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 that 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 & 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 1). 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 1). In 2021, 328 usable samples were collected from 351 sites statewide (Figure 2). Overall, the statewide average pheromone trap catch has fallen substantially from 67 in 2019, to 36 in 2020, to 16 in 2021 (Figure 3). 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 4). 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.

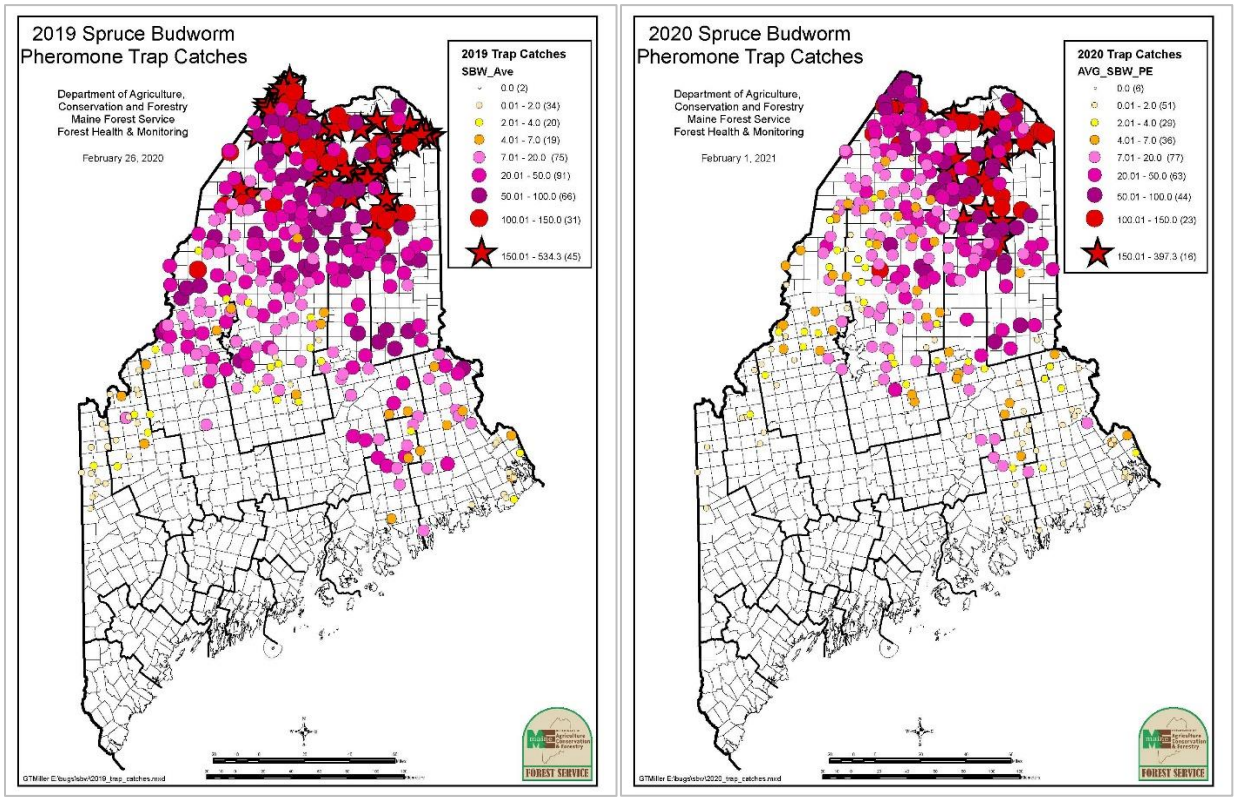

Figure 1. Statewide spruce budworm pheromone trap average catches in 2019 (left) and 2020 (right).

