Spruce Budworm Information Session
Opening Remarks
Allison Kanoti, FHM Director & State Entomologist

Amanda E. Beal
Commissioner

Patty Cormier
State Forester

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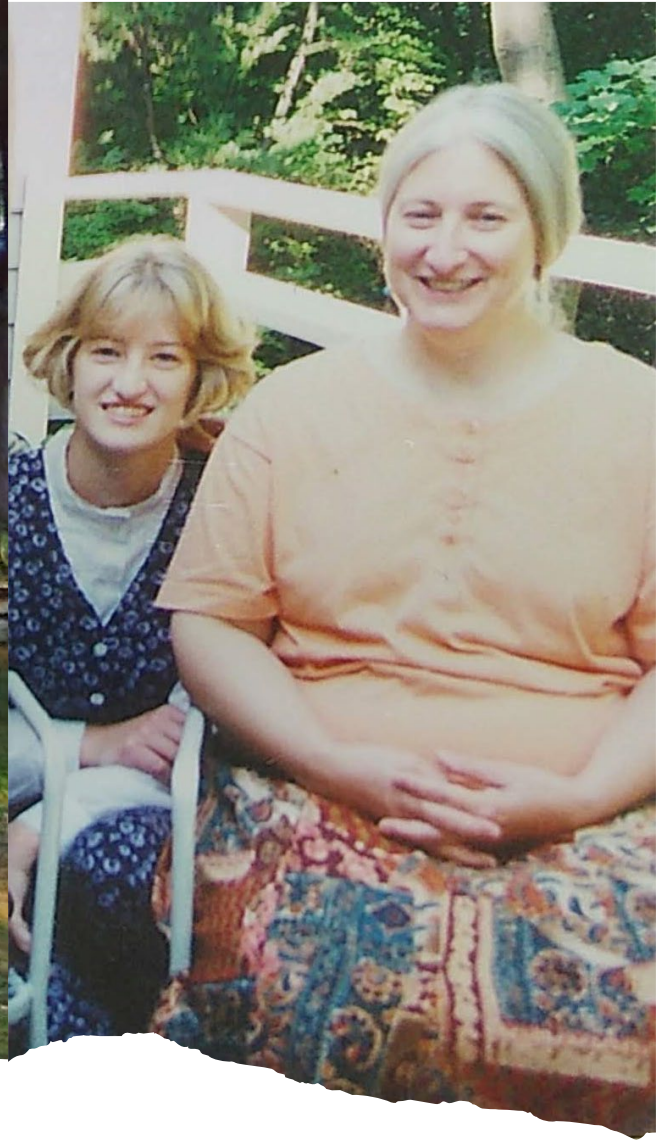
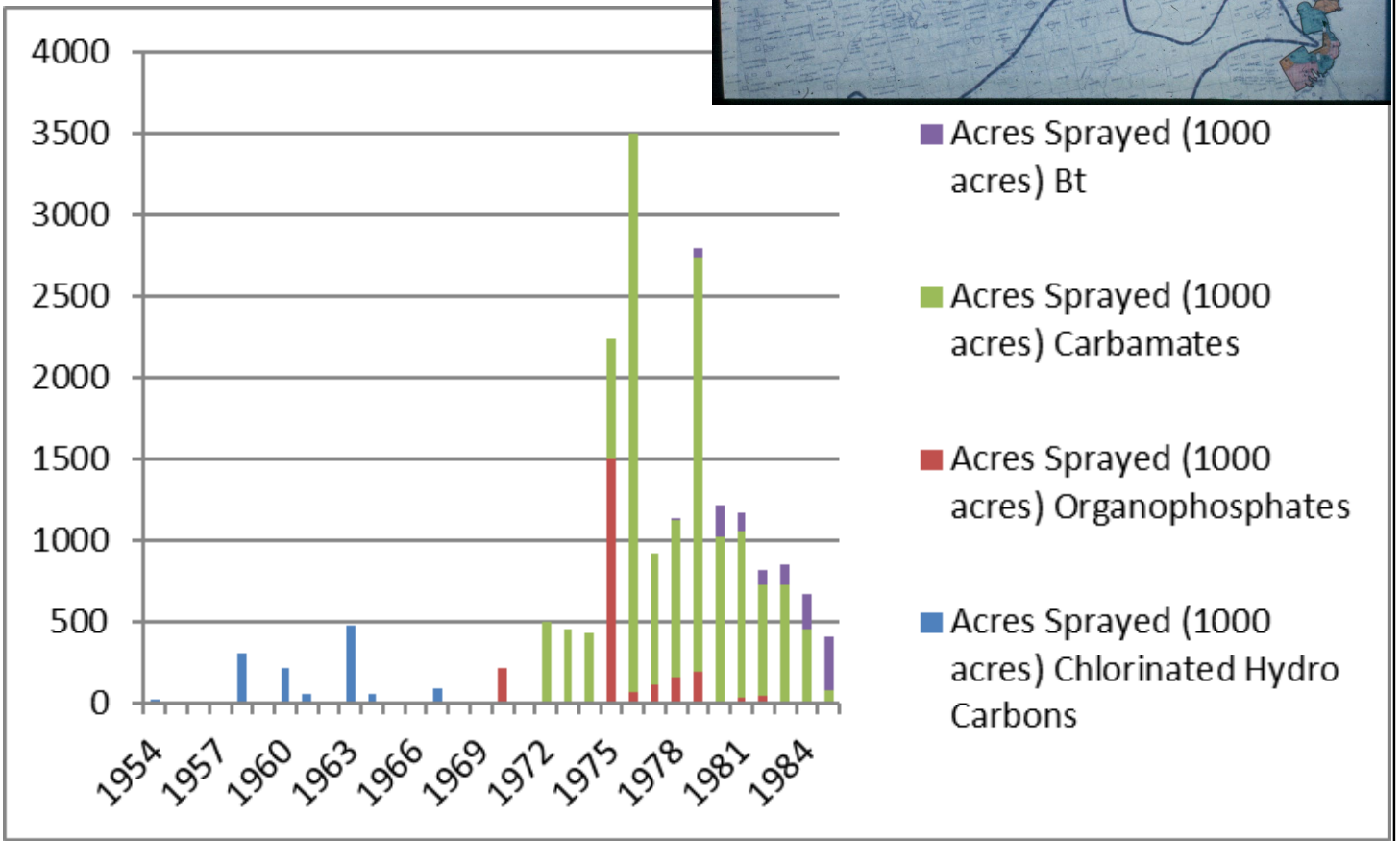
www.maine.gov/dacf

Late 1970s, New Hampshire

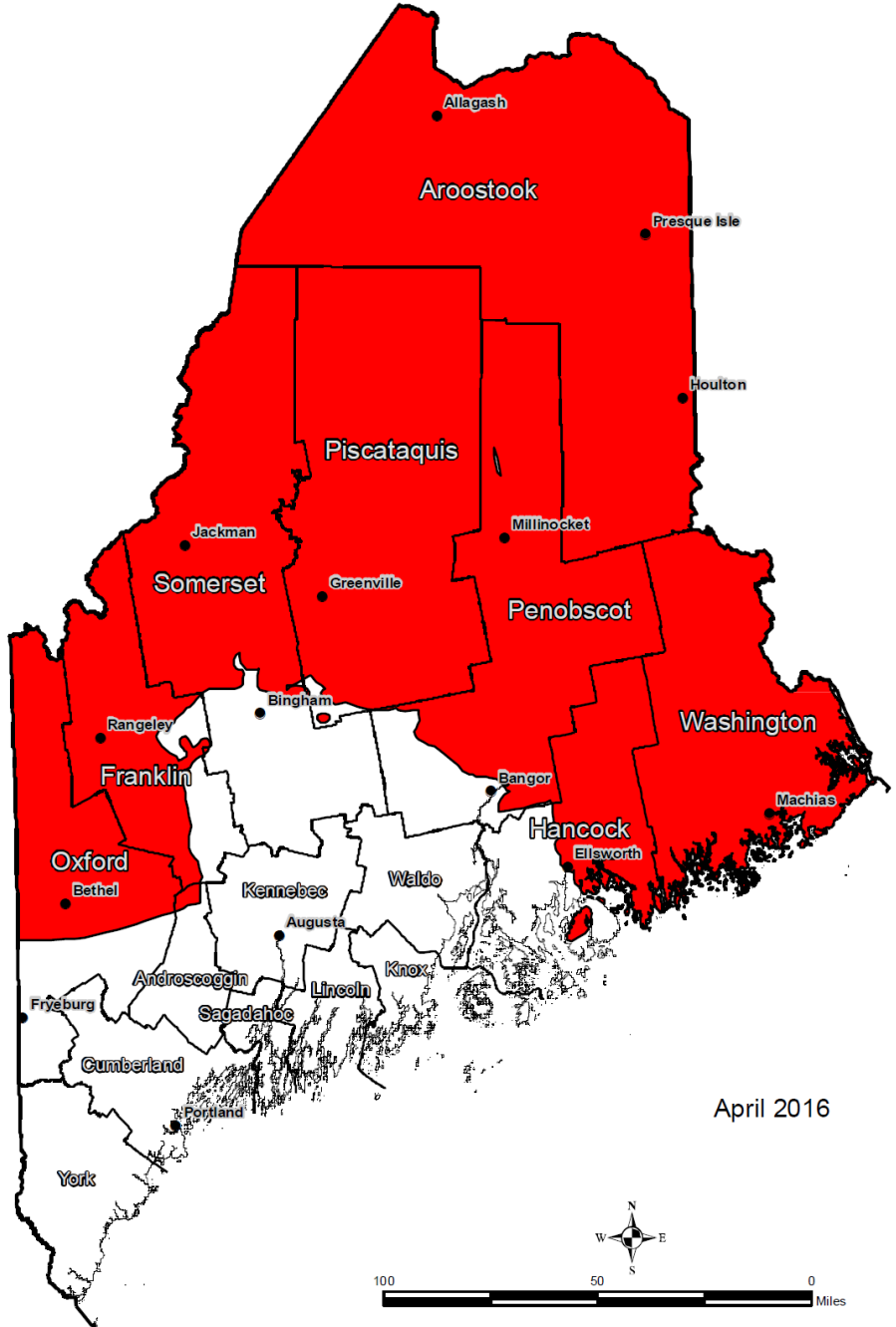


Late 1990s, Vermont

Spruce Budworm in Maine

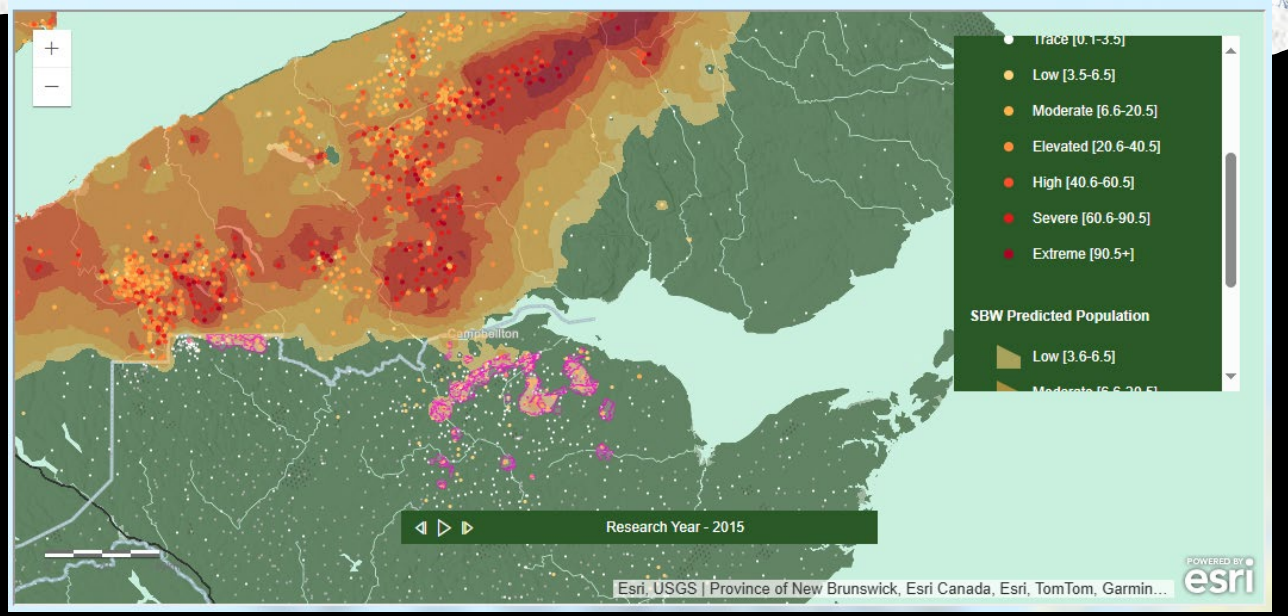


Approximate footprint with at least one year of moderate to severe defoliation during the last Spruce Budworm Outbreak (MFS,Weed)

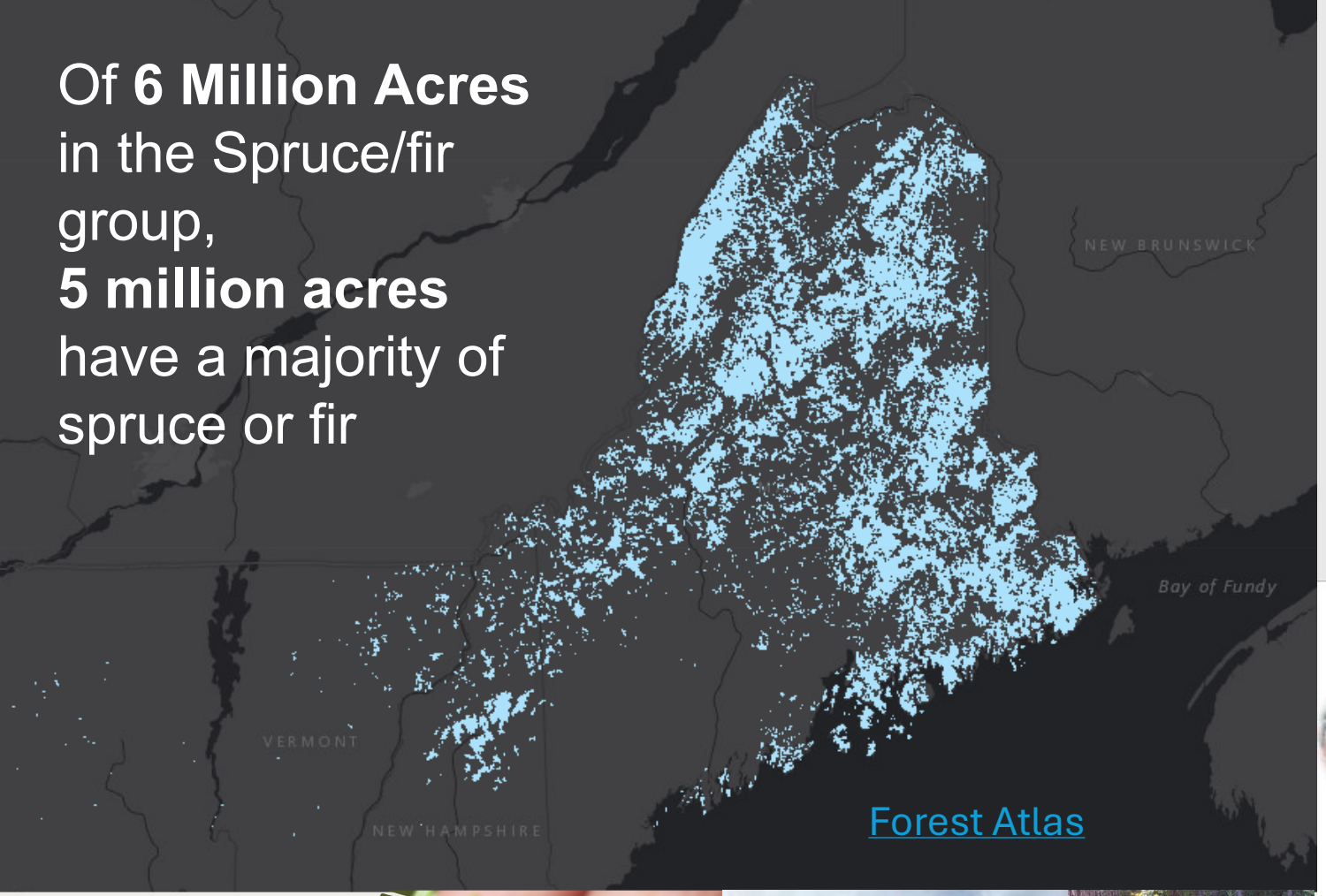


↑ Quebec North Shore 2015

Gaspe, Northern New Brunswick 2015 →



Of **6 Million Acres** in the Spruce/fir group,
5 million acres have a majority of spruce or fir

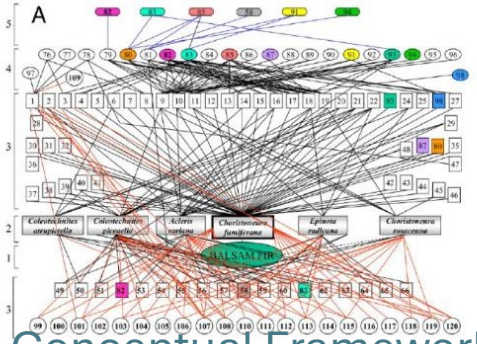


Forest Atlas

How do we control pest populations?

