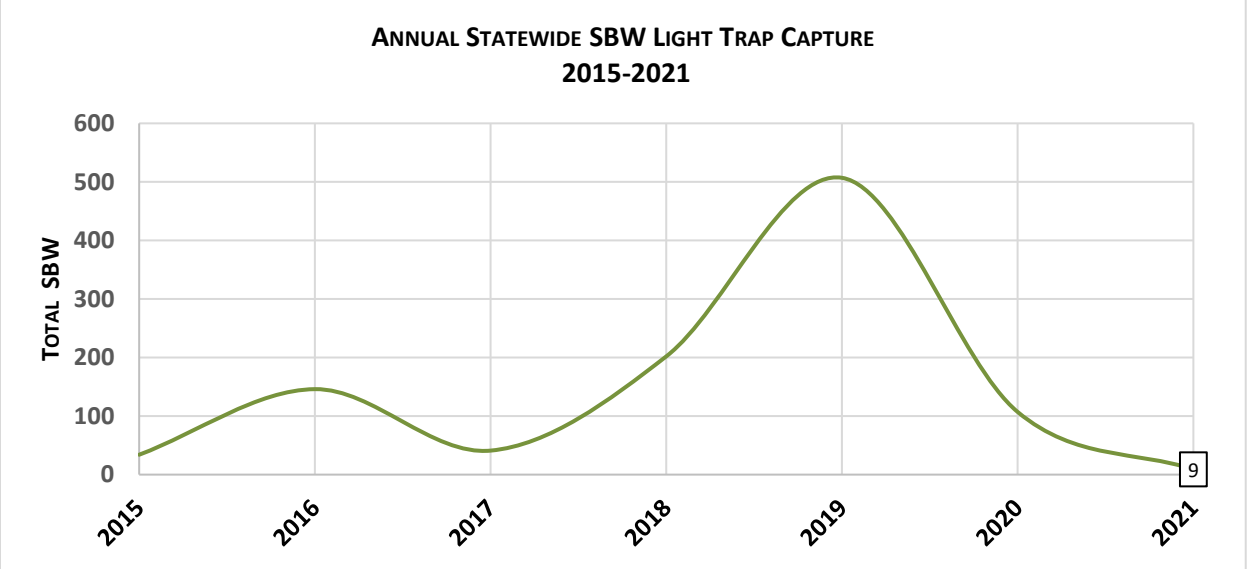

Figure 17. Total annual statewide light trap catches of SBW moths 2015–2021.

Overwintering L2 Larval Sampling (2020 Results)

CFRU continues to coordinate the overwintering larval (L2) sampling portion of the monitoring program. Since 2014, branch samples from SBW host species, primarily balsam fir, have been collected during the fall or winter in areas where pheromone trap catches were high, where modeling has predicted high-risk stands, or where previous samples had been collected. At each sample site, one 30-inch-long branch is cut from the mid-crown of each of three trees. Branch samples have historically been sent to Canada for processing, but in an exciting development in 2021, a dedicated lab for this purpose has been established through CFRU and is now up and running in Orono, ME. Due to this new development, complete results of the 2021 L2 survey are not currently available but will be made available by CFRU at a later date and included in our 2022 monitoring season report next spring.

For recent context, the 2020 overwintering L2 larval survey demonstrated a clear increase in the number of larvae recovered compared to 2019 (Figure 18). A total of 309 larvae were collected from branch samples taken at 328 sites across the state in 2020, versus only 70 larvae recovered from 317 sites in 2019. The larvae collected in 2020 came from a total of 99 independent sampling sites compared to just 29 sites in 2019, indicating a more widespread distribution of growing SBW populations. The greatest average recorded at any site in 2019 was 3.1 – 4.0 larvae per branch and was documented at just one site. In 2020, six sites averaged from 3.6 – 4.66 larvae per branch, and most notably, a single site in Cross Lake Township that averaged 7.66 larvae per branch.