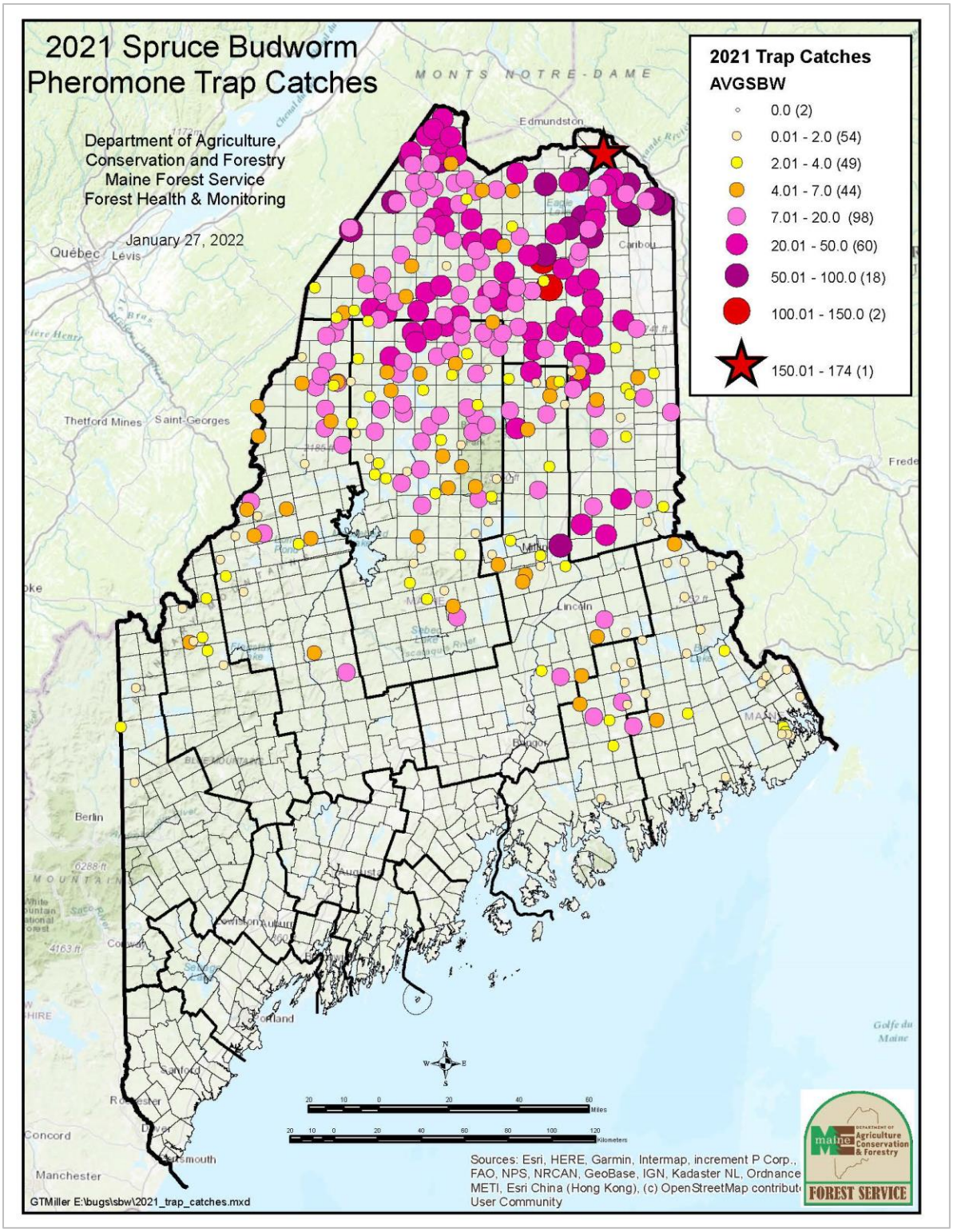

Figure 2. Statewide spruce budworm pheromone trap average catches in 2021.

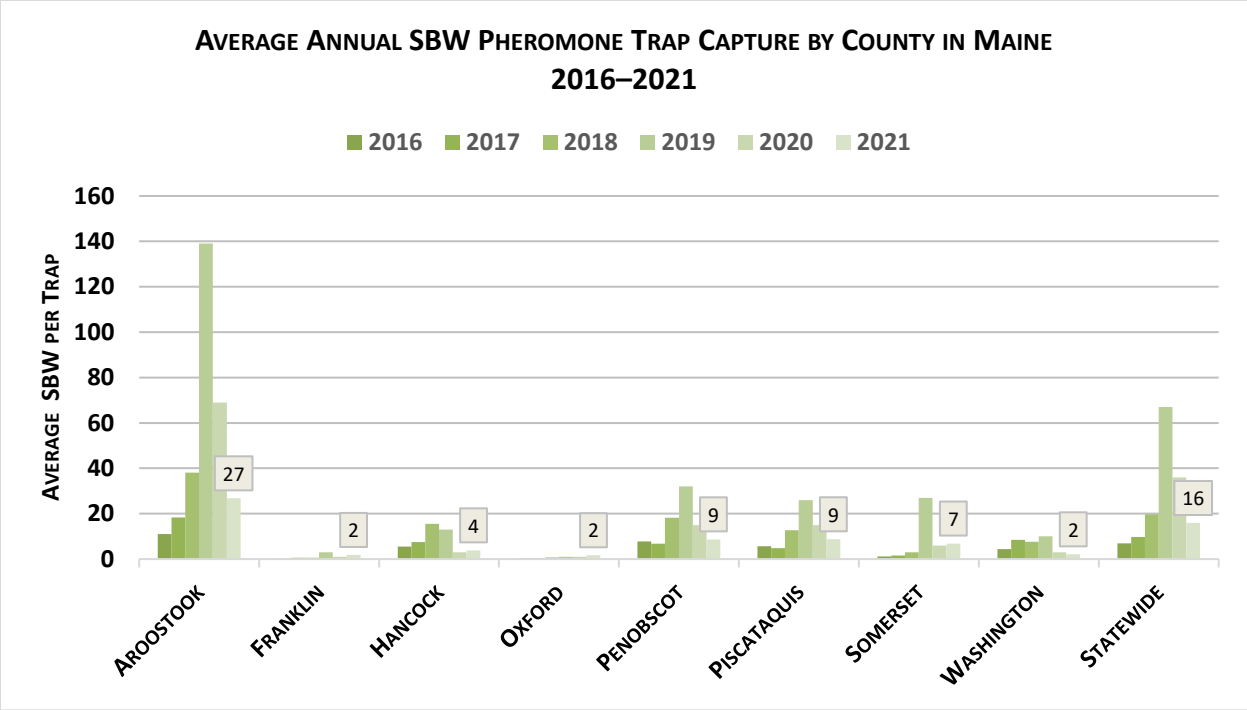

Figure 3. Average SBW pheromone trap capture by county in Maine, 2016–2021.