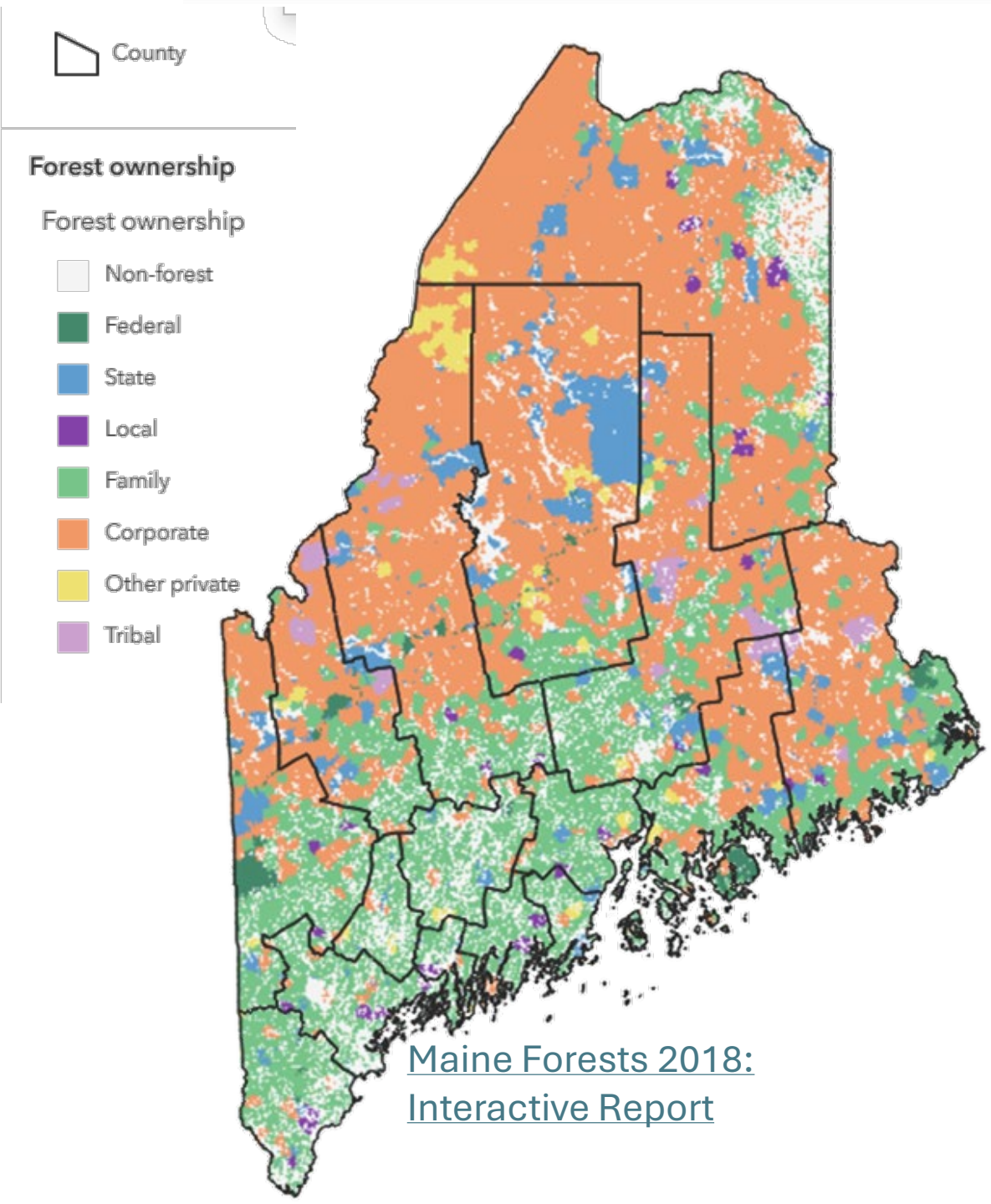
We need to '<u>add</u>' mortality:

3) Avoid impacting natural enemies or other non-target organisms.



Eveleigh et al., 2006

Conceptual Framework for EIS, R. Johns



[Maine Forests 2018: Interactive Report]

May 1st, 2025
from 1 - 3/4PM
Join via Zoom (registration required)
Join in Orono at Wells Conference Center
Join in Fort Kent at Nadeau Hall, UMFK

Session agenda and speakers:

1:00 - 1:10 PM	**Welcome & Opening Remarks** *Allison Kanoti, State Entomologist, Maine Forest Service*
1:10 - 1:25 PM	**An Introduction to Maine's Spruce Budworm History and the Current Challenges Ahead** *Mike Parisio, Forest Entomologist, Maine Forest Service*
1:25 - 1:45 PM	**Spruce Budworm Biology & Monitoring** *Angela Mech, Assistant Professor of Forest Entomology, Director of the UMaine Spruce Budworm Lab*
1:45 - 2:00 PM	**Efficacy of the Early Intervention Strategy for suppressing spruce budworm outbreaks** *Sara Edwards, Research Scientist, Natural Resources Canada*
2:00 - 2:10 PM	**Tebufenozide and BT_k: Toxicity and Risk Assessment** *Doug VanHoewyk, Toxicologist, Maine Board of Pesticide Control*
2:10 - 2:30 PM	**Maine Budworm Response Coalition (MBRC)** *Alex Ingraham, Chair of MBRC, Ked Coffin, Co-chair of Tactical Team, MBRC*
2:30 - 3:00 PM	**Q&A**
3:00 - 4:00 PM	**Location dependent activities**

Thank You

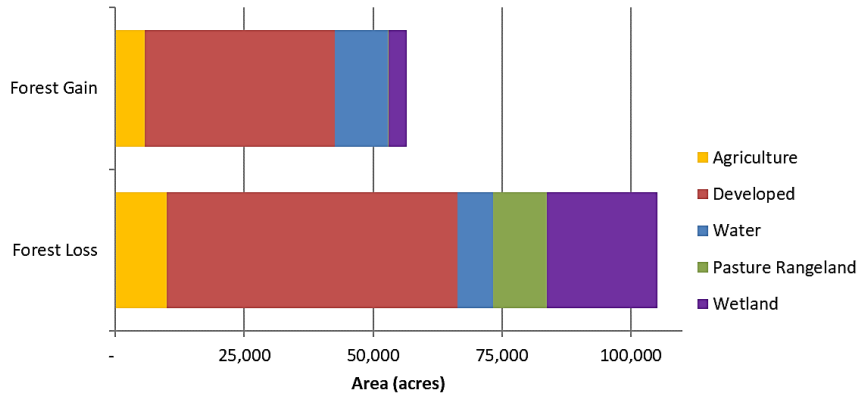


Figure 3.—Gross area forest loss and forest gain by land use category, Maine, 2013 to 2018.

An Introduction to Maine's Spruce Budworm History and the Current Challenges Ahead

SPRUCE BUDWORM INFORMATION SESSION

MAY 1, 2025

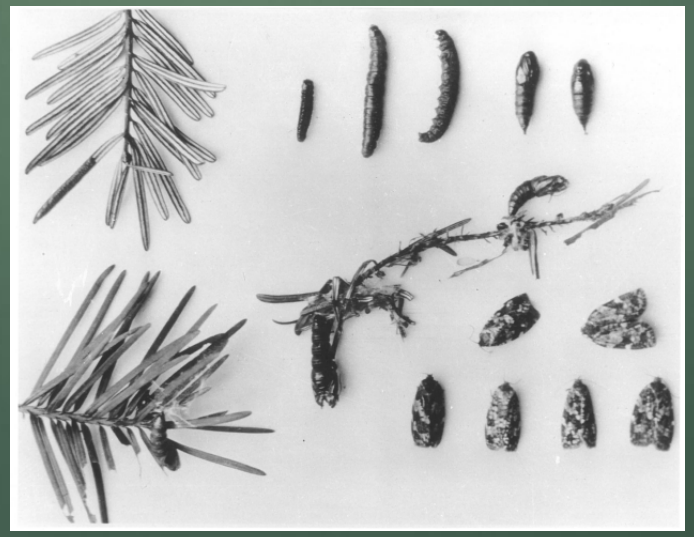
maine DEPARTMENT OF Agriculture Conservation & Forestry

FOREST SERVICE
FOREST HEALTH & MONITORING

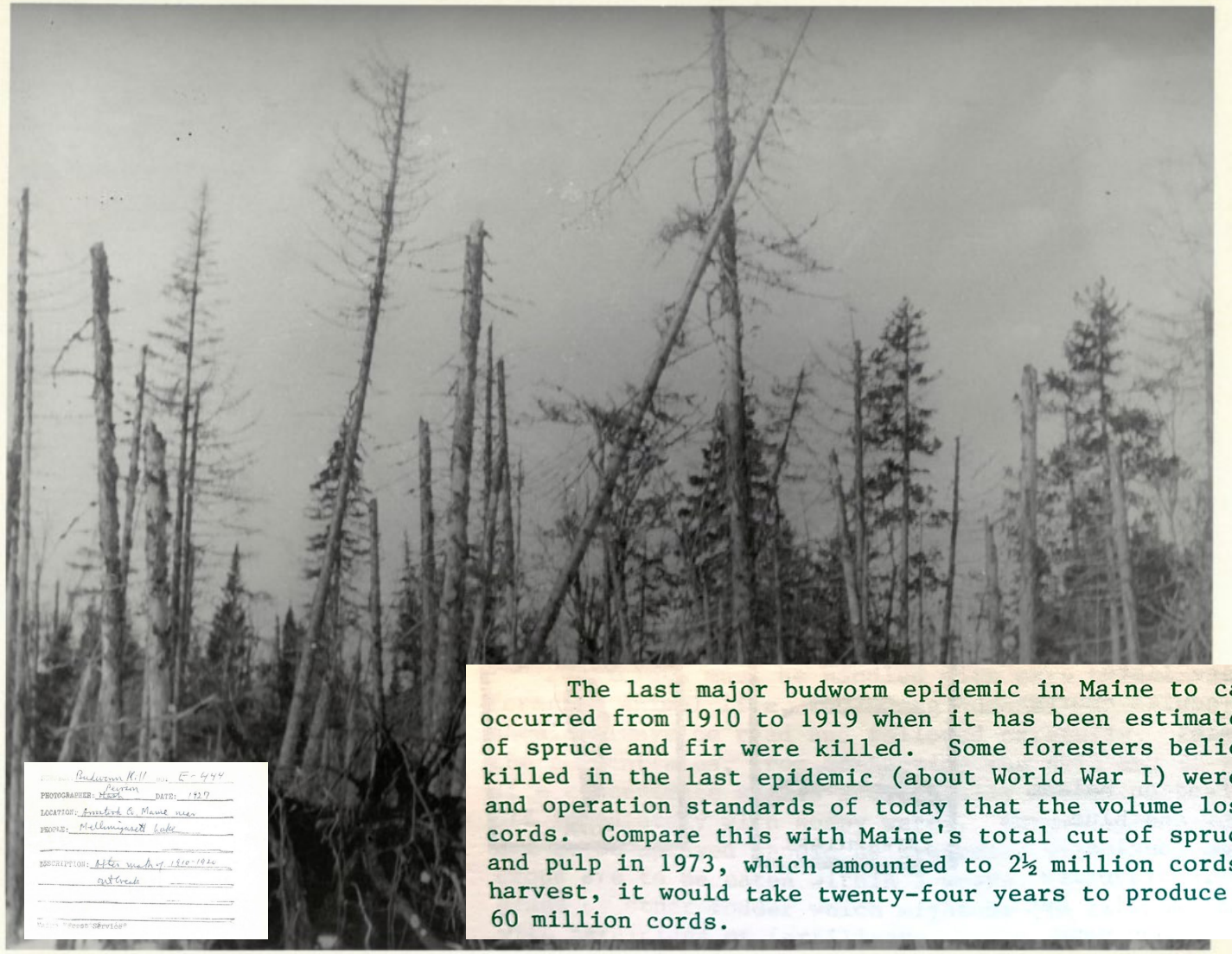
Spruce Budworm History Basics

The spruce budworm is cyclical and comes and goes in epidemics many years apart. Major budworm epidemics have occurred in eastern North America in 1770, 1806, 1878, 1910, and in 1949. These epidemics generally have lasted about 10 years with noticeable tree mortality occurring after three to five years of moderate to severe defoliation. Mortality may continue for 15 to 20 years after that. Trees not killed may also sustain fiber loss due to decay fungi invading budworm-killed tops.

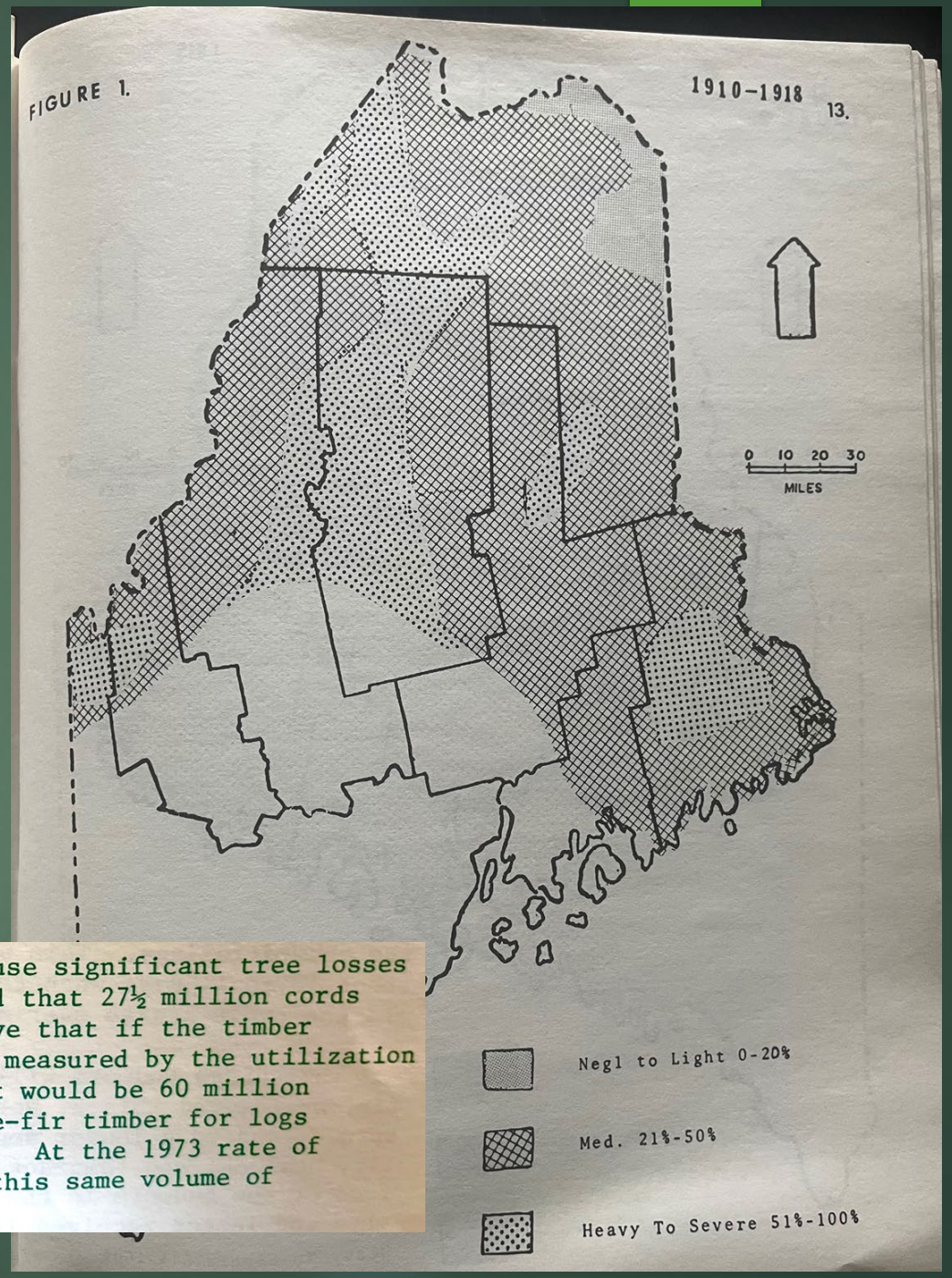
Written in the 1970s looking back – now we are in the 2020s looking back at the 1970s