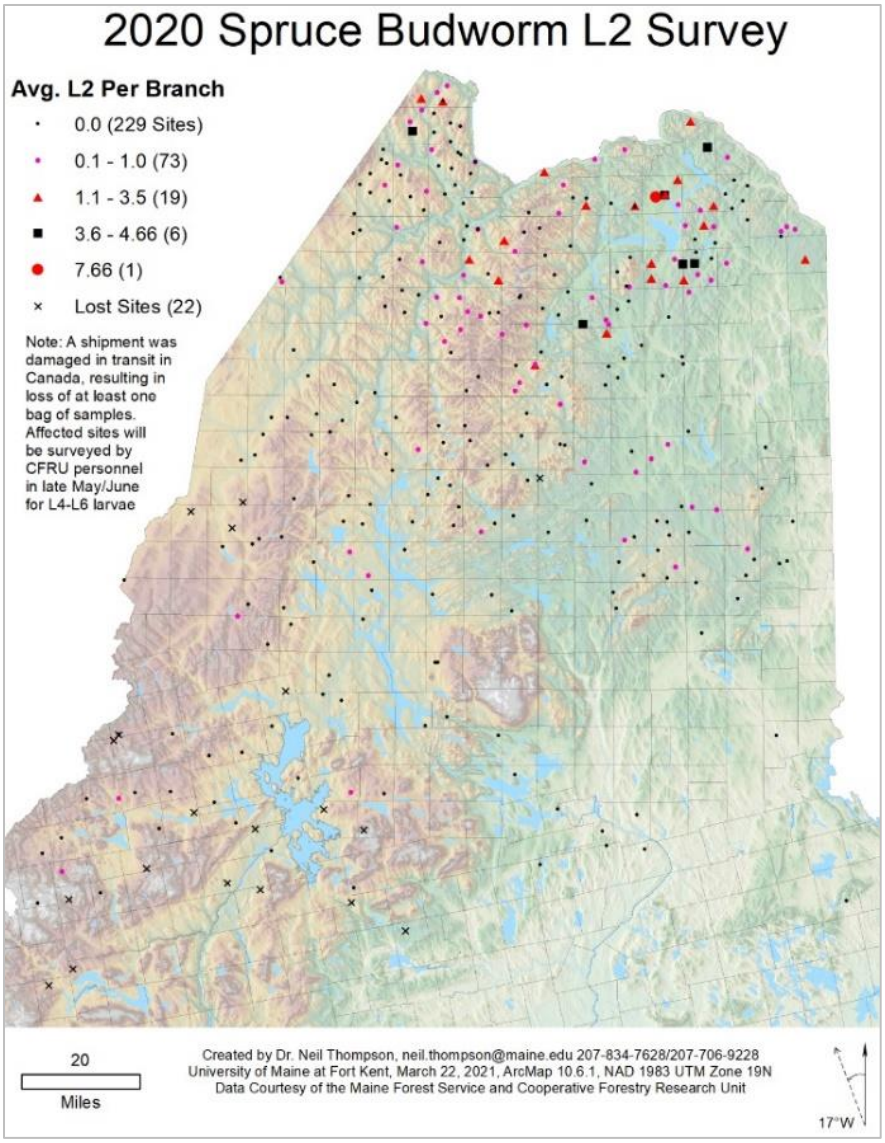

Figure 18. Map of statewide results for 2020 overwintering spruce budworm L2 larvae survey.

2021 Maine Early Intervention Strategy (EIS) Treatments

The Cross Lake Township site averaging 7.66 larvae per branch sample, located on land owned by J.D. Irving Ltd, marked the first time in recent years where a local population was above the management threshold of the SBW Early Intervention Strategy (EIS) threshold being employed in Atlantic Canada (https://healthyforestpartnership.ca/what-we-do/targeting-and-treating/). In response to this detection, and subsequent samples taken to delimit the population also above threshold, J.D. Irving Ltd decided to treat this area in accordance with EIS management guidelines.

Initial data from standard sampling presented an area of concern of roughly 20,000 acres, however a more intensive follow-up survey led to the development of a much smaller spray block of just 5,000 acres, created by interpolating populations across these supplementary sampling sites (Figure 19). This spray block was treated with two aerial applications of Foray 76B from a rotor-winged aircraft, with the first application taking place from June 1–4 and the second from June 8–11. These dates were selected

after monitoring SBW larval development on-site in order to target larvae at their most vulnerable stages and multiple days were required to ensure spraying was performed under optimal conditions for safety and effectiveness. Additional planning and precautions were also required given the proximity of both water bodies and nearby private residential properties. Foray 76B is a biological insecticide containing the spores and endotoxin crystals of the bacterium *Bacillus thuringiensis kurstaki* (Btk) that targets the larvae of Lepidoptera, such as SBW. It is not a contact insecticide and must be ingested by a feeding larva in order to be effective, therefore limiting non-target effects of other organisms. While effective, Btk also has the advantage of a short residual period and degrades readily in sunlight within a short period of time, sometimes only a matter of days depending on environmental conditions.

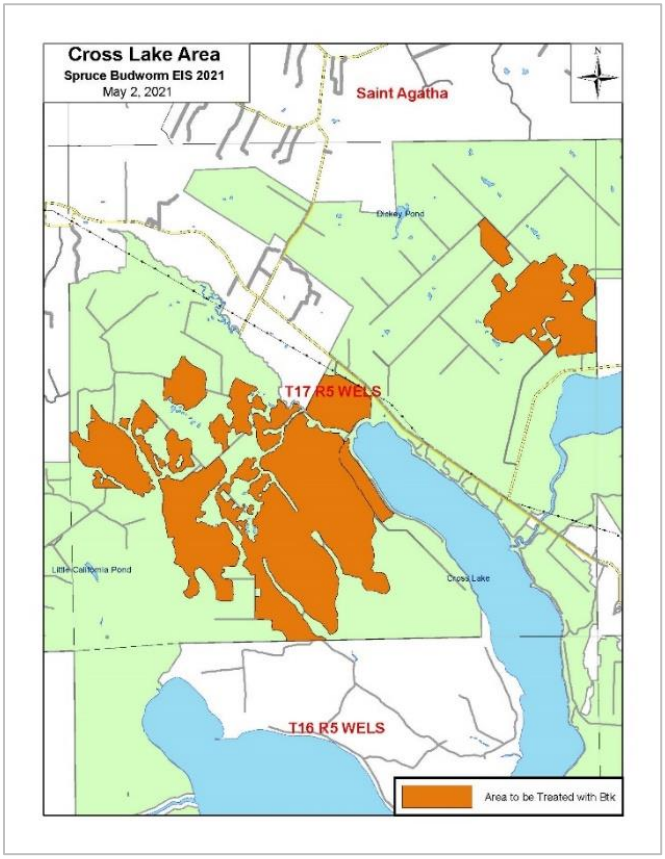

Figure 19. 2021 EIS treatment area in Cross Lake Twp, Aroostook Co. Courtesy J.D. Irving Ltd.