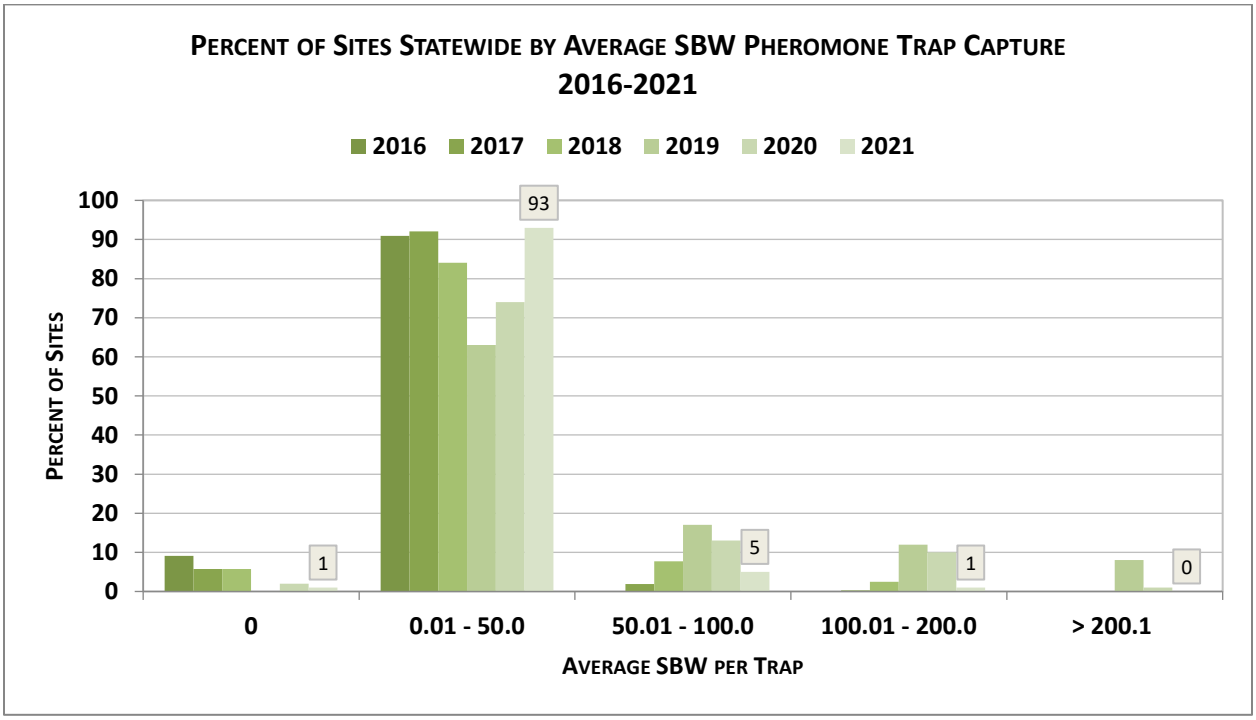

Figure 4. Percent of monitoring sites by average SBW pheromone trap capture, 2016–2021.

As noted earlier, MFS and cooperators have been monitoring a core set of long-term pheromone trap sites since 1992. 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.

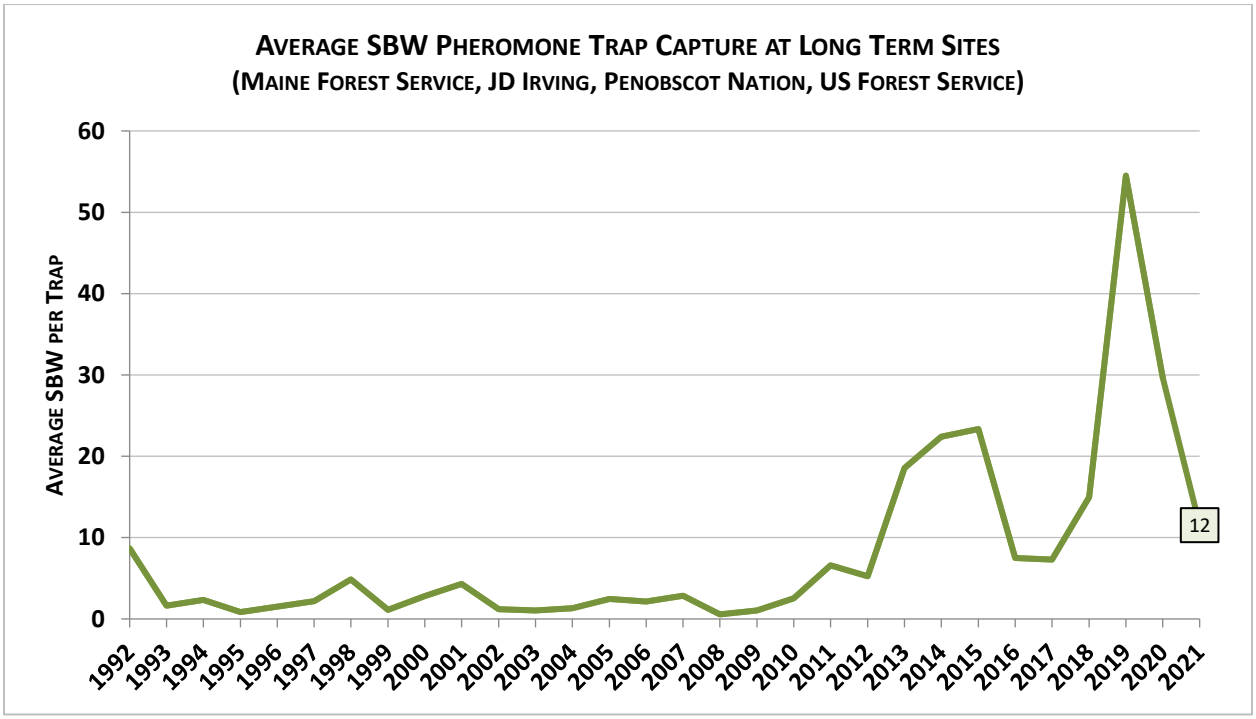

Figure 5. Average SBW pheromone trap capture at long term sites operated since 1992 by the Maine Forest Service, J.D. Irving Ltd., Penobscot Nation DNR, and USDA Forest Service.