SBW History:
100 Year Lookback to1920s

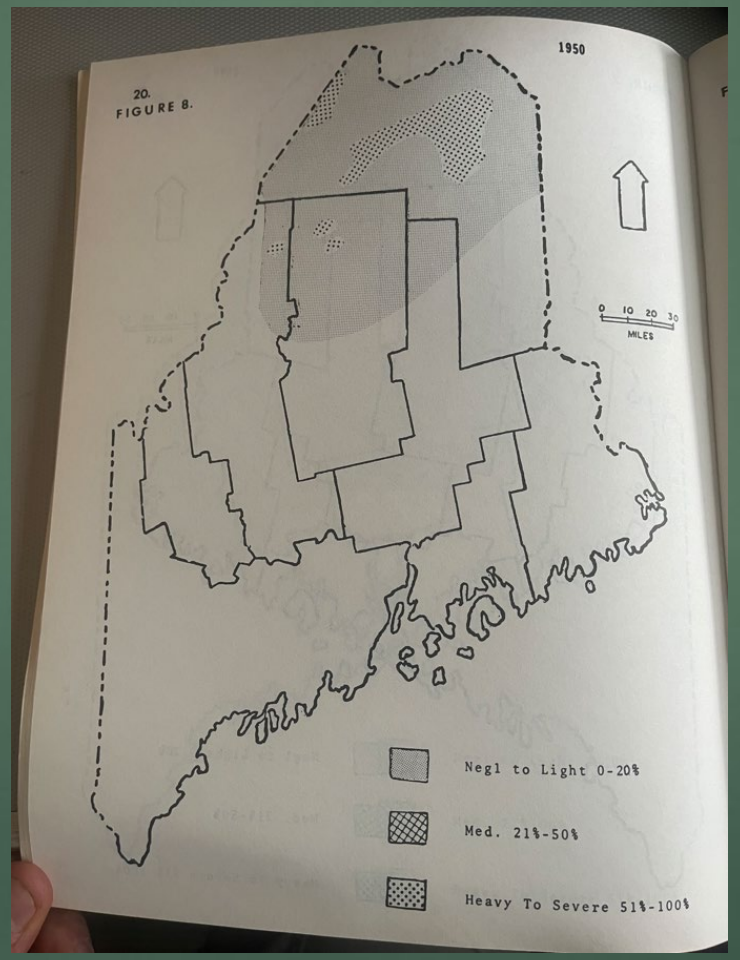


The last major budworm epidemic in Maine to cause significant tree losses occurred from 1910 to 1919 when it has been estimated that 27½ million cords of spruce and fir were killed. Some foresters believe that if the timber killed in the last epidemic (about World War I) were measured by the utilization and operation standards of today that the volume lost would be 60 million cords. Compare this with Maine's total cut of spruce-fir timber for logs and pulp in 1973, which amounted to 2½ million cords. At the 1973 rate of harvest, it would take twenty-four years to produce this same volume of 60 million cords.



SBW History:
75 Year Lookback to 1950s

Maine's first SBW aerial spray program occurred in 1954 and consisted of 21,000 acres treated with DDT



84.

Aircraft Employed on Maine Spruce Budworm Suppression Projects, 1954-1977.

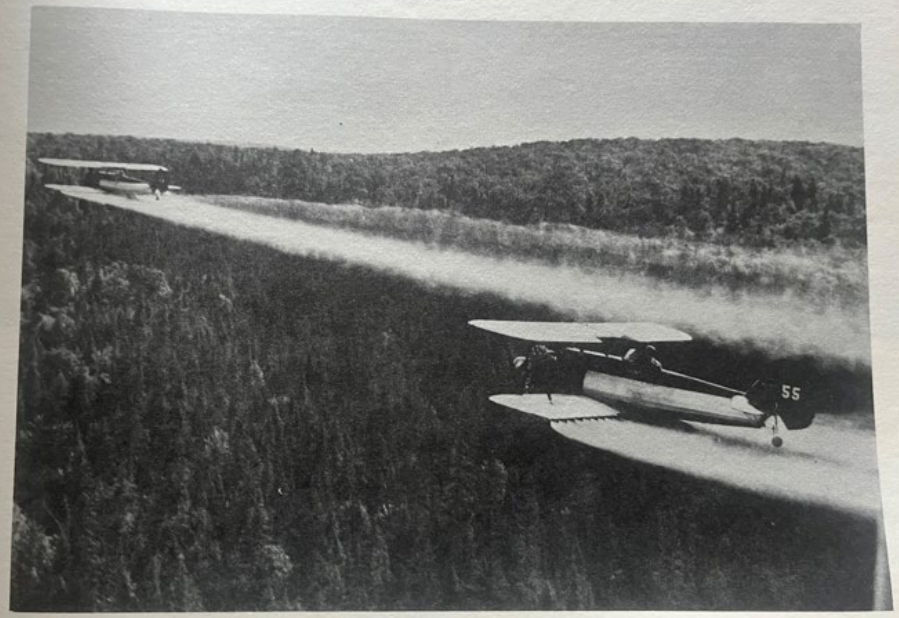
1954: (First year of budworm spraying)

6 Stearman

1 observer plane

Planes were contracted for through Barney W. Flieger of Forest Protection Limited of New Brunswick, a non profit corporation set up to handle aerial spray projects using cooperative government - industry funds.

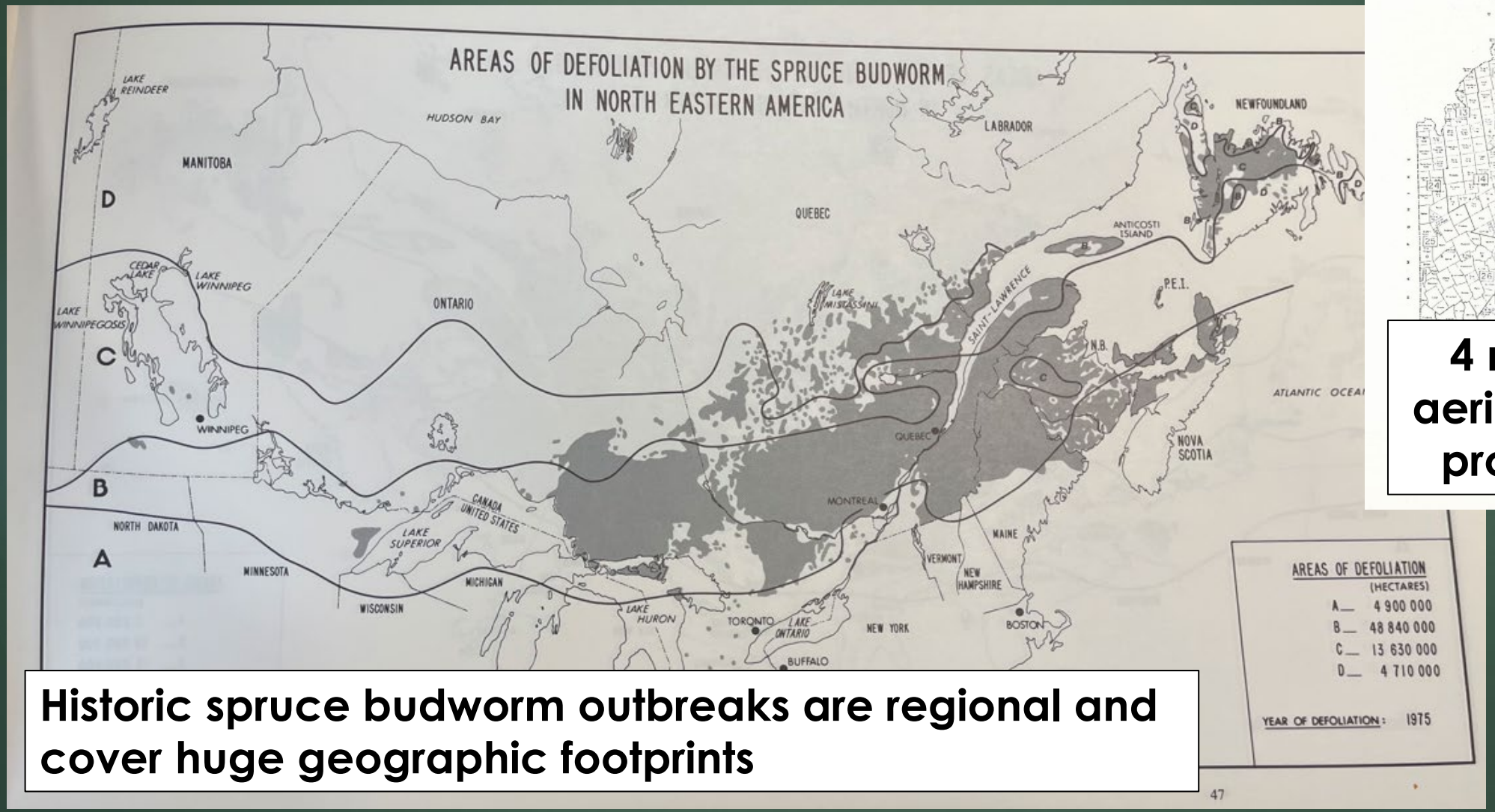
Plate 2



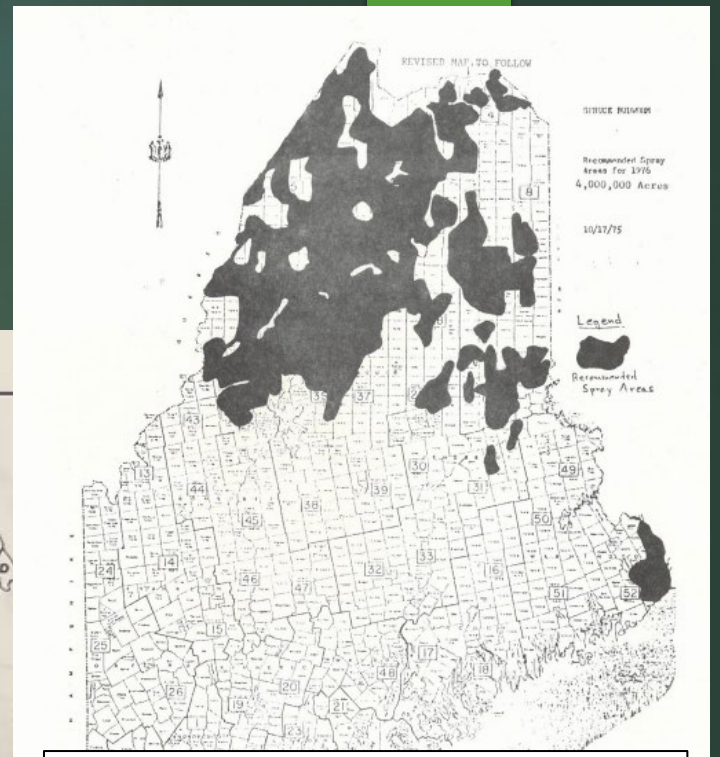
Stearman spraying, 1950's. Photo courtesy of Forest Protection Limited, Fredericton, New Brunswick.

YEAR	INSECTICIDE	ACRES TREATED
1954	DDT	21,000

SBW History:
50 Year Lookback to 1970s



Historic spruce budworm outbreaks are regional and cover huge geographic footprints

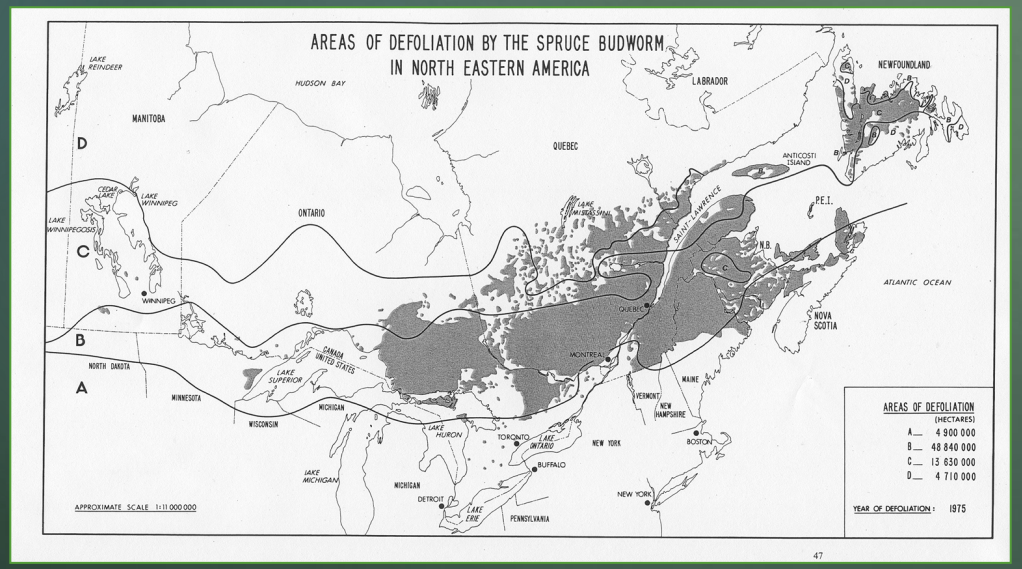


4 million acres of aerial spraying were proposed in 1976!

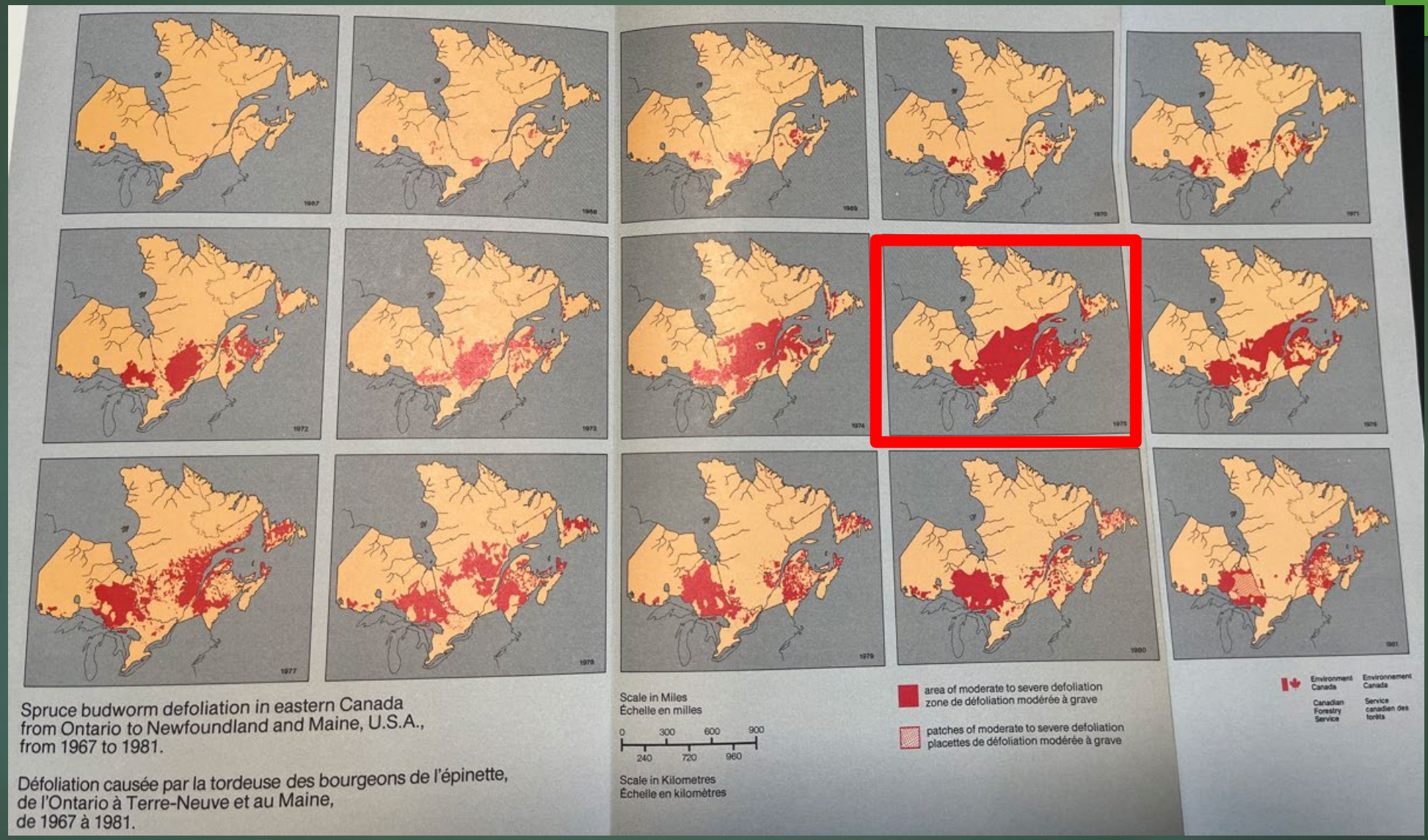
Almost 180 million acres of SBW defoliation in North America in 1975