Statewide Defoliation Survey (2020 Results)

Prior to being submitted for L2 assessment, all branch samples collected undergo defoliation assessment by CFRU staff using the Fettes Method, which systematically quantifies missing foliage on current-year growth. It was used during the last budworm outbreak in Maine and is currently being used in the Canadian provinces. The Fettes Method captures defoliation from all causes and can be used to estimate both current-year defoliation and cumulative defoliation. A brief introduction to the Fettes Method is provided in this document: http://www.sampforestpest.ento.vt.edu/defoliating/spruce-budworm/pdf/montgomery-etal1982-sbw.pdf. Results of the 2020 Fettes defoliation assessment survey performed by CFRU are displayed below and each point represents the average defoliation of three branch samples taken at each site (Figure 20). The results of the 2021 statewide defoliation survey along

with results of the L2 survey will be available directly from CFRU at a later date and will be included in our 2022 monitoring season report next spring.

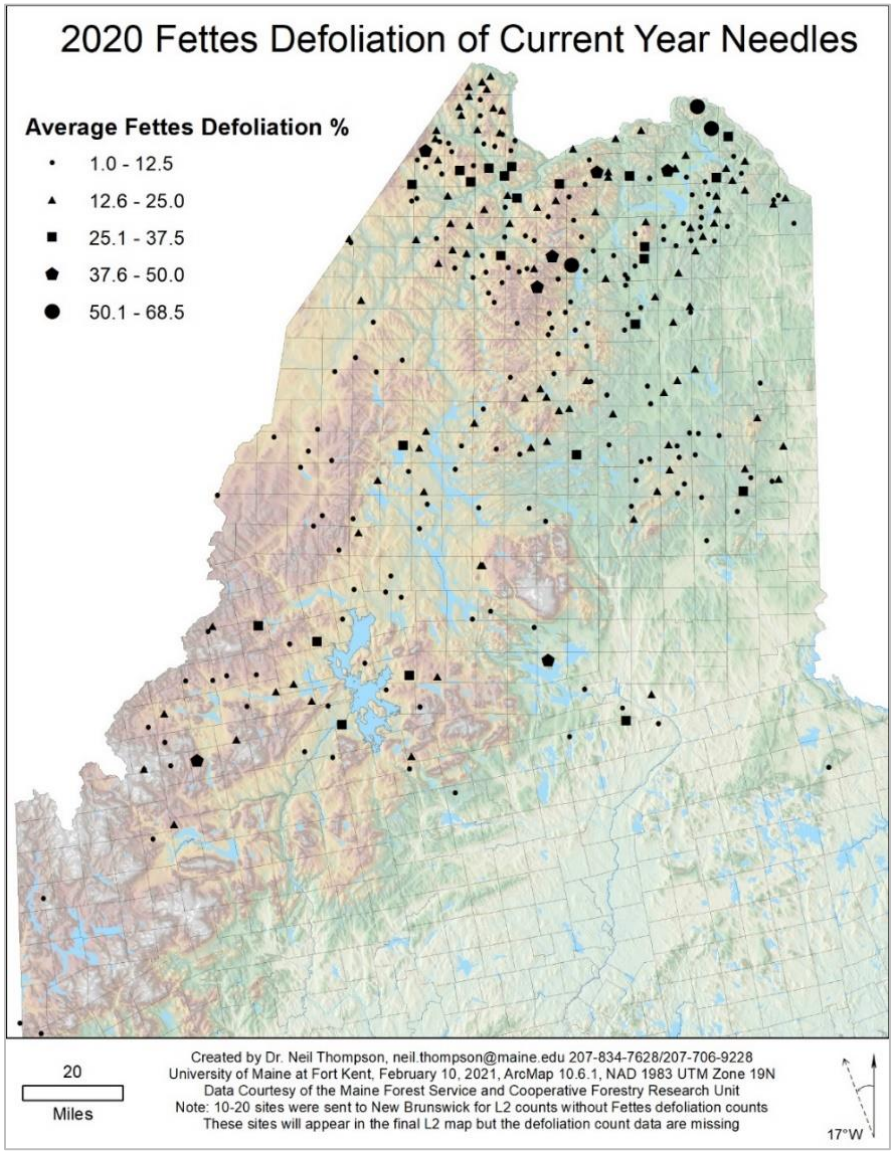

Figure 20. Map of statewide results for 2020 Fettes defoliation survey.

Aroostook County mid-season Defoliation Surveys

Ground surveys for SBW defoliation were conducted in 2020, looking specifically for spruce budworm in northern Maine where damage would be expected to first appear. For the first time since the end of the last major SBW outbreak in Maine, mature SBW larvae are easily found at survey sites in northern Penobscot and Aroostook Counties. A mid-season defoliation survey at 60 sites in Aroostook County found widespread, low-level defoliation from SBW. Sites were reevaluated in 2021 and 37 sites showed slight increases in current season defoliation levels, whereas 23 sites showed decreases. On sites where defoliation increased, it did so only marginally, with an average increase of just 1.5% across all 37 sites and a maximum increase of just 5.5%. None of the sites evaluated in 2020 or 2021 showed concerning levels of defoliation at this point in time (Figure 21a and 21b).