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 6). These data also help to inform flight models.

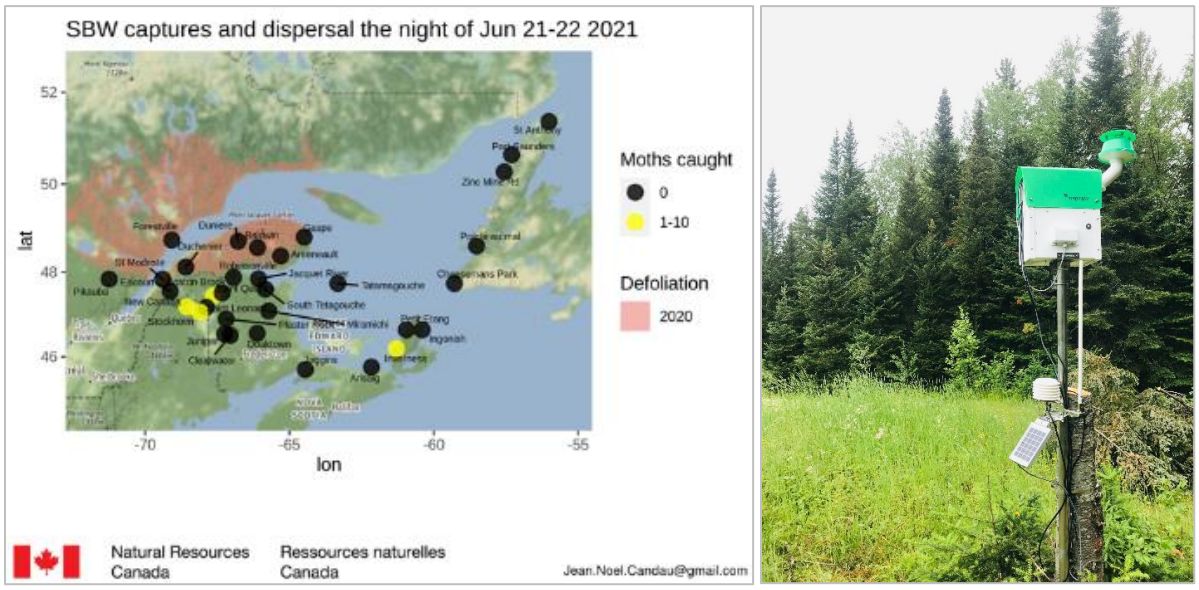

Figure 6. (*left*) Map of automated SBW pheromone trap locations throughout Canada and Maine and first flight dates for Maine during 2021 monitoring season. (*right*) Example of automated SBW pheromone trap operated in New Canada, Aroostook County during 2021.

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 1, Figure 7). 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 1. Spruce budworm moth capture in light traps from 2015 through 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**

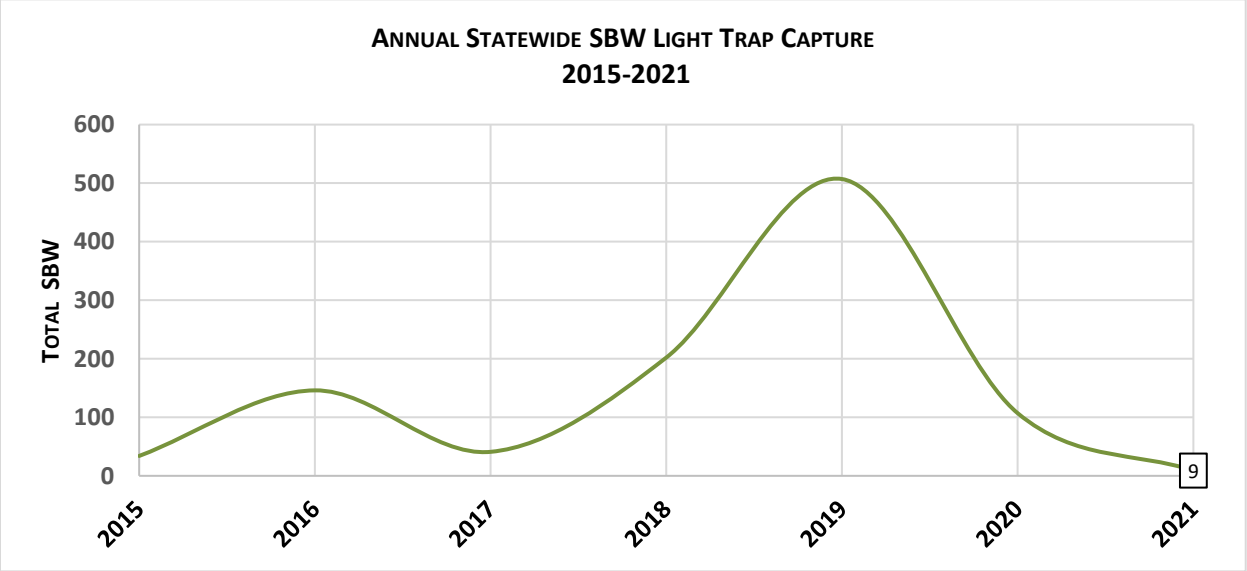

Figure 7. Total annual statewide light trap catches of SBW moths 2015–2021.