Remembering "The Big One"

- Last major SBW outbreak in Maine spanned roughly from 1967 to 1993
- Regional outbreak covered ~136 million acres across eastern Canada and Maine
- Mortality rates for balsam fir reached 84-97%
- Mortality rates for red spruce reached 30-66%
- Resulted in an estimated 20-25 million cords of spruce-fir mortality
- Hundreds of millions of lost revenue to forest industry

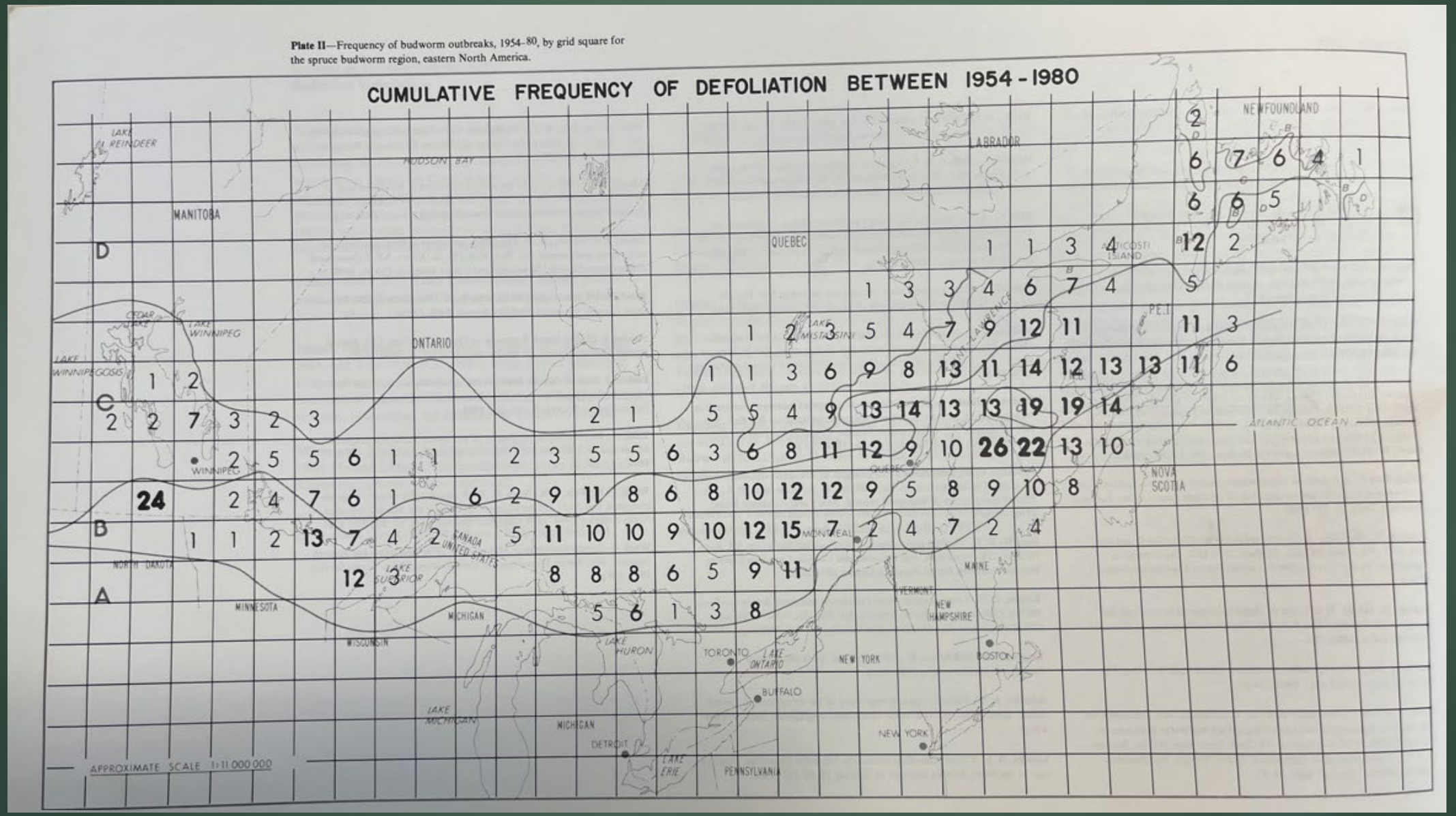


Long Lasting, Regional Impacts



The last major SBW outbreak spanned from Ontario to Newfoundland and lasted decades

Maine is no stranger to SBW…



Foliage Protection in the Face of Overwhelming SBW Populations

AERIAL SPRAYING AGAINST THE SPRUCE BUDWORM

IN QUEBEC IN 1975 AND PLANS FOR 1976

Gerard Paquet - Real Desaulniers
Quebec Department of Lands and Forests

The Spruce Budworm infestation has spread so much in Quebec in the last two years that it is no longer possible to spray all the balsam and spruce stands that would need to be treated. The infested areas have indeed increased from 28.2 million acres in 1973 to 79.6 million acres in 1974 and 87.4 million acres in 1975.

Aerial spraying operations have been carried out in 1975 on a total area of 7.1 million acres, distributed as follows: operational treatments with chemicals, 6.647 million acres; experimental treatments with chemicals 249,100 acres; experimental treatments with B.t., 237,600 acres.

The results of this spraying program are satisfactory, considering the fact that the Spruce Budworm larval have reached in 1975 population levels that had never been recorded in the previous infestation.

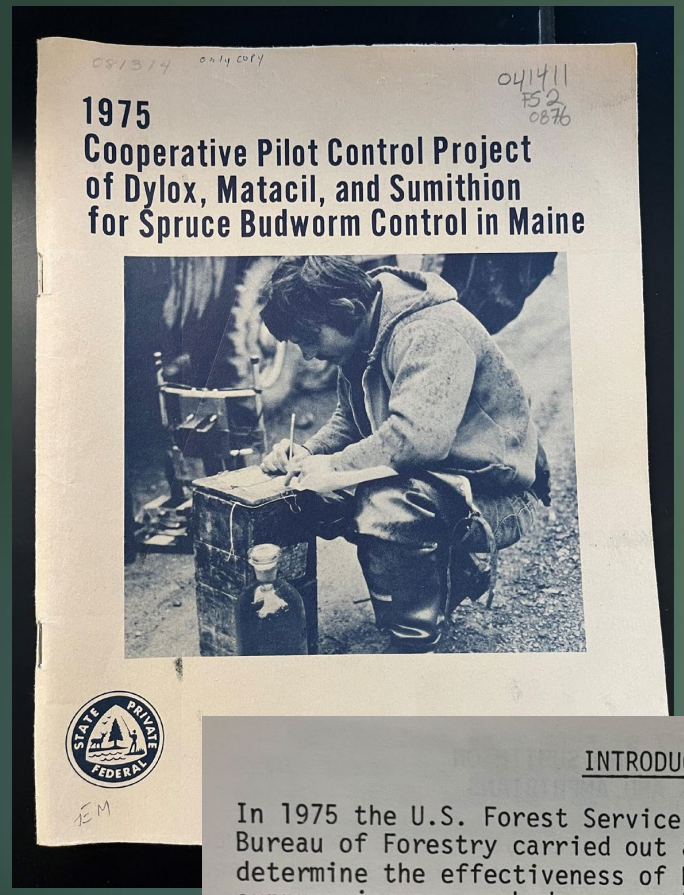
The strategy in New Brunswick

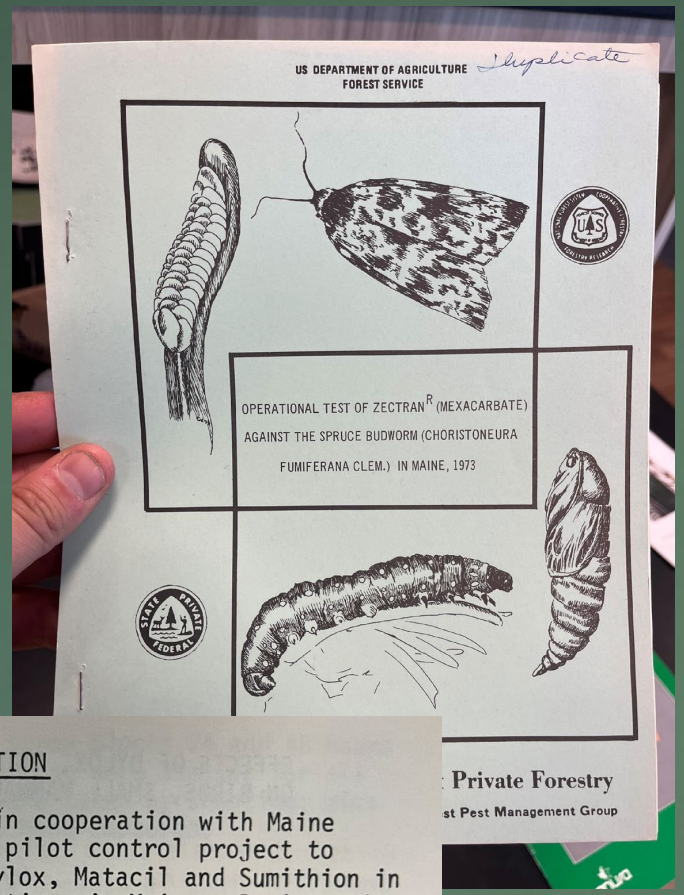
Afraid of losing its pulpwood supply, New Brunswick launched its first large-scale spray operation in 1952, in the expectation that DDT would reduce the budworm density to a tolerable level, and permit the return of pre-outbreak conditions within a few years. However, it was soon observed that although the treatment killed spectacular numbers of budworm (as high as 99% in some areas), defoliation remained quite heavy, and the sprayed areas were quickly repopulated by the next generation of budworms. Apparently the most that could be expected was relief from defoliation on a year-to-year basis. Thus from 1953 onward, insecticide dosages (weight of active ingredient) were reduced and the timing of application was adjusted to optimize foliage protection against cost. The strategy, which was then developed and followed to the present time, was to afford just enough protection to keep trees alive at the lowest application rate over the least acreage. Spraying has been limited to areas where further delay in treatment would result in substantial tree mortality; consequently only 30 – 70% of the heavily infested stands have been protected in any one year. Some degree of damage is implicitly accepted in this strategy of limited protection. The emphasis has been on tree protection, not on budworm kill, and any major collapse of budworm populations within sprayed areas has been considered a bonus effect and not an objective.

Unquestionably the forest spraying strategy employed in New Brunswick has largely met its objectives by maintaining the forest intact. With the exception of two unsprayed check areas, no large single tract of forest has yet been lost to the budworm. This strategy has been crop insurance on a year-to-year basis, and remains so today.

Traditionally, forest managers have tried to reduce the impacts of budworm outbreaks using a “foliage protection strategy”. The goal of this approach is to apply pesticide when populations are at their most destructive point. This approach reduces feeding but doesn’t dramatically reduce populations. The approach aims to keep trees alive until natural processes eventually pull populations back down over the course of many years. -NB

Chemical Options: Then vs Now





INTRODUCTION

In 1975 the U.S. Forest Service in cooperation with Maine Bureau of Forestry carried out a pilot control project to determine the effectiveness of Dylox, Matacil and Sumithion in suppressing spruce budworm populations in Maine. Registration of additional insecticides for this purpose is necessary because Zectran[R] production has been stopped and the spruce budworm outbreak is a continuing threat to the spruce-fir forests in Maine.

General

Bacillus thuringiensis was first reported in 1901 as a pathogen causing death in silkworm larvae (2). It has since been isolated from a number of insects in different parts of the world. It was shown to have unique insecticidal properties, particularly against the larval forms of foliage feeding Lepidoptera (butterflies and moths).

It was not until the early 1950's that serious commercial development of the bacterium was begun (3). Early commercial products met with varying degrees of success. Perhaps the most satisfactory results were obtained on lettuce, cabbage and other crucifers for control of cabbage loopers and imported cabbage worms. Success on other agricultural pests varied.

Use of B.t. for forest insect control was either not examined or was inconclusive. With the isolation and development of a more potent strain in the late 1960's (4), development of B.t. as an insecticide for many pests on many crops was stimulated by the manufacturers. Forest insects were looked at as potential markets for the new product and extensive testing of B.t. formulations produced by several companies was begun.

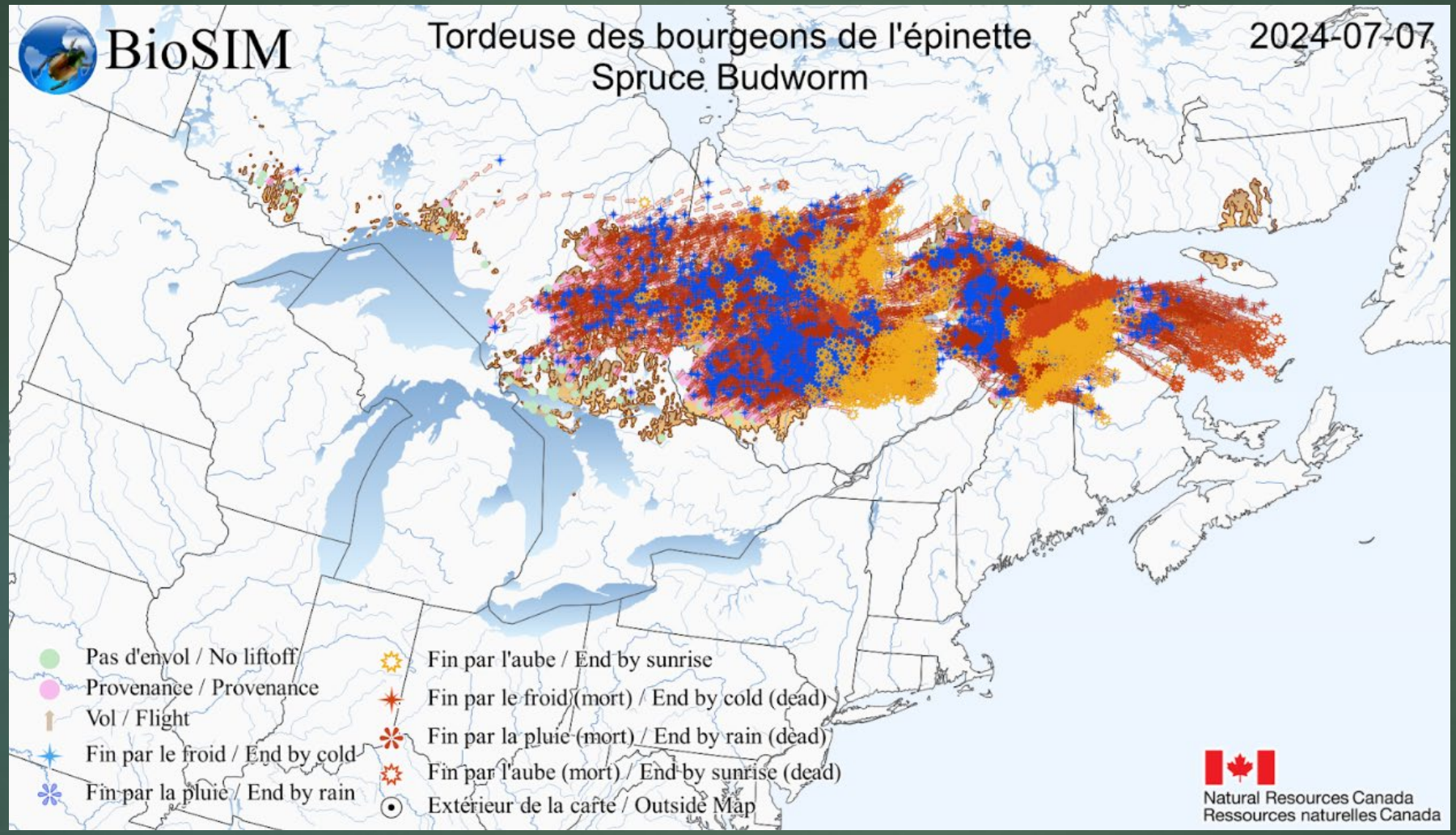
In May 1978, Bacillus thuringiensis, formulated as Thuricide 16B, was applied operationally for the first time against spruce budworm in Maine. This operation was a part of the 1978 Maine Cooperative Spruce Budworm Suppression Project, a cooperative undertaking of the Maine Forest Service, the USDA Forest Service, and the state's forest landowners. The planning for this project was based on a series of past experimental trials in Maine going back to 1963 (Morrison and Dimond, 1978, p. 3) and an experience in Canada.