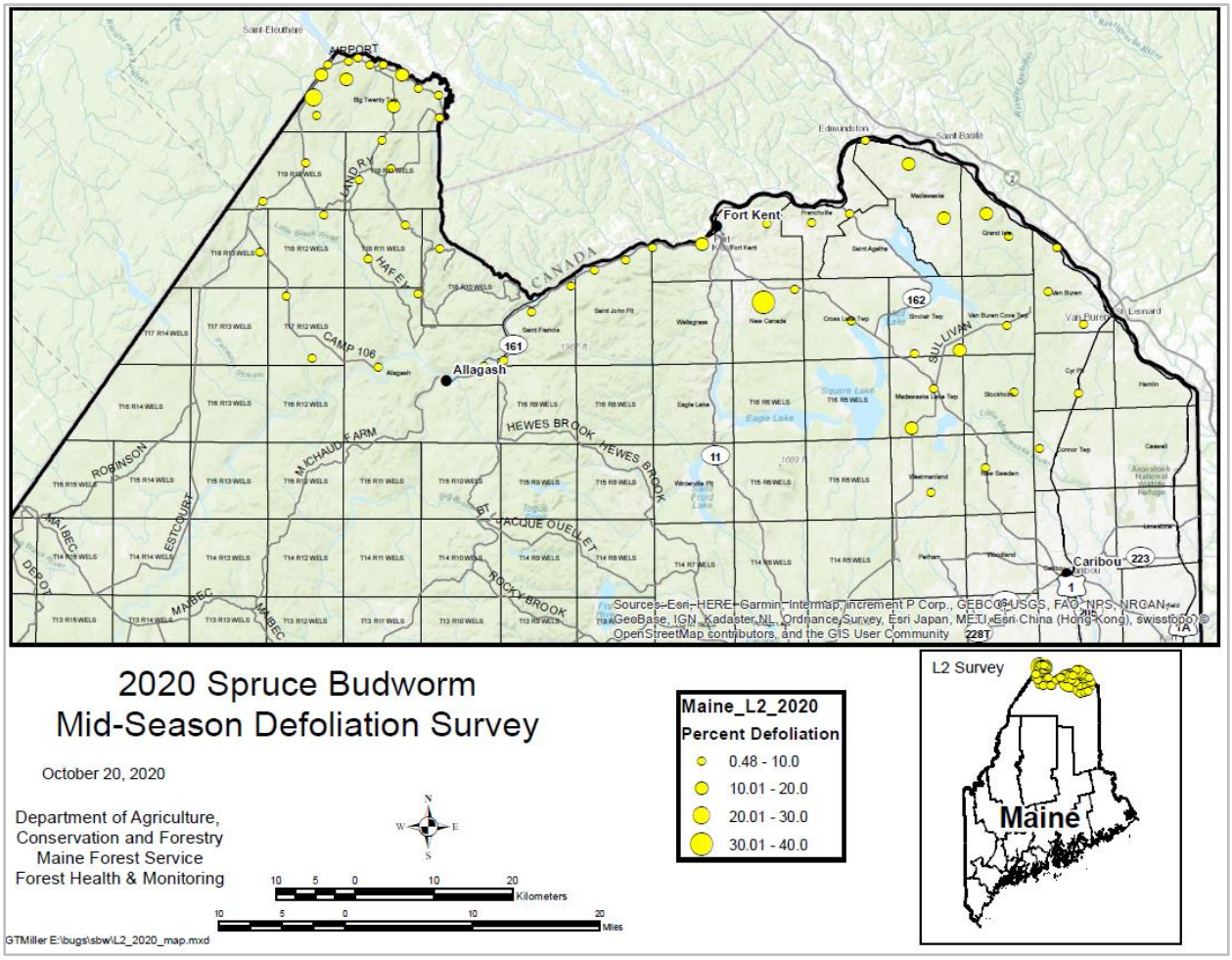

Figure 21. Maps of sites evaluated during 2020 (above) and 2021 (next page) SBW mid-season defoliation survey and corresponding defoliation intensities.