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 8). 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.

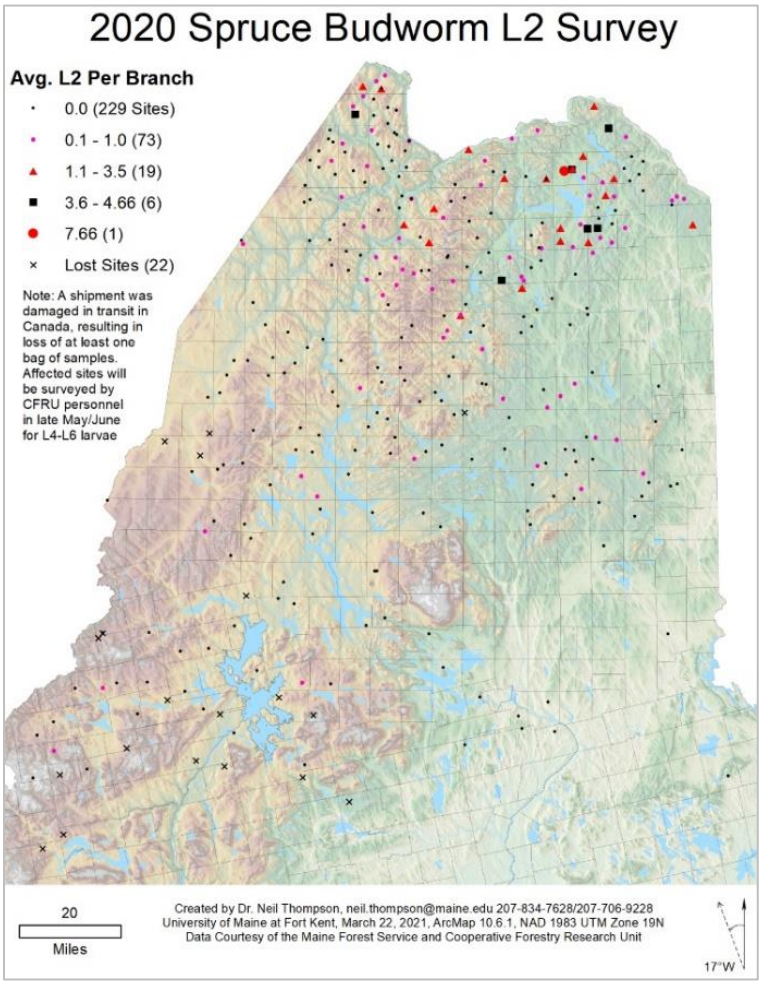

Figure 8. Map of statewide results for 2020 overwintering spruce budworm L2 larvae survey.

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 9). 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.

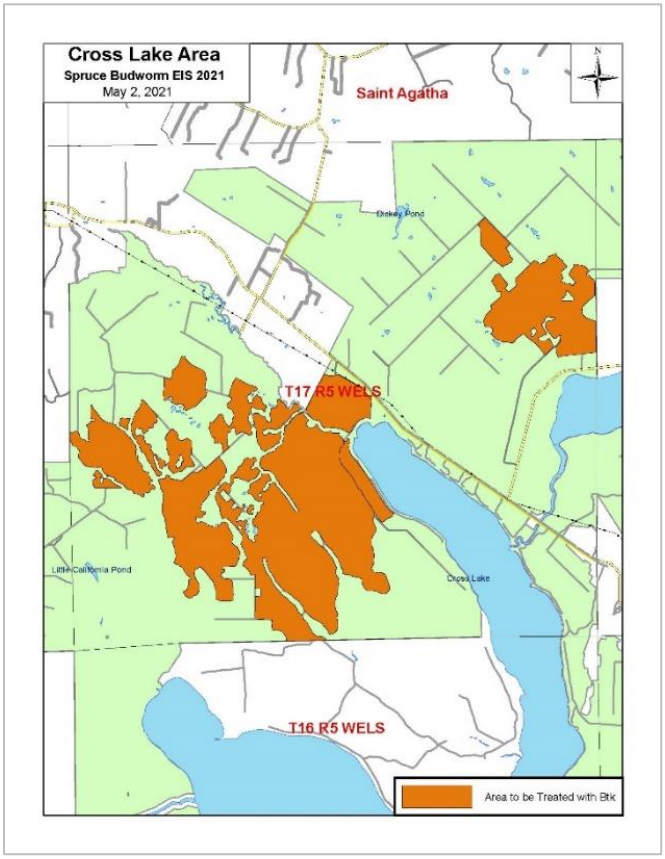

Figure 9. 2021 EIS treatment area in Cross Lake Twp, Aroostook Co. Courtesy J.D. Irving Ltd

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 (Figures 9). 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.