DDT was banned in 1972. In 1975, many pesticide options were experimental and in rapid, early development. Products still widely used today, like Bt, were relatively new. Tebufenozide would not exist until the 1990s.

1974 versus 2024

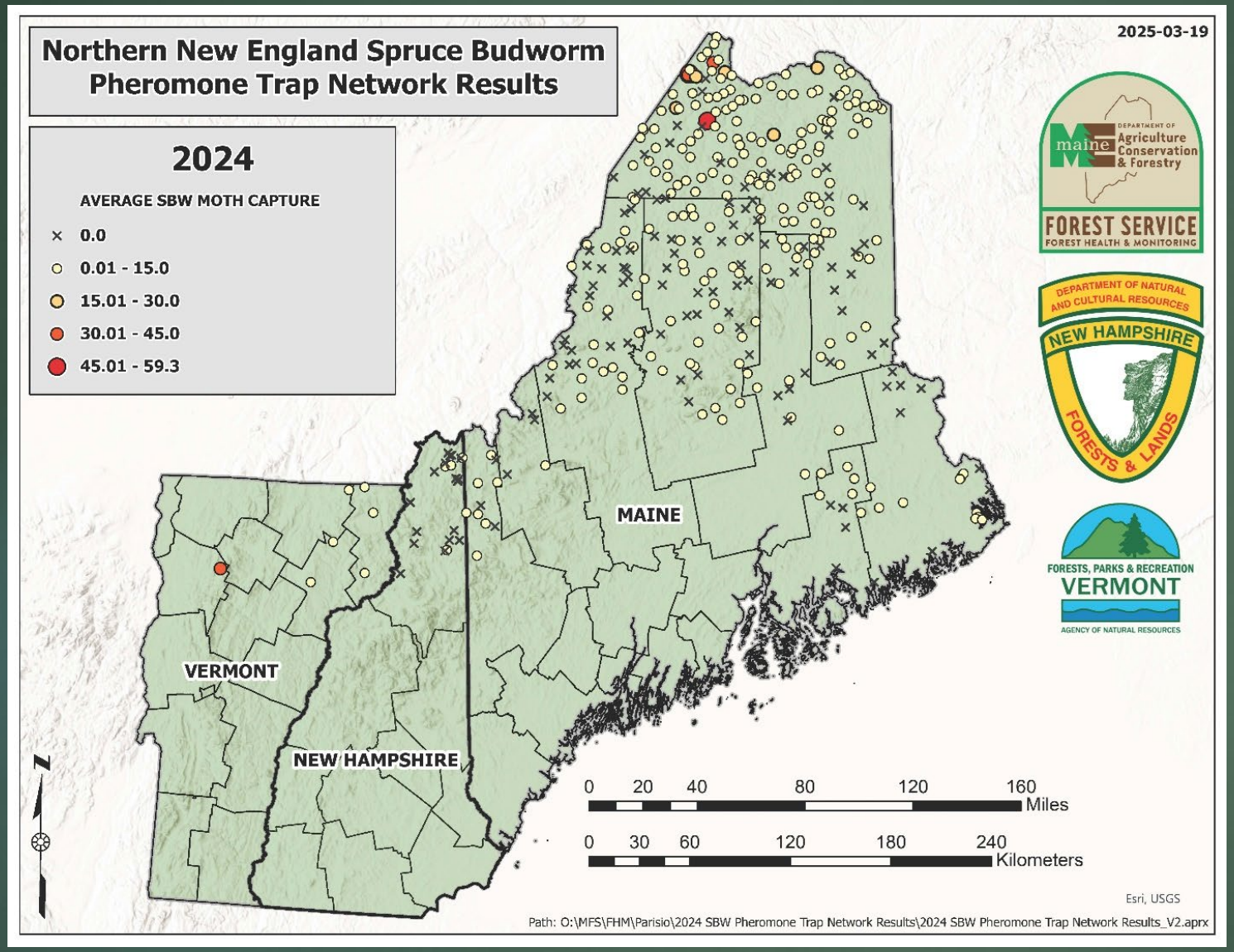
This aerial photo was taken west of Chesuncook Lake and shows browning of budworm-infested spruce and fir along the West Branch of the Penobscot River in July, 1974. Entomologists of the Maine Forest Service are currently committed to a control program which will be presented to Congress and the state legislature for funding. Entomologists emphasize that aerial spraying of the spruce budworm is designed to save trees, and that this control program is essential. A second phase of their program is to develop a long-range solution to the problem through research currently aimed at various possible methods of controlling budworm populations.

Monitoring Tools: Regional Models

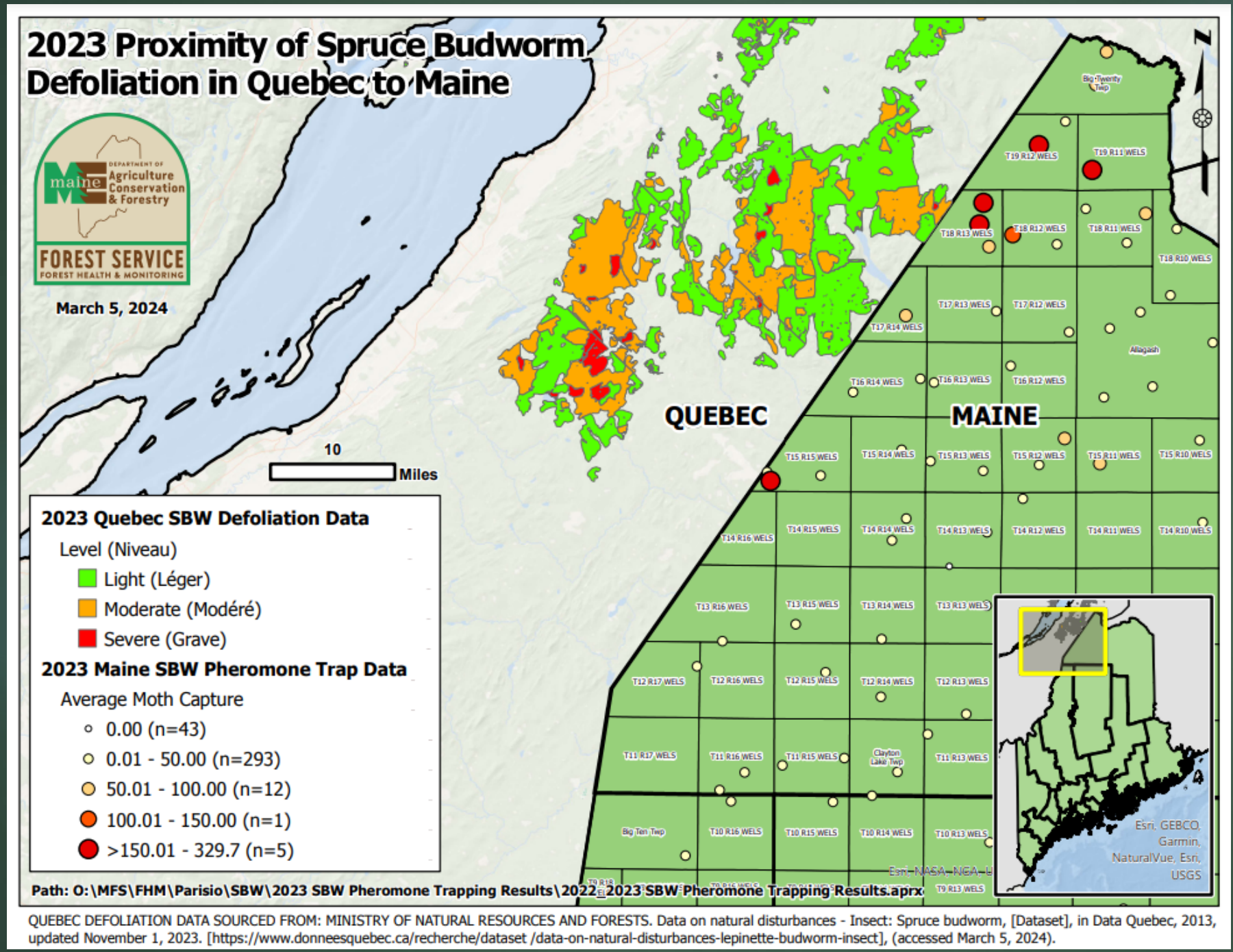


SBW outbreaks remain regional in nature but now we can monitor regional dispersal through advanced flight modelling. Images generated using BioSIM, R. Saint-Armant, Canadian Forest Service

Monitoring Tools – Pheromone Trap Network



An extensive pheromone trap network helps monitor moth activity and can inform us where SBW populations might be building

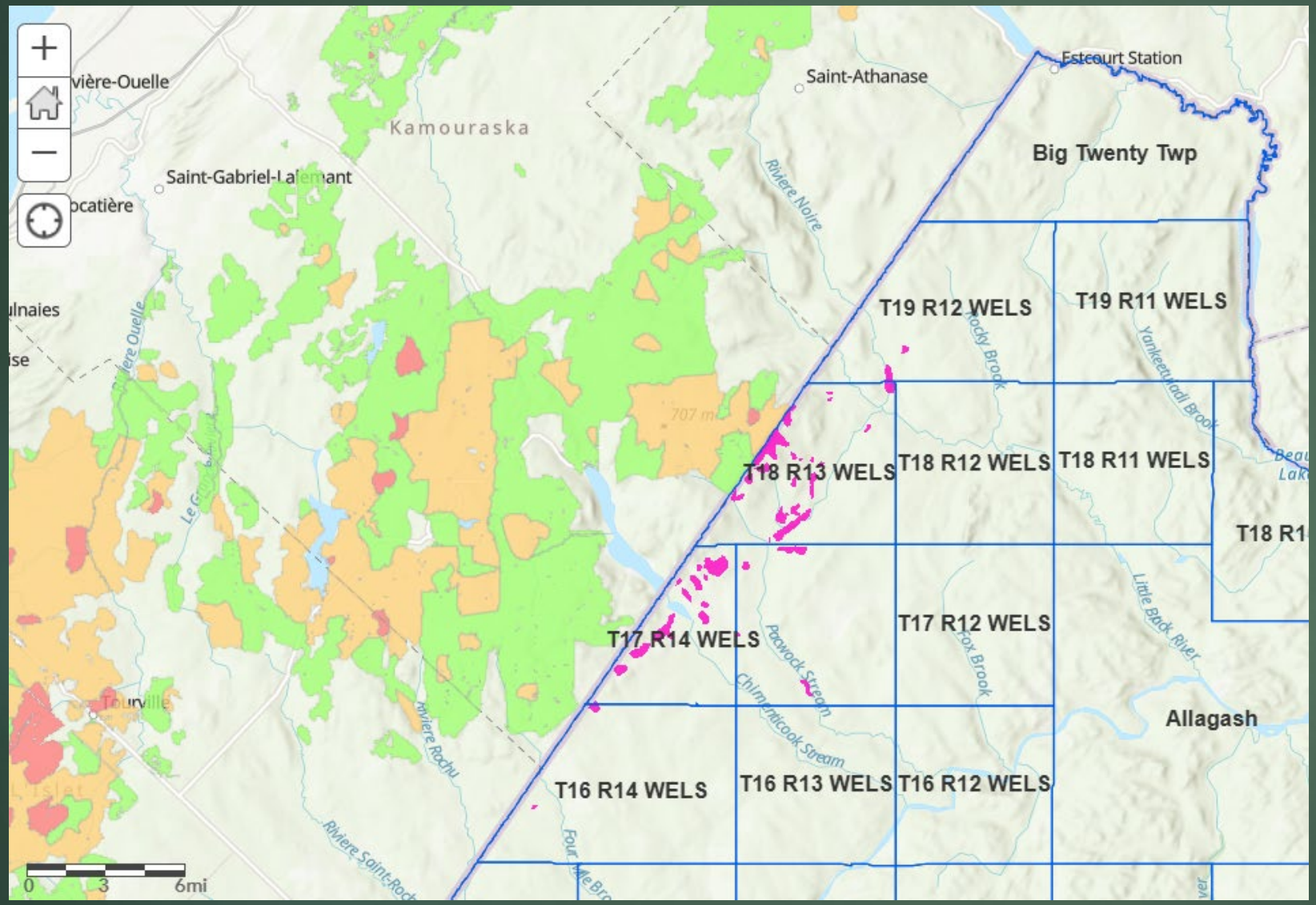


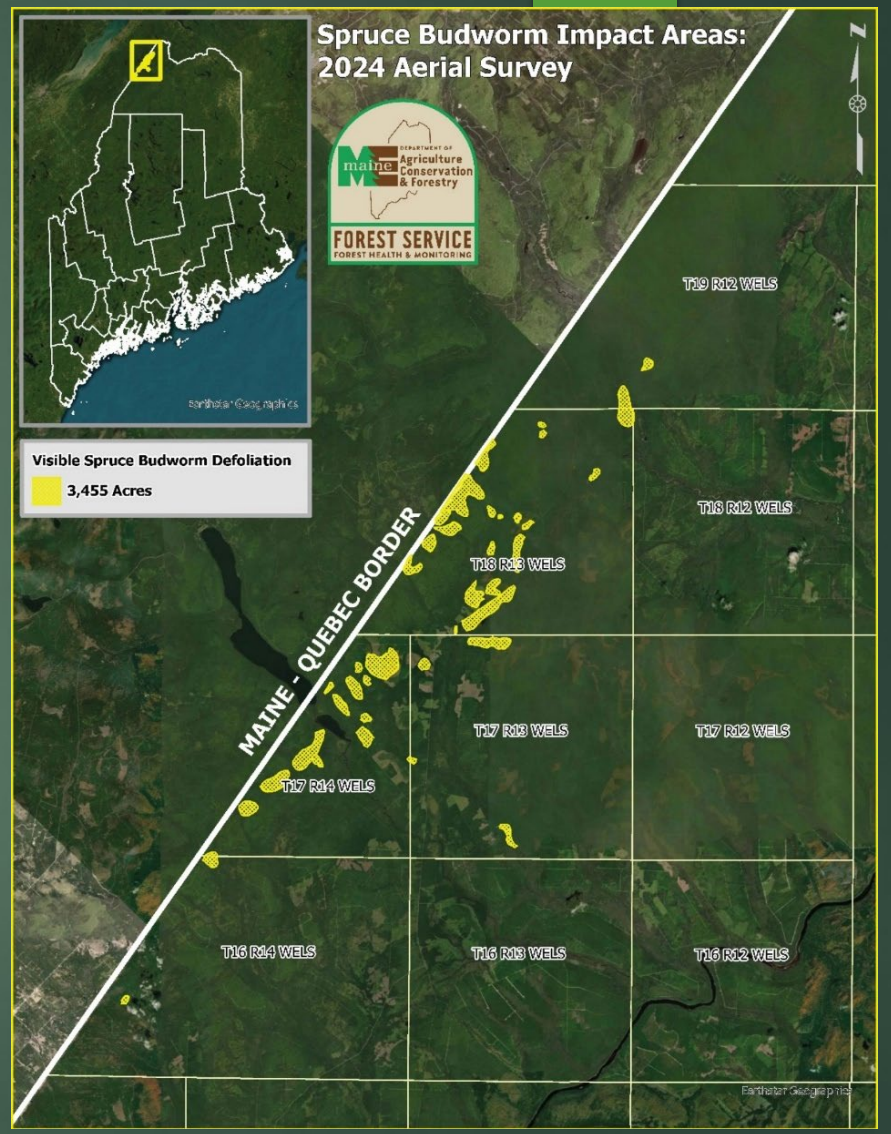
QUEBEC DEFOLIATION DATA SOURCED FROM: MINISTRY OF NATURAL RESOURCES AND FORESTS. Data on natural disturbances - Insect: Spruce budworm, [Dataset], in Data Quebec, 2013, updated November 1, 2023. [https://www.donneesquebec.ca/recherche/dataset /data-on-natural-disturbances-lepinette-budworm-insect], (accessed March 5, 2024).