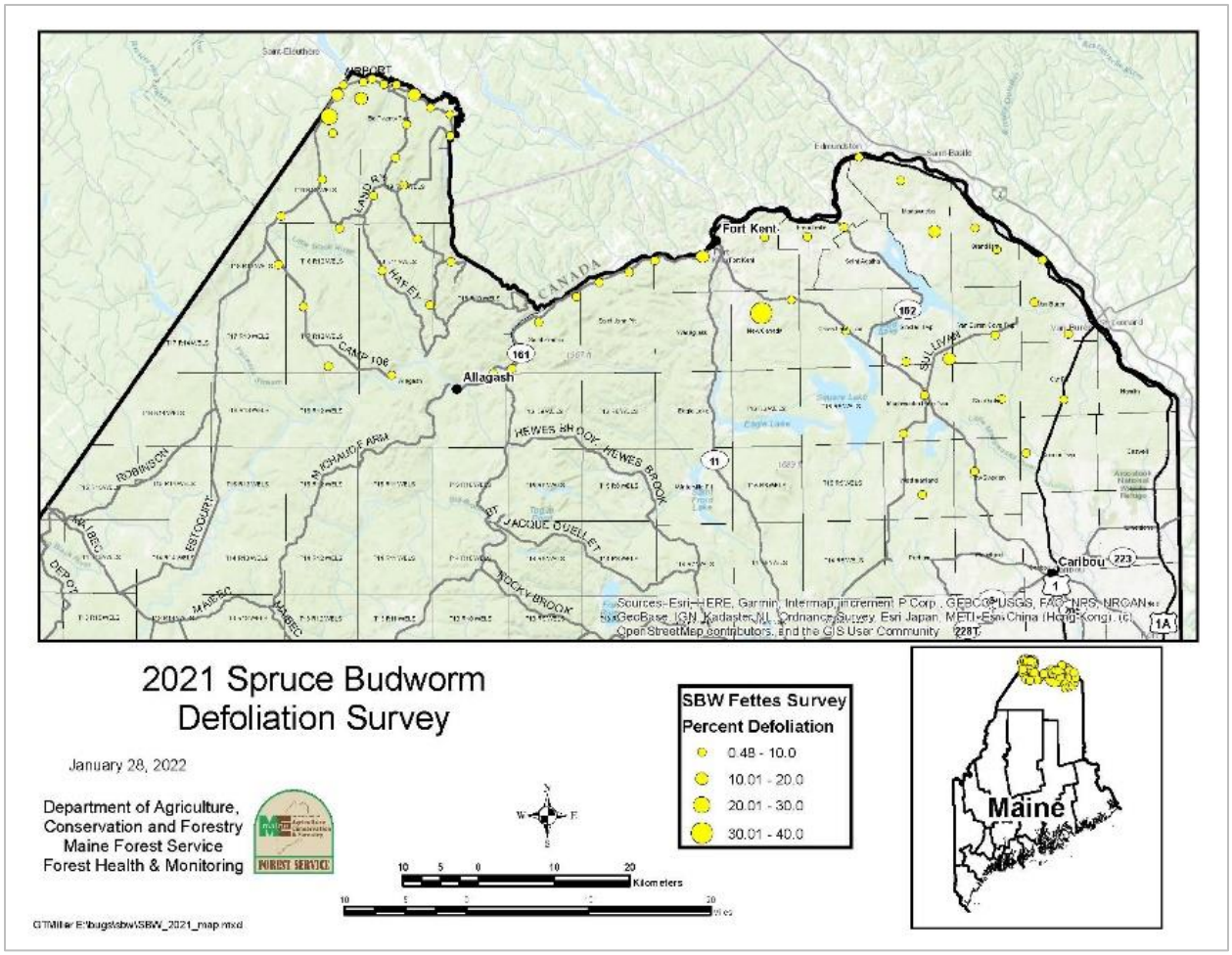

Figure 21. Maps of sites evaluated during 2020 (previous page) and 2021 (above) SBW mid-season defoliation survey and corresponding defoliation intensities.

Aerial Defoliation Survey

MFS conducts extensive aerial survey each season to search for large-scale damage from a variety of forest pests throughout the state, including SBW. Although SBW defoliation visible at ground level has been increasing over the past several seasons, as evidenced from various defoliation surveys and landowner reports, it remained undetectable from the air until 2021 (Figure 22). Since this specific type of damage has not been seen by any of our current aerial surveyors, we used a series of known defoliation sites in Aroostook County to calibrate our search image. This resulted in the identification of several additional areas of defoliation damage in those areas corresponding with above average pheromone trap captures and numbers of overwintering larvae, supporting the results of these other monitoring efforts well. Interestingly, similar damage has not been observed from the air over Big Twenty Township to the west, where results from pheromone trapping and overwintering larval surveys have returned similar numbers over the past several seasons. Although nearly 850 acres of defoliation was documented in 2021, the severity of the damage remains moderate at worst. Additionally, it is important to remember that SBW defoliation at lighter levels is much more widely distributed across northern Maine than these limited areas visible during aerial survey.