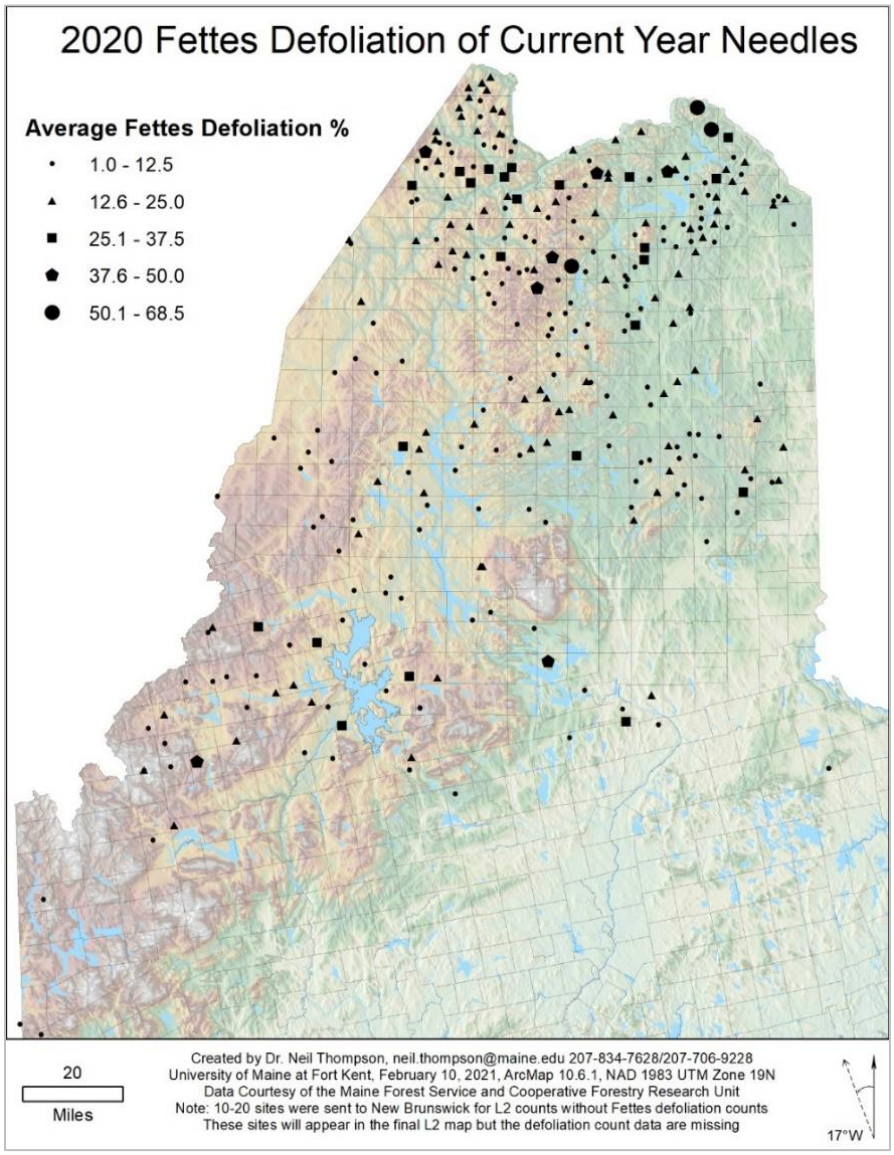

Figure 9. Map of statewide results for 2020 Fettes defoliation survey.

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 10).