Monitoring Tools: Satellite Imagery

Defoliation data from satellite imagery indicates defoliation in Quebec finally reached Maine in 2023

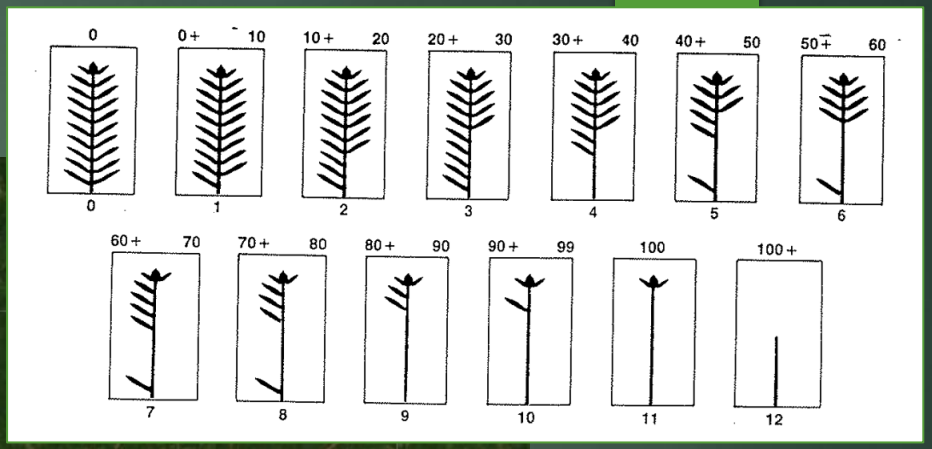
Monitoring Tools – Aerial Survey

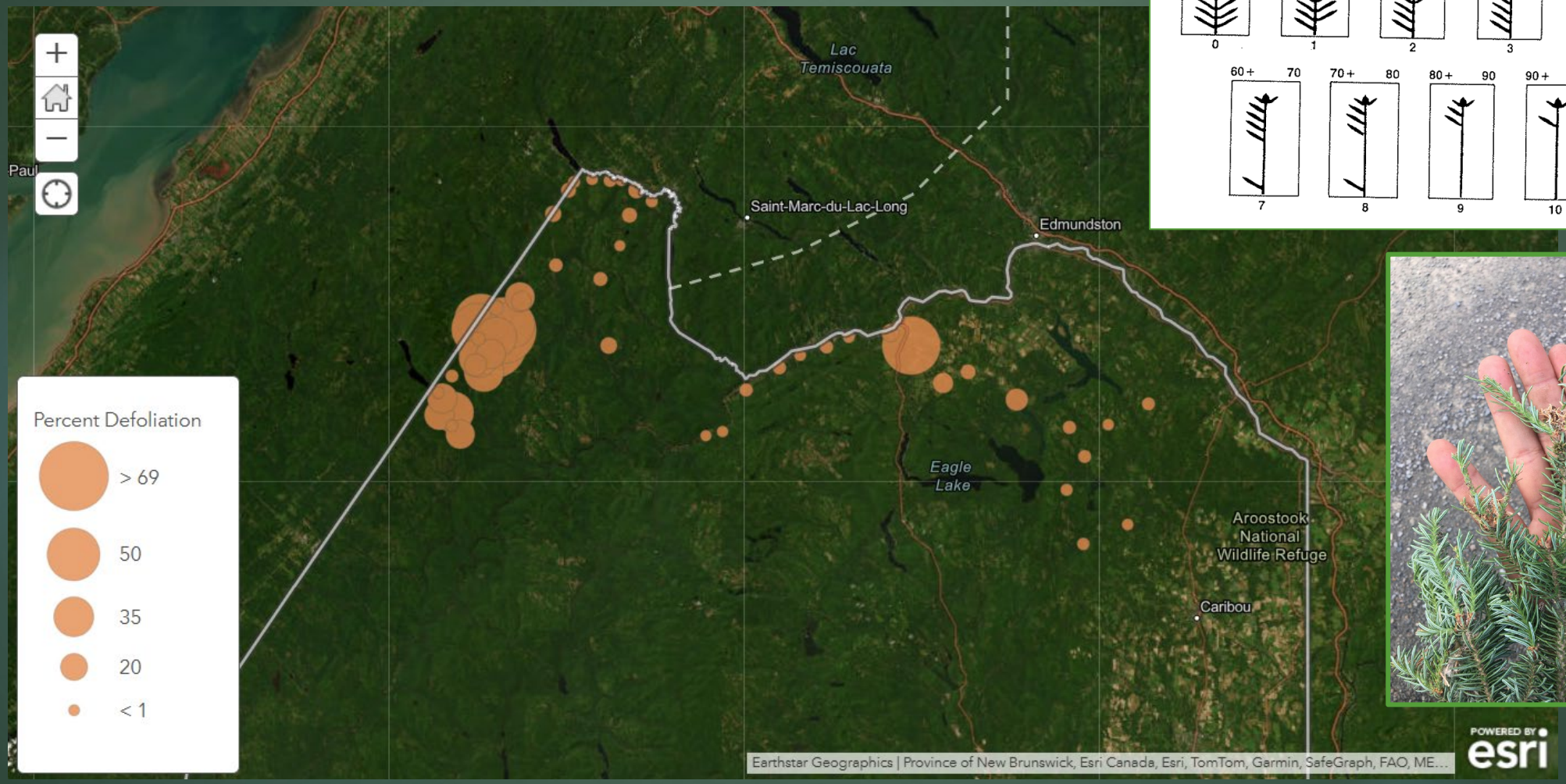




Almost 3,500 acres documented at the time of MFS aerial survey in July 2024

Monitoring Tools: Ground Survey





Ground defoliation data at survey plots in 2024 indicated dramatic increases in defoliation rates

What you'll learn next:

How improved L2 sampling at the UMaine SBW Lab has helped us to have the best understanding possible of current SBW populations in Maine

How the Early Intervention Strategy (EIS) has improved on the prior foliage protection strategy for SBW and how it can be applied in Maine

How advancements in the products used for aerial SBW control have provided safer and more effective alternatives to the chemicals used for SBW in the old days

How landowners and natural resource agencies are working together to design and implement an effective EIS program for SBW control in Maine

Spruce Budworm Biology & Monitoring

Angela Mech, Ph.D.
Assistant Professor of Forest Entomology
Director of the Spruce Budworm Processing Lab
University of Maine – School of Biology and Ecology

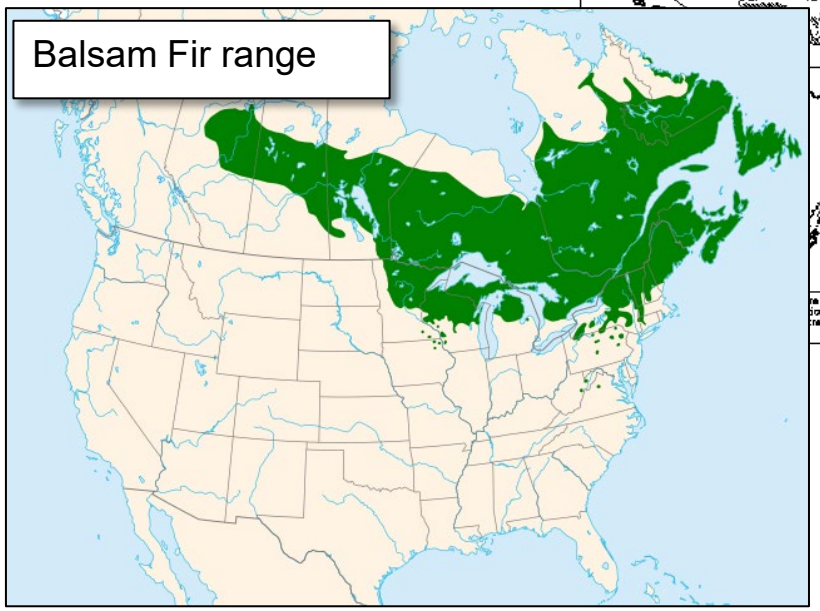
1865 THE UNIVERSITY OF MAINE
Spruce Budworm Lab

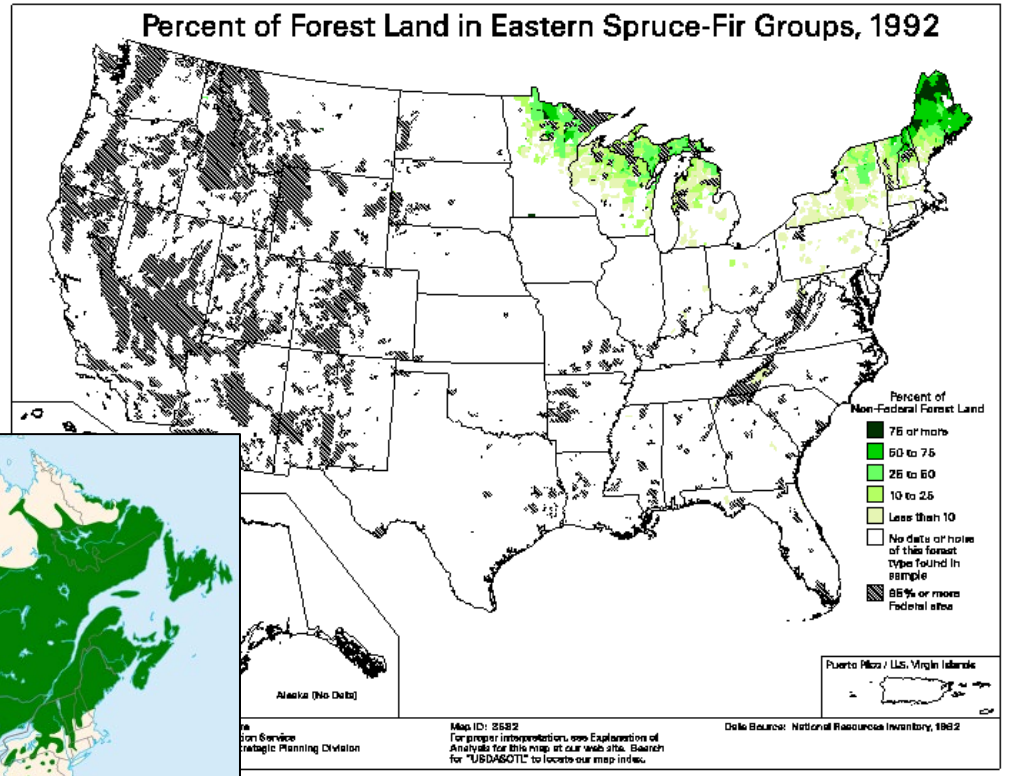
School of Biology and Ecology

Spruce Budworm:

The most severe defoliating pest of spruce and fir in North America

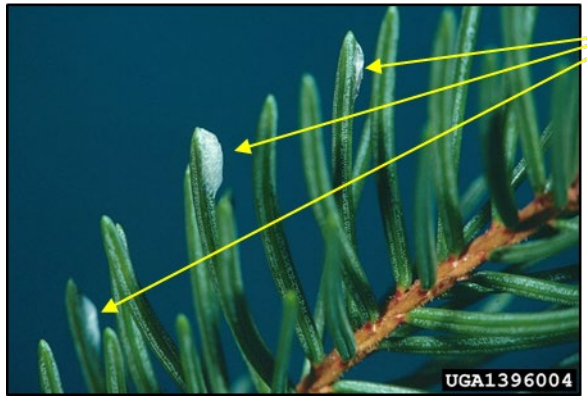
- Native insect
- Range = where there is spruce and balsam fir
- Experiences cyclical outbreaks ~every 30 years
- Has been happening for thousands of years

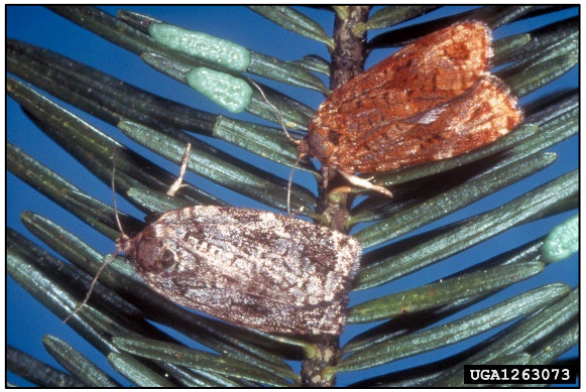




Spruce Budworm Life Cycle – 1 generation per year

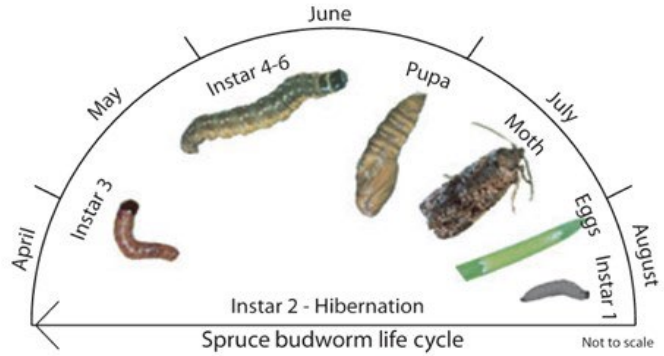
Egg masses laid on needles
(~200 eggs total per female)





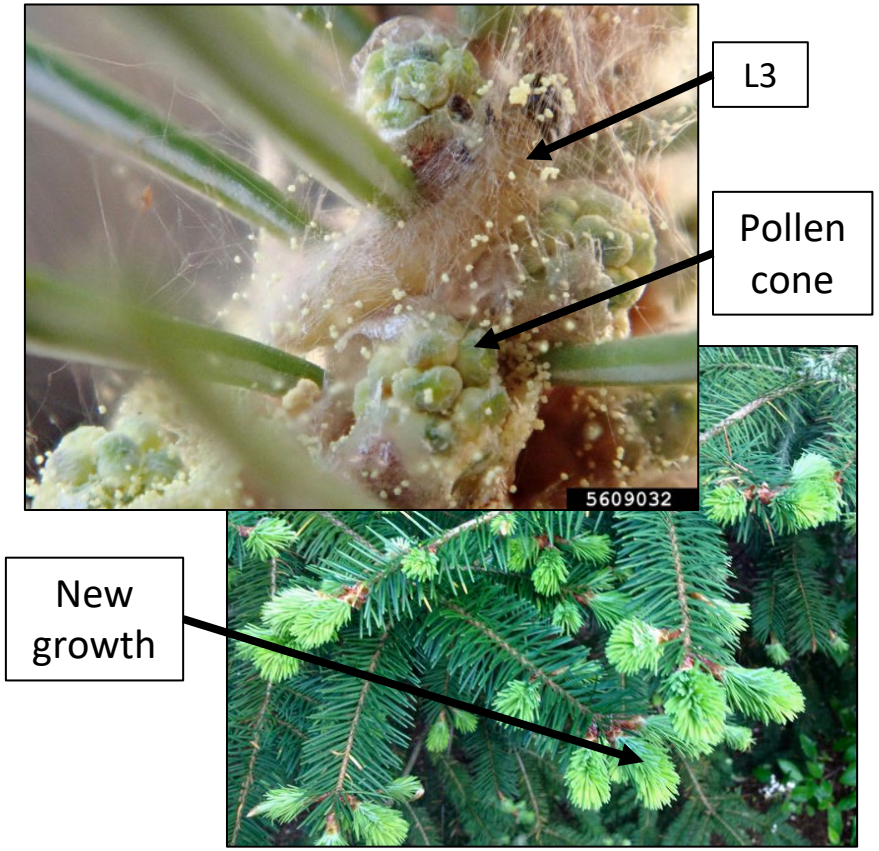
Hatched caterpillars (**1st instar larvae**) disperse
They don't eat

Caterpillars molt (**2nd instars**)
Hibernate in silk nest for 7-8 months (Late August – April)



Spruce Budworm Life Cycle – 1 generation per year

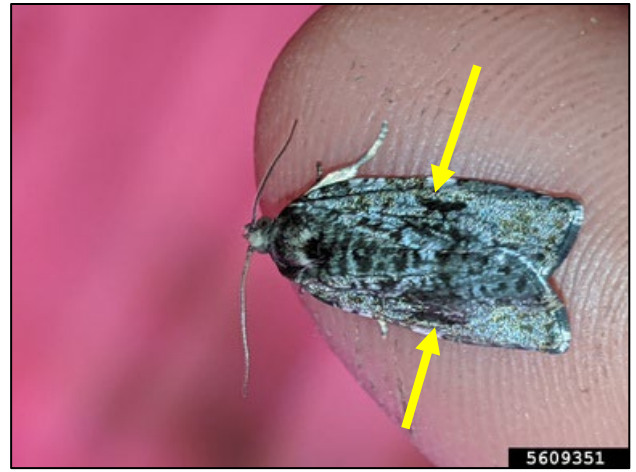
3rd – 6th instars
Feeding: starts on seeds & pollen cones; feed on current year's growth when they're bigger