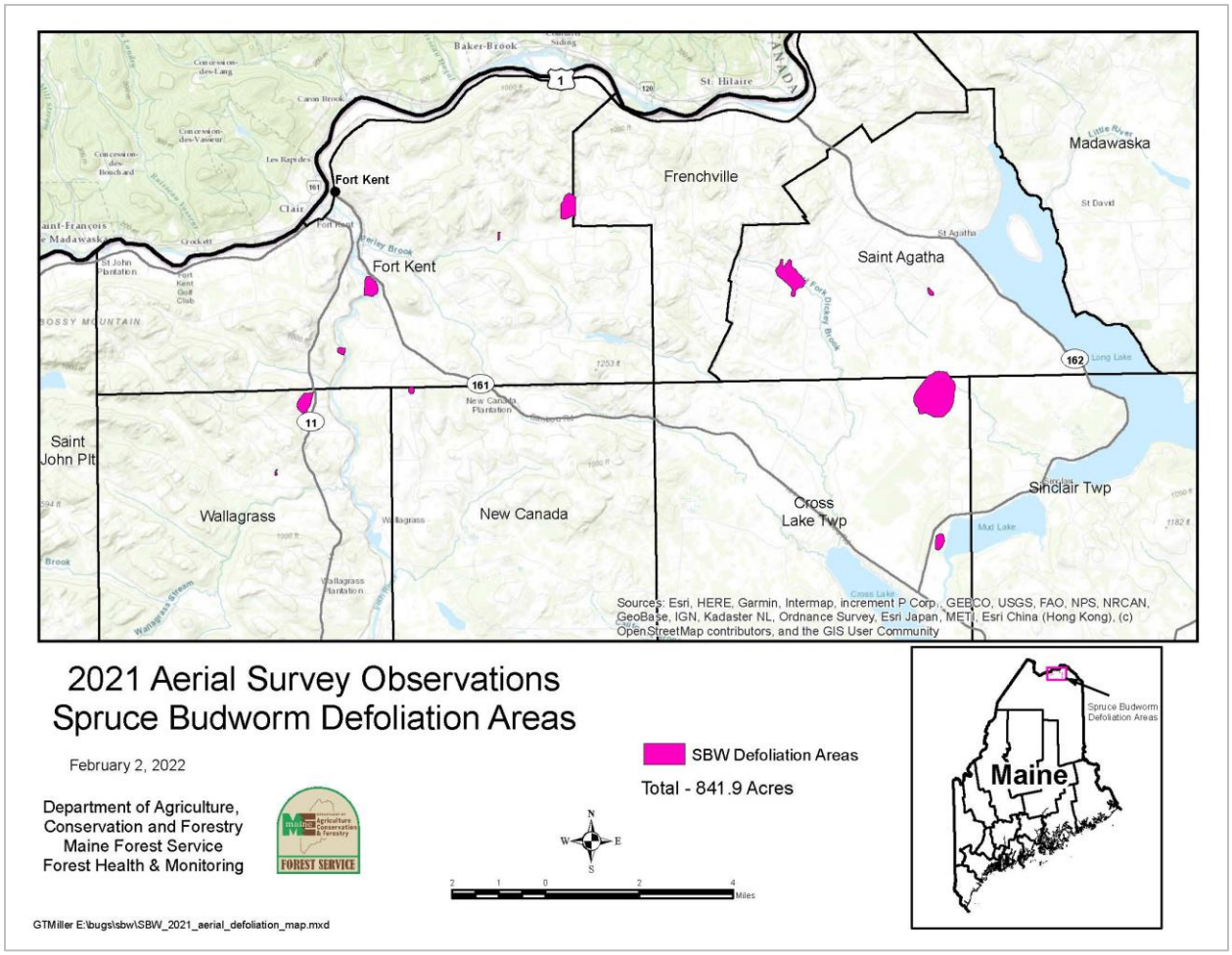

Figure 22. Areas of spruce budworm defoliation in Maine detected during 2021 aerial survey.

Remarks

The 2021 monitoring season has spelled yet another interesting turn of events in the pursuit to better understand and predict the trajectory of Maine's current SBW situation. From prior monitoring data, particularly our long-term light trap data, we know to expect ups and downs in the populations during periods of build-up and outbreak (Figure 23).

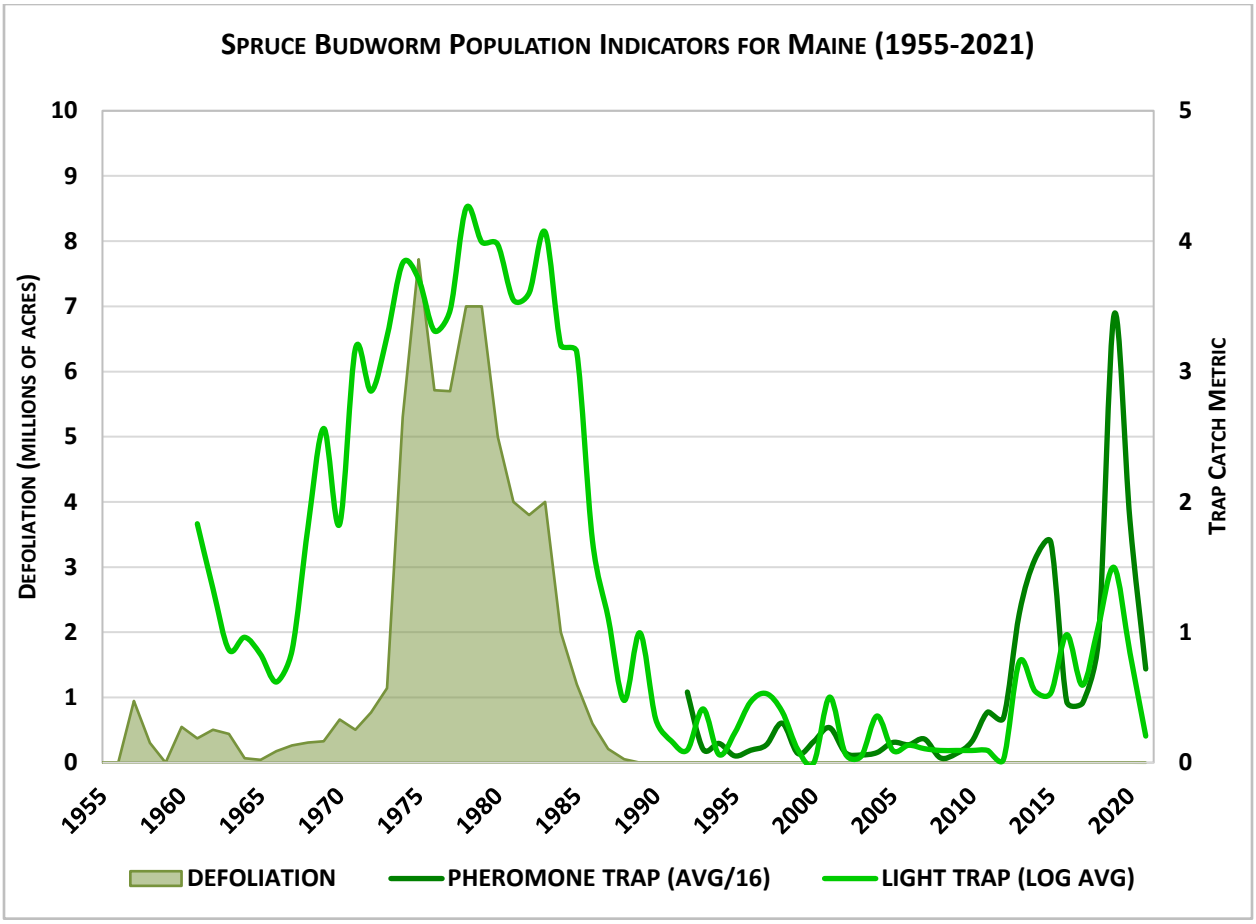

Figure 23. Long-term monitoring data provide a look at annual variation in Maine SBW populations as measured by light trap catch, acres of defoliation, and pheromone trap catch.