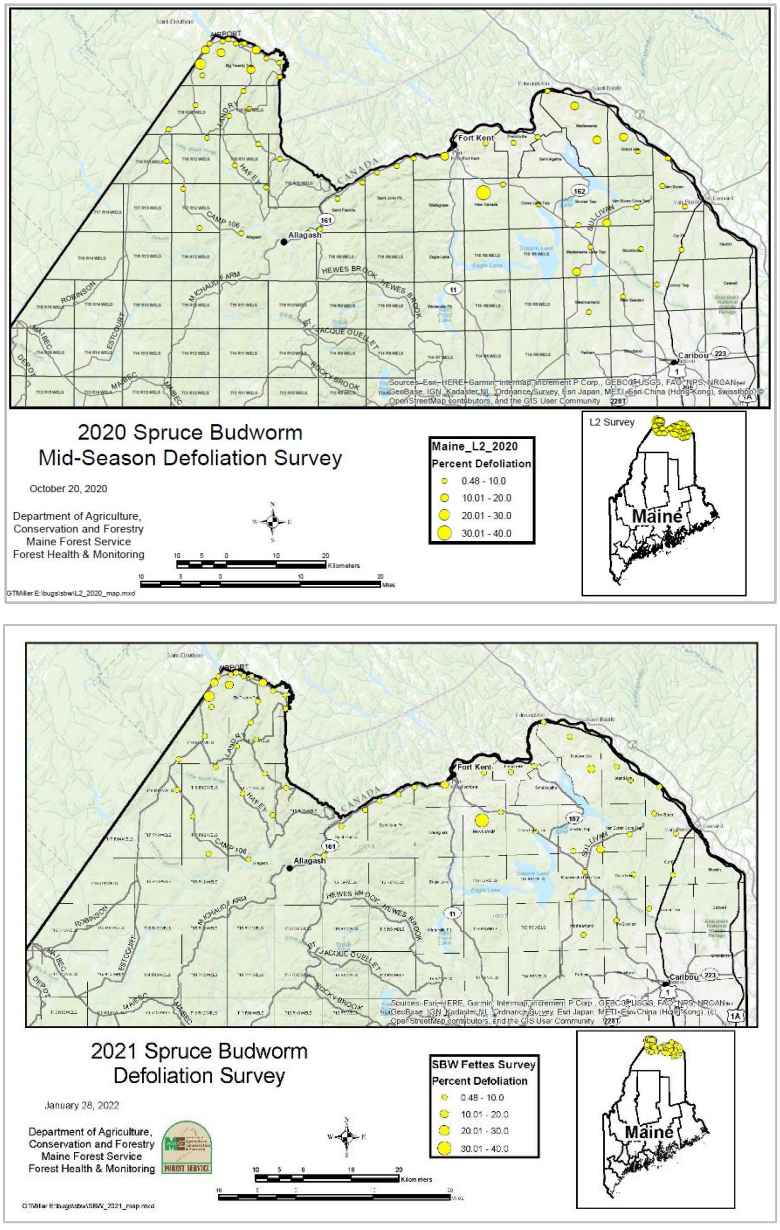

Figure 10. Maps of sites evaluated during 2020 (*above*) and 2021 (*below*) SBW mid-season defoliation survey and corresponding defoliation intensities.

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 11). 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.

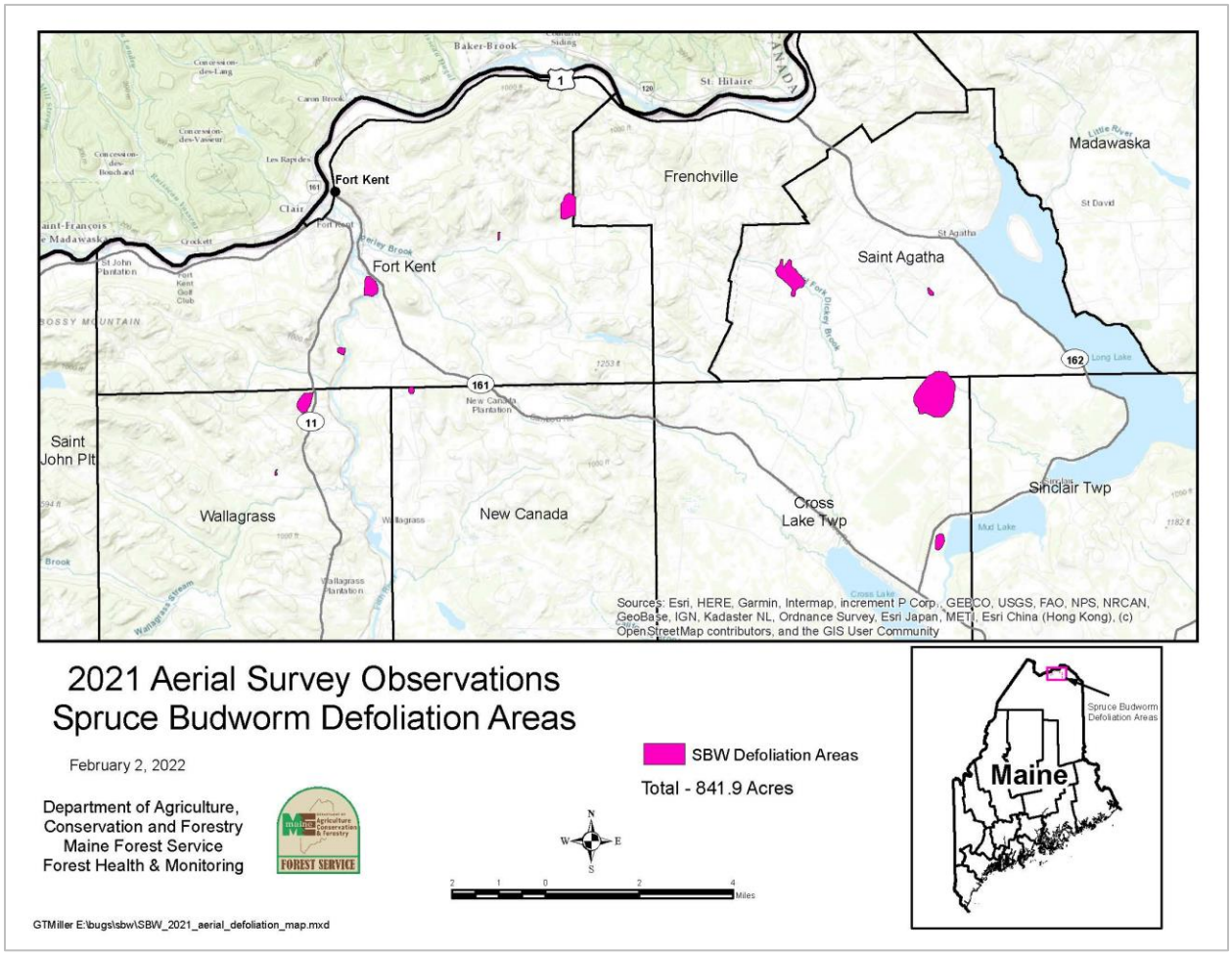

Figure 11. Areas of spruce budworm defoliation in Maine detected during 2021 aerial survey.

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 12).