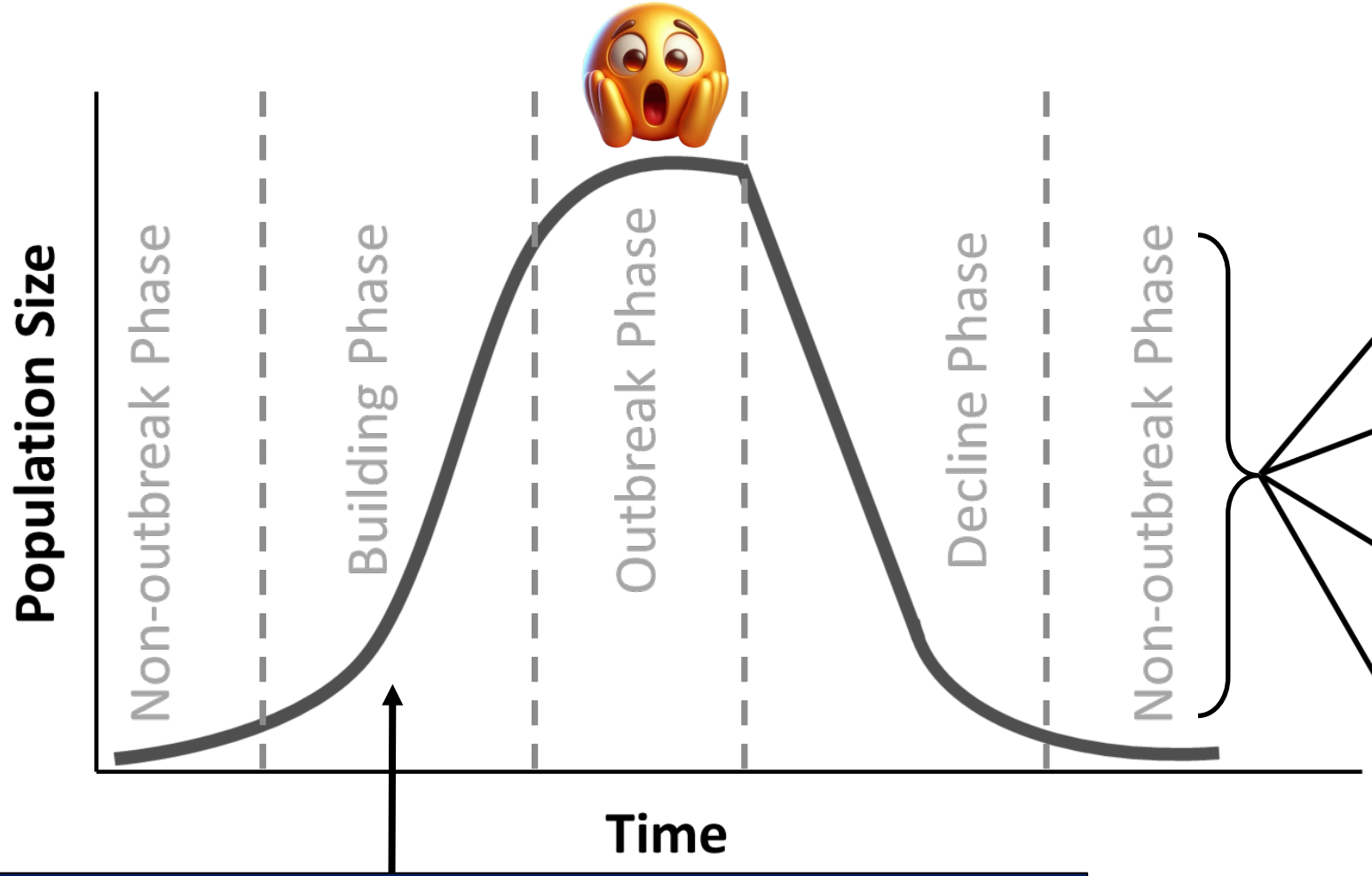
3rd – 6th instars
"messy eaters"
Scorched tips

Pupae - Early July

Adults – Mid-July to August



Stages of an Insect Outbreak



The building phase usually goes unnoticed because there are no significant impacts yet

Spruce Budworm Outbreaks

- Outbreaks generally last 10+ years
- During an outbreak, caterpillars forced to feed on the older needles when the tree stops producing new needles
- Tree mortality occurs after 3-6 years of moderate-severe feeding

During last outbreak:
Balsam Fir = 84-97% mortality
Spruce = 30-66% mortality

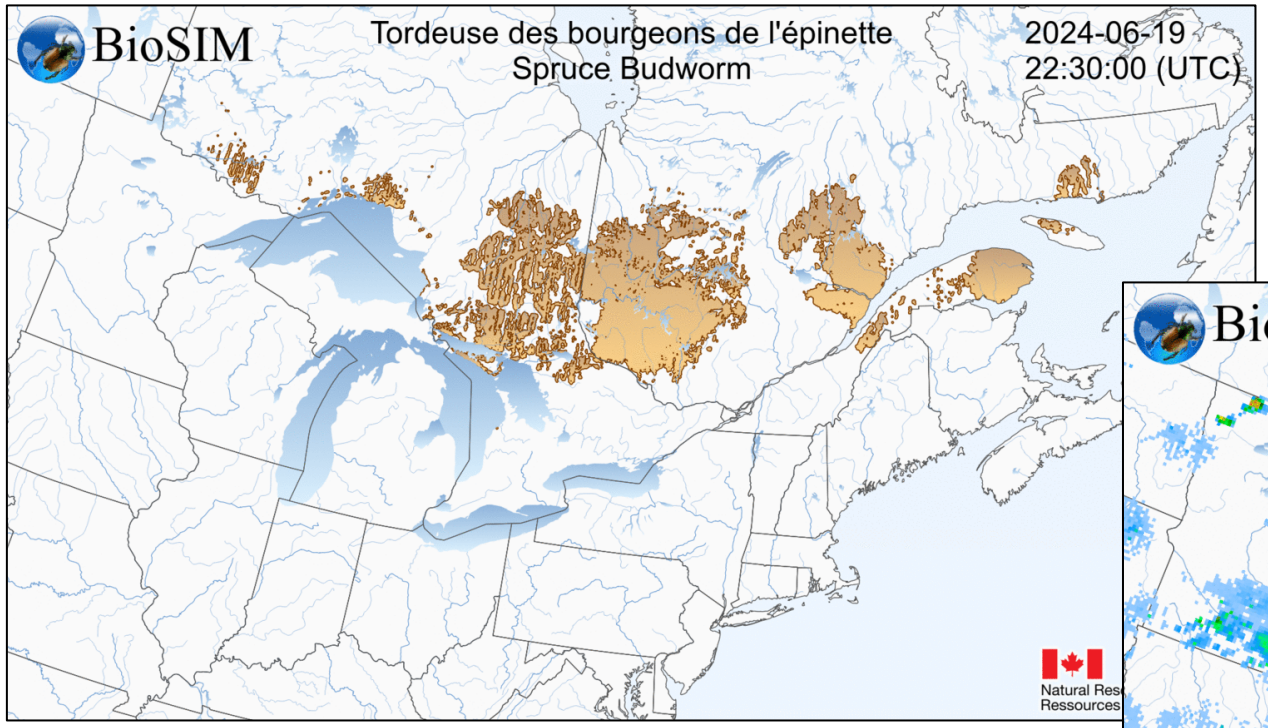
Spruce Budworm Outbreaks

"In places they died in masses and could be shoveled like snow. Crushed bodies made road traffic hazardous. Clouds of moths caused traffic to stop. In July, coastal fisherman reported 20-50 dead moths per ft^2 of ocean miles out from shore."

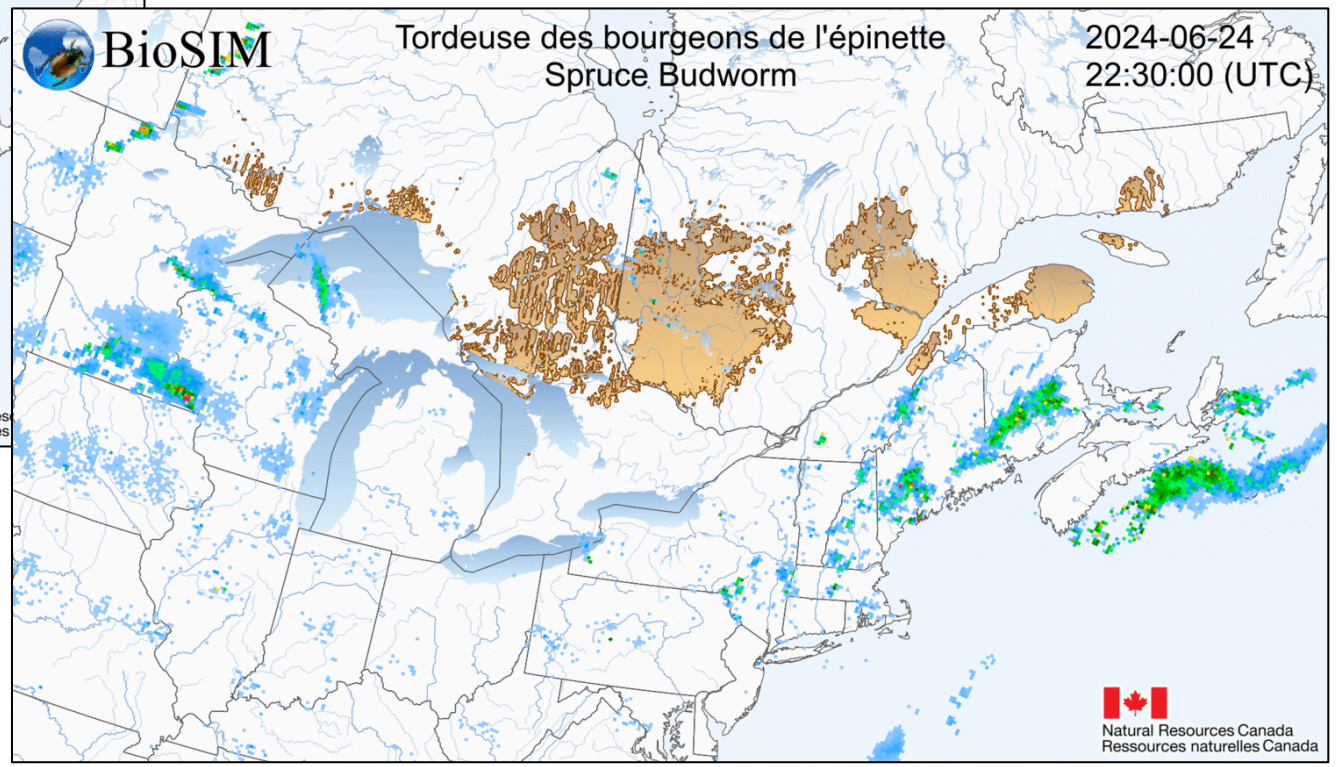
HealthyForest PARTNERSHIP

Spruce Budworm Outbreaks

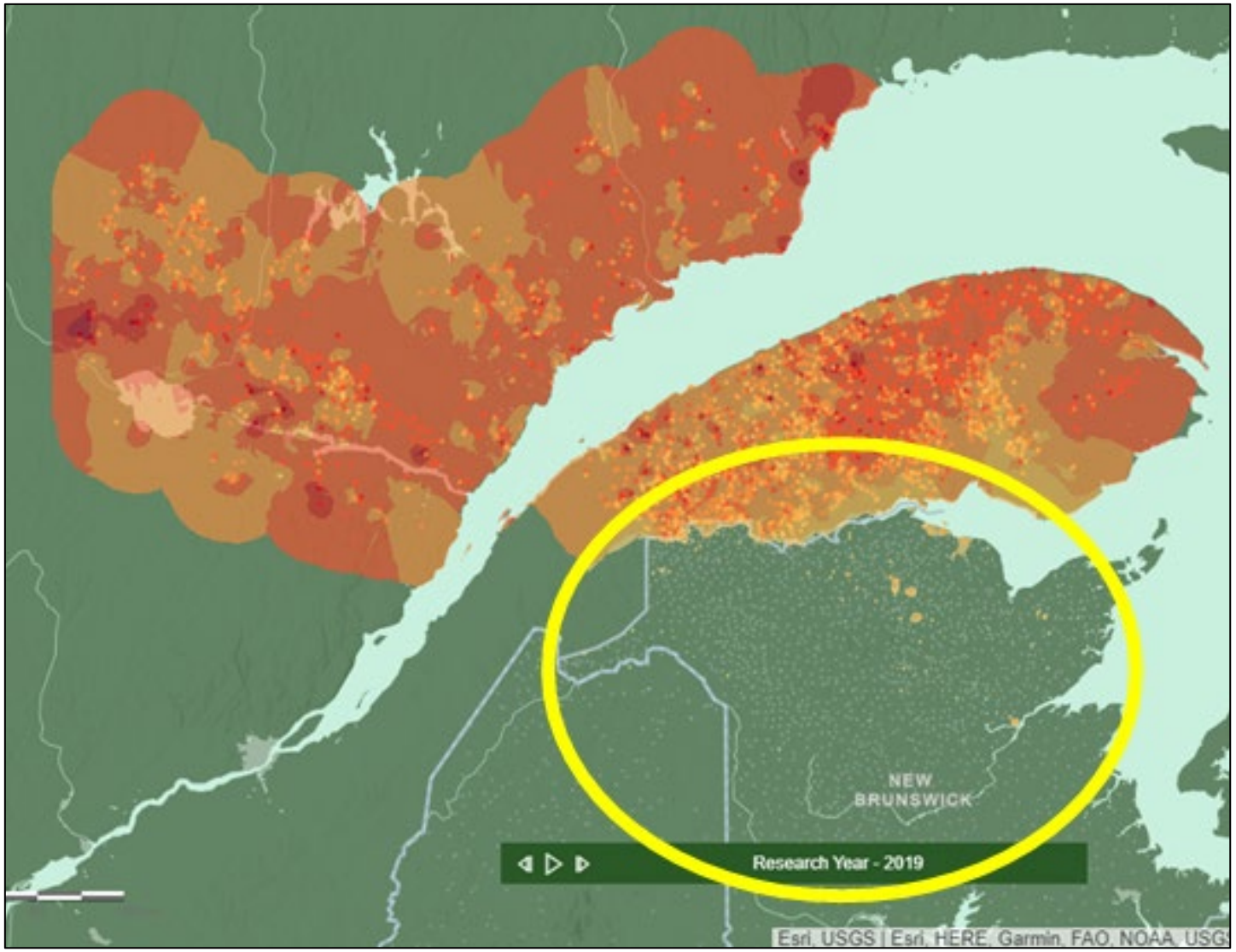
Massive SBW flights can be seen on weather radar



Can travel hundreds of miles with help from wind currents

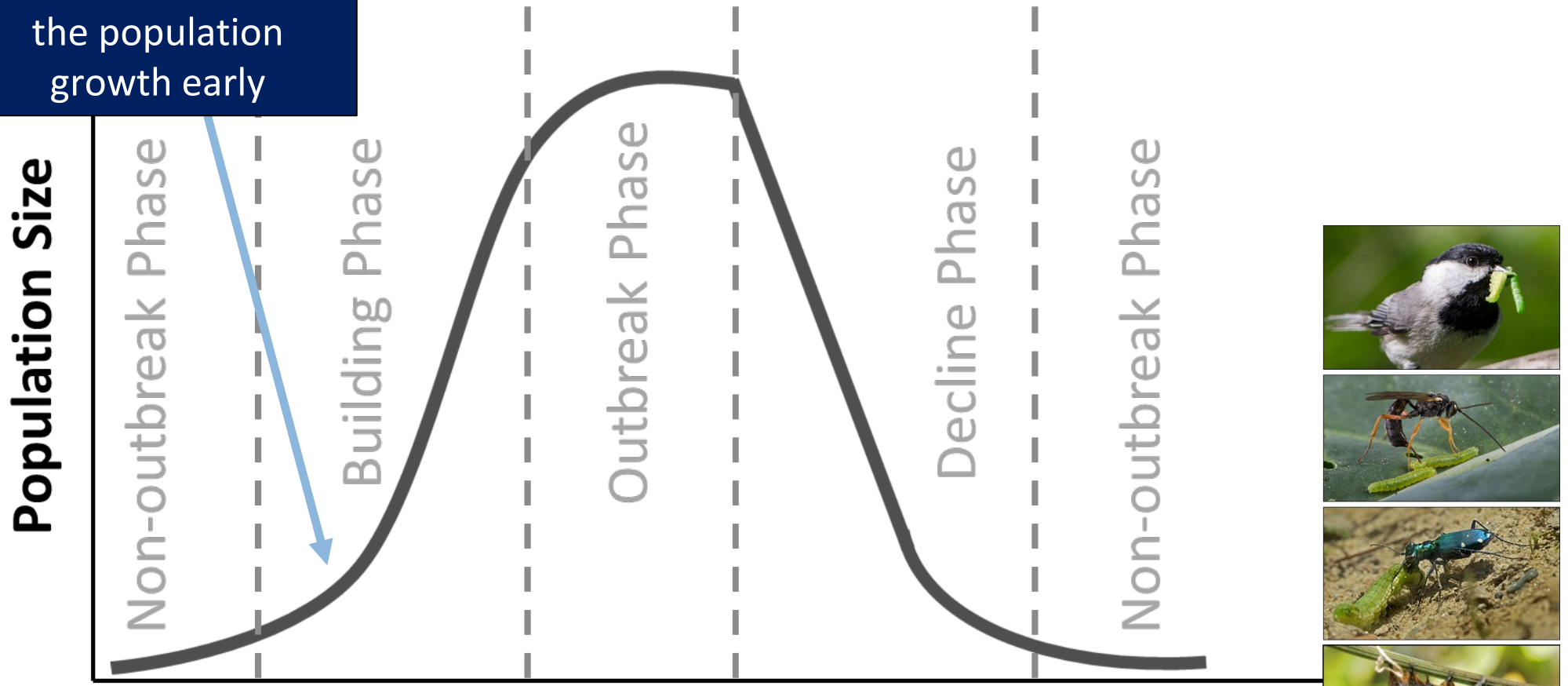


New Brunswick has escaped a large-scale SBW outbreak



What if the Outbreak Phase could be prevented?