Abiotic factors may be playing a significant role in explaining some of the current oscillations. It has been hypothesized that 2021 weather patterns in northwestern New Brunswick and northern Maine could have negatively impacted larval development in these areas and in turn reduced the number of adult moths captured in pheromone traps. For example, June 2021 was the all-time warmest June on record for the Caribou, ME weather station (since that record was previously set in June 2020) and marked the first time since temperature recording began in 1939 that a 90-degree day was reached in the first 10 days of June, with back-to-back 92-degree days on June 7 and 8. This was then followed immediately by the coolest July since 2009. Although these events may seem insignificant to us, the effects on temperature-dependent natural processes such as larval/pupal development and host plant phenology can be much more extreme. Under current climate change models, given the long return interval of SBW, there is even conjecture as to whether Maine might ever have an outbreak similar to the 1970's to 1980's again as the range of suitable climatic conditions for SBW continues to move northwards.

As interesting as this may be, it is impossible to determine, since Maine likely received an influx of migrating moths from Quebec on the night of July 17 (Figure 24). This flight could have certainly influenced pheromone trap captures in northern Maine where numbers remained the highest, and so we await further information from the 2021 L2 survey results as we gear up for the 2022 monitoring season.

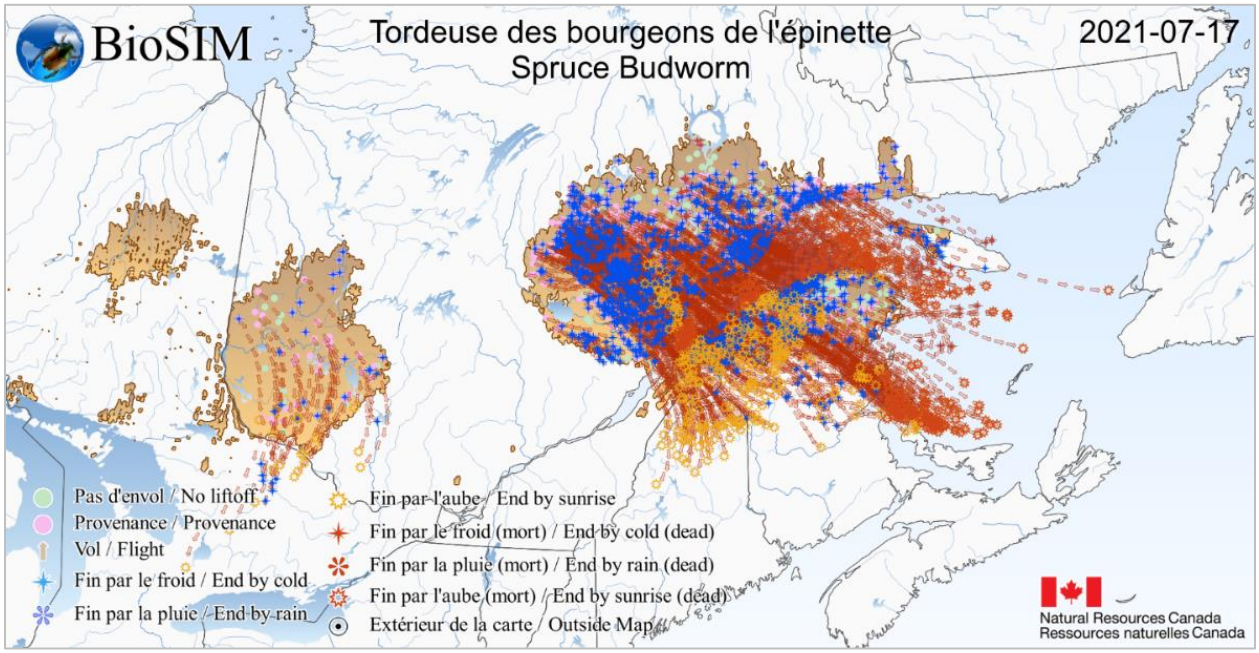

Figure 24. Predicted results from SBW flight models for July 17, 2021. Courtesy Rémi Saint-Amant.

As always, it is our hope that this information will provide land managers with insight on current events so that adequate preparations and responses can be made. Updates during 2022 will be relayed to cooperators and other stakeholders through our monthly conditions report newsletter from the MFS Insect and Disease Lab and through the Spruce Budworm Task Force communications network as important information becomes available.

Acknowledgements

On behalf of the Maine Forest Service, we wish to thank our cooperators for their continued participation and dedication to this large-scale and long-term project. The overall success of this program would not be possible without them. This was especially true in a SECOND field season plagued with countless logistics issues for all parties stemming from the ongoing COVID-19 pandemic.

Special thanks are due to our partners at the University of Maine Cooperative Forestry Research Unit, especially Dr. Neil Thompson, Dr. Angela Mech, James Stewart, and their staff, who continue to coordinate the overwintering L2 larval survey. The establishment of a dedicated L2-processing lab right here in Maine was an important milestone for these monitoring efforts and will be critical to response.

Thanks to each and every one of our SBW colleagues in Canada who provide guidance on many aspects of our SBW monitoring and management activities. We were especially excited to join the automated pheromone trap network this past year with our two traps on loan from Canada and look forward to whatever future collaborations between our groups lie ahead.

Another special thank you is due to Maine Forest Service staff, especially Abby Karter, who participated in receiving and counting SBW samples as they came in from the field this season. With more reliable

access to the lab again in 2021, this responsibility went back to just a few dedicated sample processors who spent their fair share of time hunched over the lab counter.

This program would not be able to function as well as it does without the assistance and experience of our Senior Entomology Technician in northern Maine, Joe Bither. In addition to other SBW tasks and coordinating with cooperators, he alone performs the mid-season defoliation survey across northern Aroostook County. Finally, thanks to Greg Miller for mapping these and all the rest of our SBW survey results for us.

We are looking forward to the upcoming monitoring season and working with all of you once again. Let's hope the numbers remain low but be well-prepared for whatever comes.