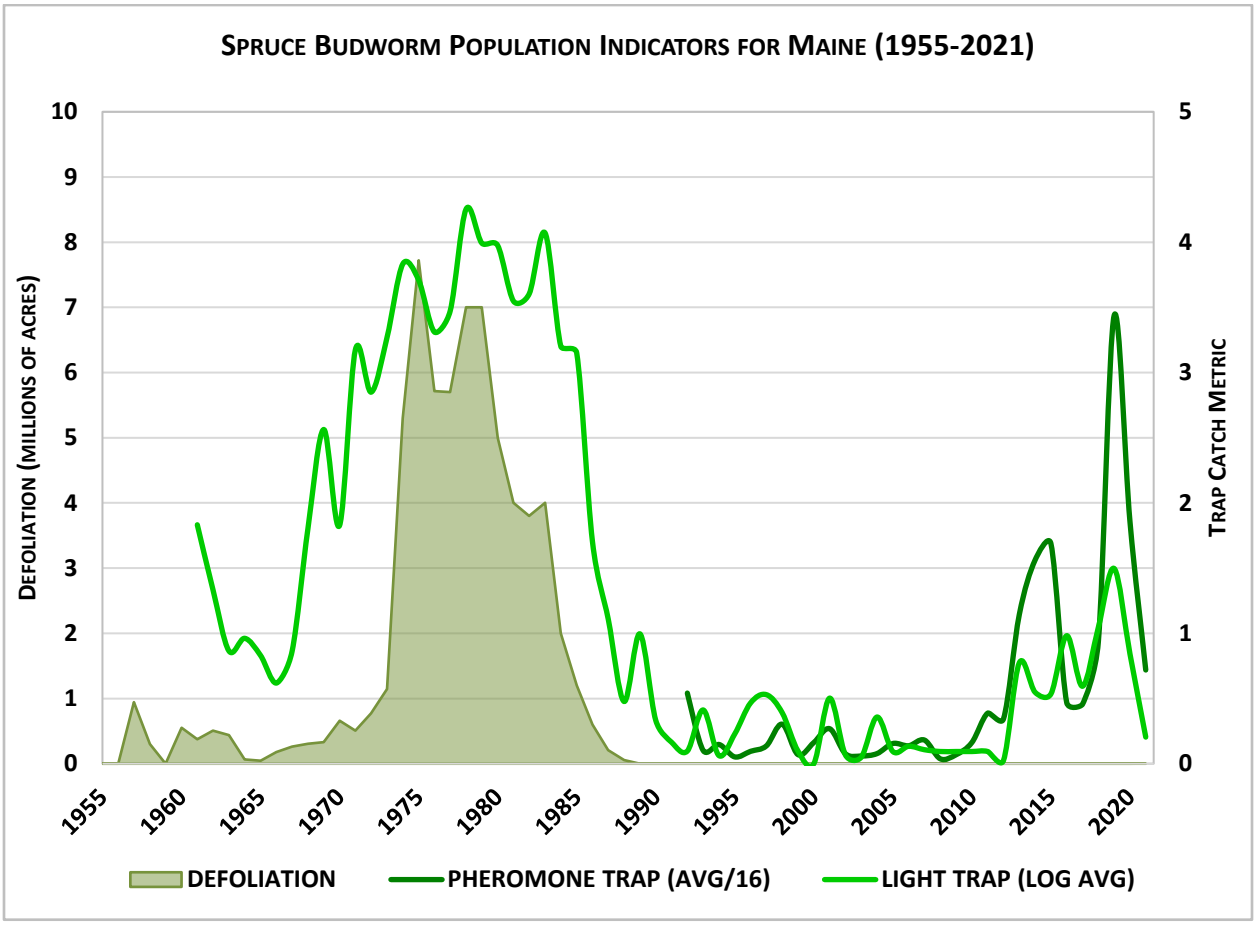

Figure 12. Long-term monitoring data provide a look at annual variation in Maine SBW populations as measured by light trap catch, acres of defoliation, and pheromone trap catch.

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 12). 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.

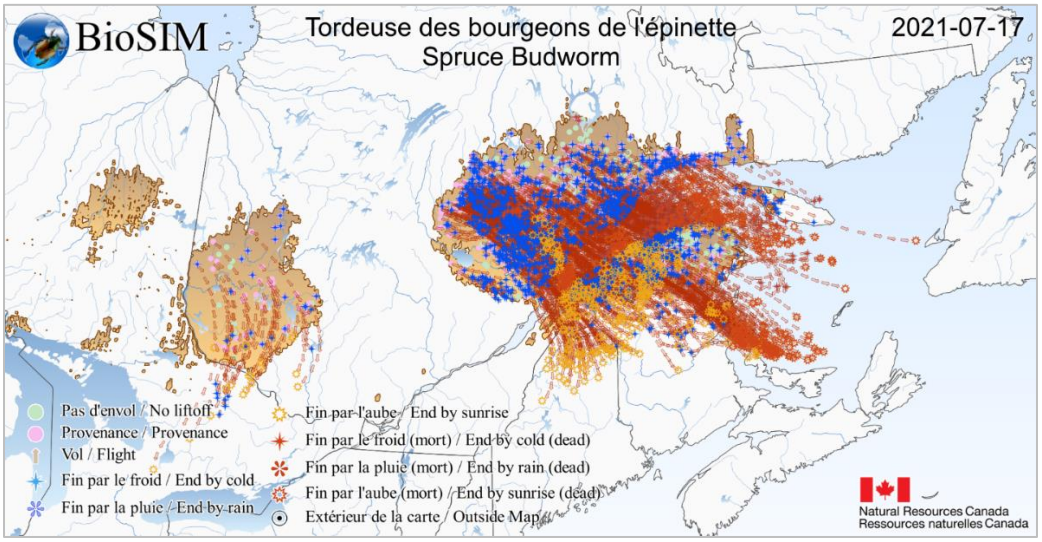

Figure 12. Predicted results from SBW flight models for July 17, 2021. Courtesy Rémi Saint-Amant

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 & 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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