Best,
Mike

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Appendix E
Current distribution map of confirmed reports of Beech Leaf Disease in Maine as of October 26, 2021

Aaron Bergdahl, Forest Pathologist
Maine Forest Service, DACF
168 State House Station, Augusta, ME 04333

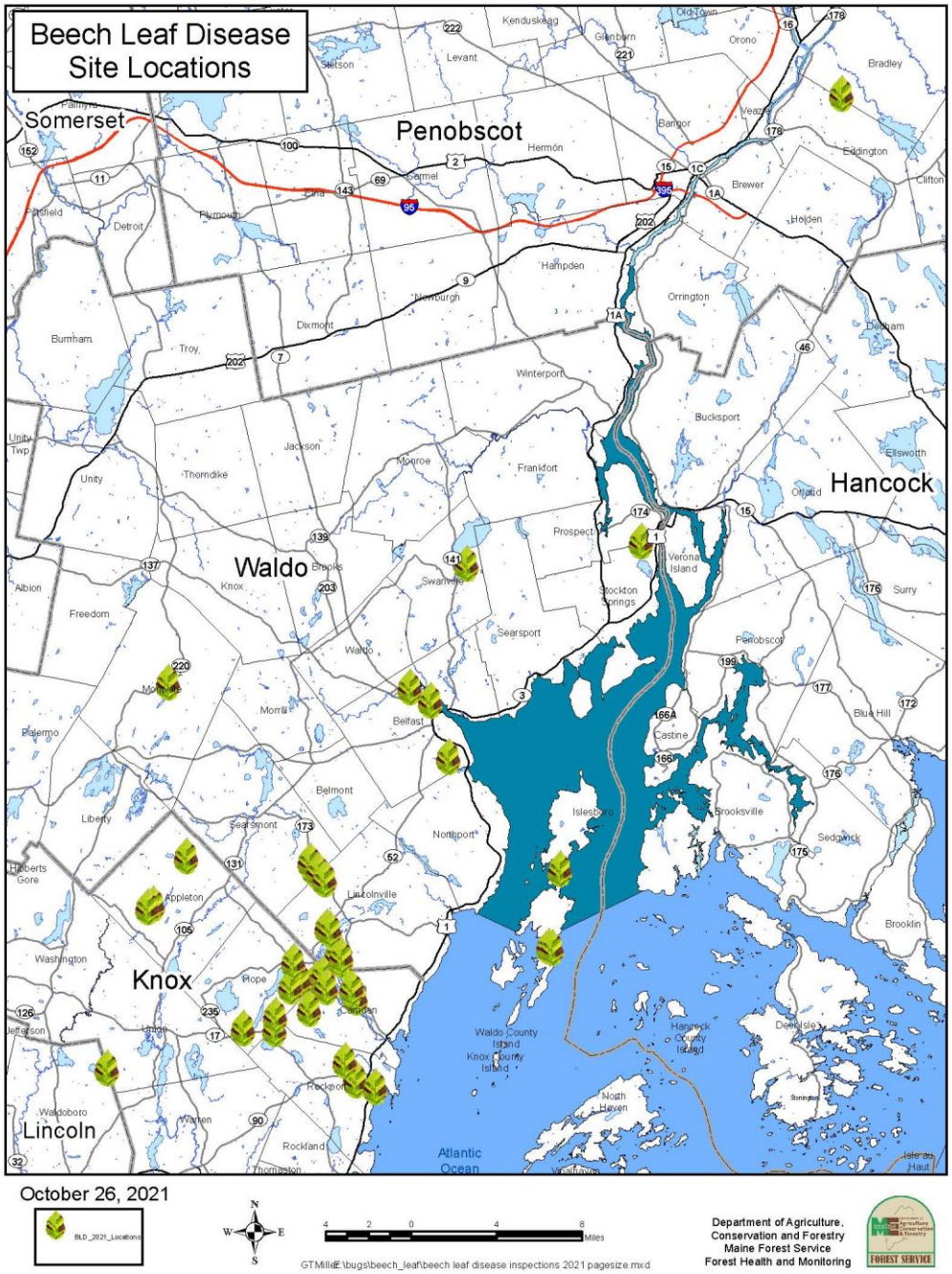

Figure 25. Current known distribution of BLD in Maine.

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List of Abbreviations

ALB: Asian longhorned beetle
APH: Animal and Plant Health
APHIS: Animal and Plant Health Inspection Service
BL: Blacklight
BGM: Balsam gall midge
BLD: Beech leaf disease
BSLB: Brown spruce longhorned beetle
BWA: Balsam woolly adelgid
CFRU: University of Maine Cooperative Forestry Research Unit
COVID-19: Coronavirus disease caused by SARS-CoV-2 virus
DACF: Department of Agriculture, Conservation, and Forestry
DED: Dutch elm disease
EAB: Emerald ash borer
EDRR: Early Detection and Rapid Response
EHS: Elongate hemlock scale
EIS: Early intervention strategy
ELC: European larch canker
EM: Evaluation and Monitoring
EWBB: Exotic woodborers and bark beetles
FEMC: Forest Ecosystem Monitoring Cooperative
FHM: Forest Health and Monitoring
FIA: Forest Inventory Analysis
HWA: Hemlock woolly adelgid
L2: Refers to second instar spruce budworm larvae
MFS: Maine Forest Service
PPQ: Plant Protection and Quarantine
SBW: Spruce budworm

SLF: Spotted lanternfly
SPB: Southern pine beetle
TNC: The Nature Conservancy
USDA: United States Department of Agriculture
USDA-APHIS-PPQ: US Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine
WMA: Wildlife Management Area
WPBR: White pine blister rust
WPND: White pine needle diseases