Would need to catch the population growth early



Stable, non-outbreak population

Stable, non-outbreak population

Need to Monitor SBW Populations

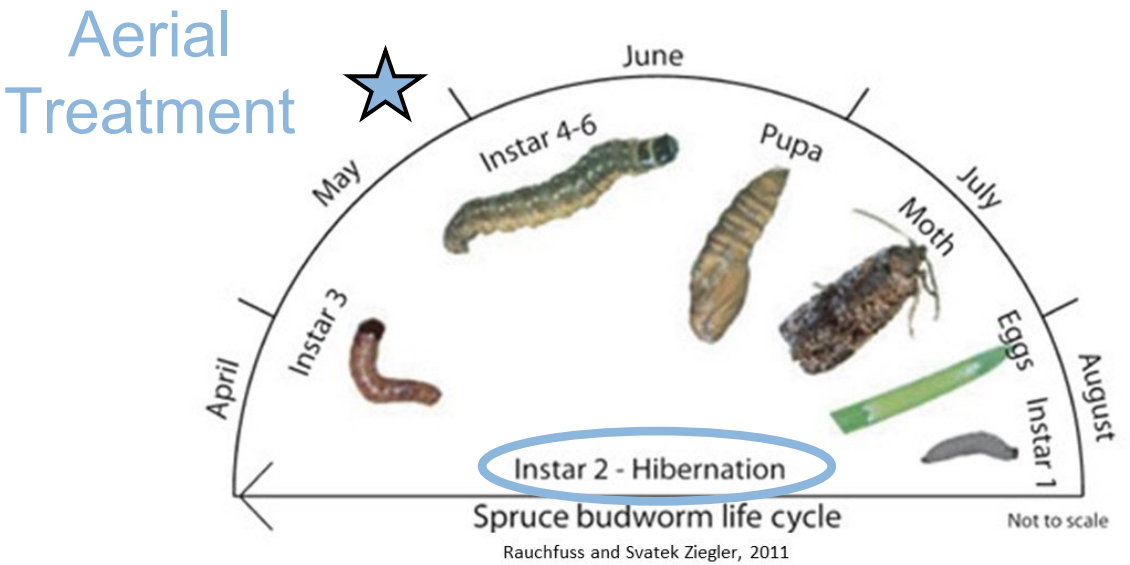
Volunteers conducting SBW egg mass surveys

<u>Previous Outbreak</u> (1970s & 80s) = egg mass surveys

- Short window: SBW eggs = 2 weeks
- Where SBW was low, egg masses = too scarce to be sampled efficiently
- Big possibility of human error

SBW Monitoring – L2 Sampling

- Looks at the number of 2nd stage caterpillars/larvae (L2's) per branch
- Good indicator of actual population that will be causing damage in spring
- Branch sampling can occur over a 7-8 month time period
- Can have enough time for treatment planning
- Relatively low cost



Rauchfuss and Svatek Ziegler, 2011

SBW Monitoring – L2 Sampling

Clip a mid-height branch because that's where SBW eggs predominantly laid

Step 1: A 30" branch is clipped from each of 3 trees at a monitoring site

3 branches per site

SBW Monitoring – L2 Sampling

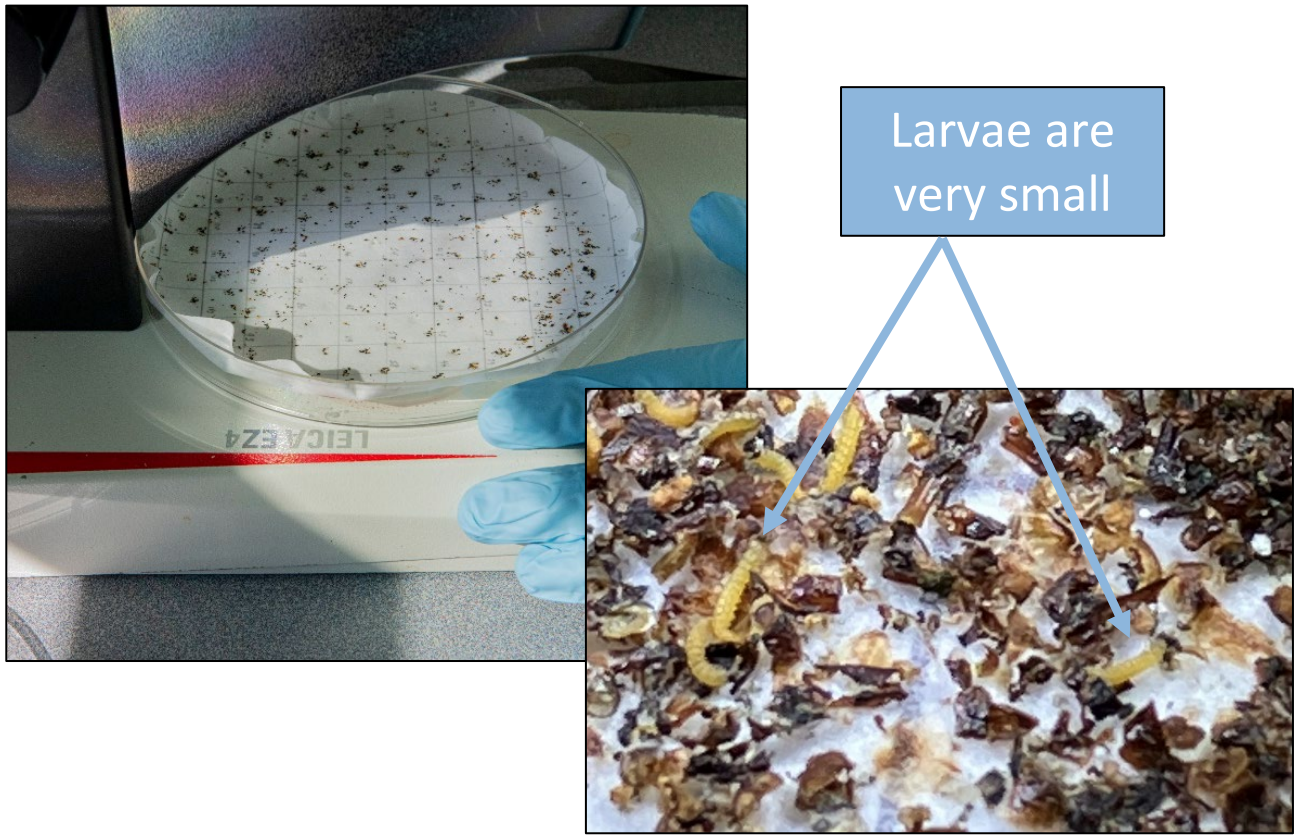
Step 2: Branches are cut up and soaked in hot sodium hydroxide to dissolve silk

L2s fall through the top filter

Step 3: Buckets are filtered to remove large debris (twigs and needles)

SBW Monitoring – L2 Sampling

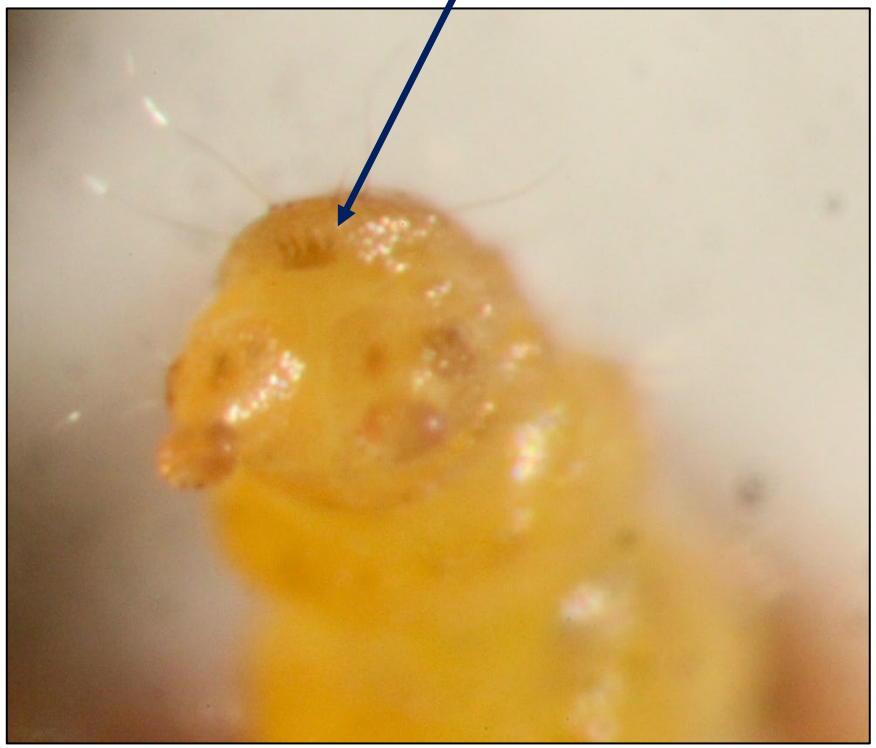
Step 4: Larvae are separated from most of the plant material (chemistry magic!)



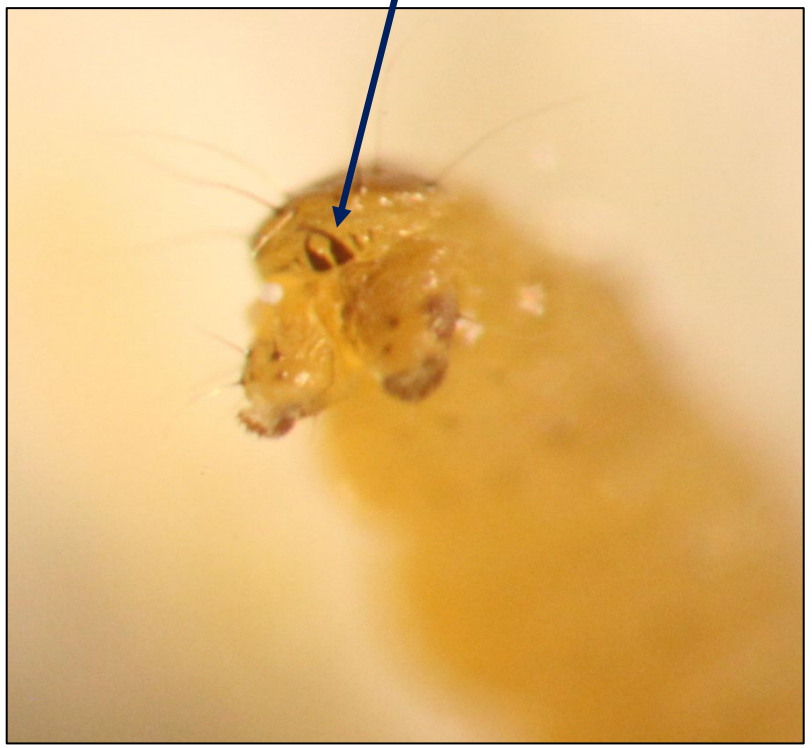
Step 5: Identify larvae and determine average L2 per site

SBW Monitoring – L2 Sampling: Identifying SBW

Spruce Budworm
Anal Comb



Non-SBW
Anal Comb



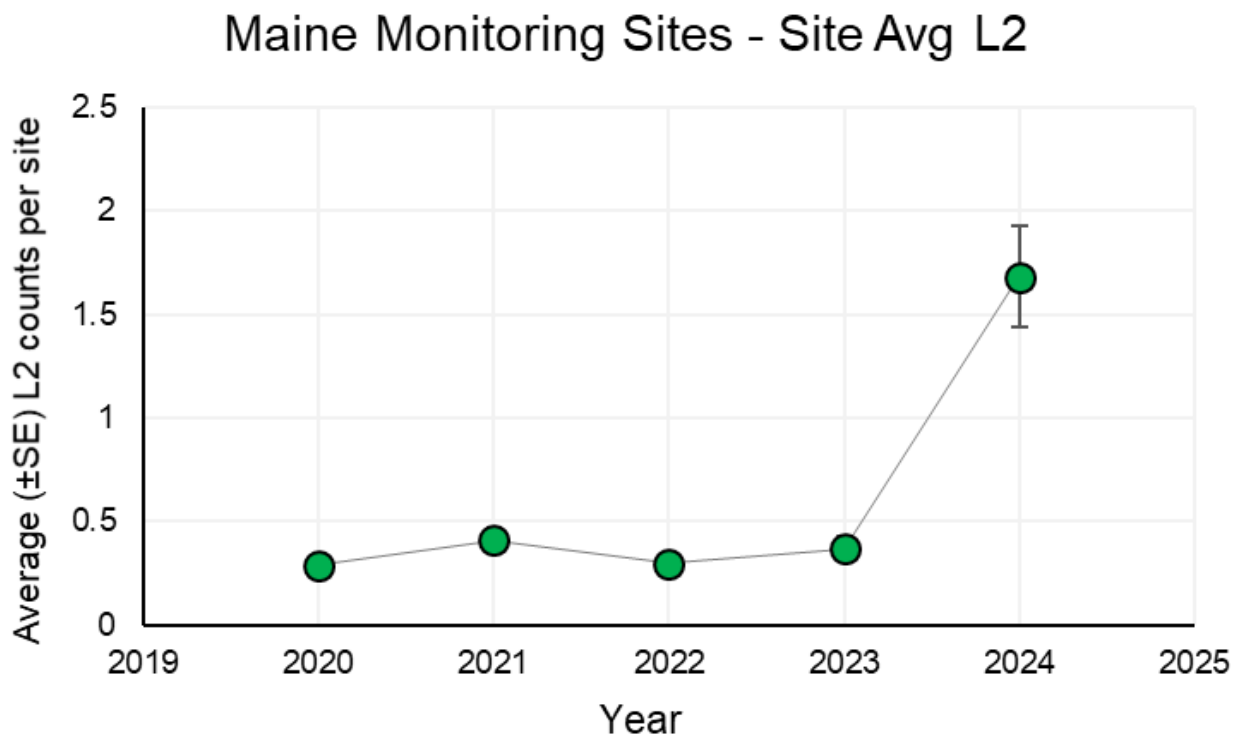
7 SBW L2s = threshold

UMaine lab opened in 2021

SBW Monitoring in Maine

- Yearly monitoring for ~300 sites spread across ME (+ NH, VT, NY)
- Offers fee-for-service option to landowners ($35/site):
  allows them to determine size of the hotspot

Monitoring trends over time

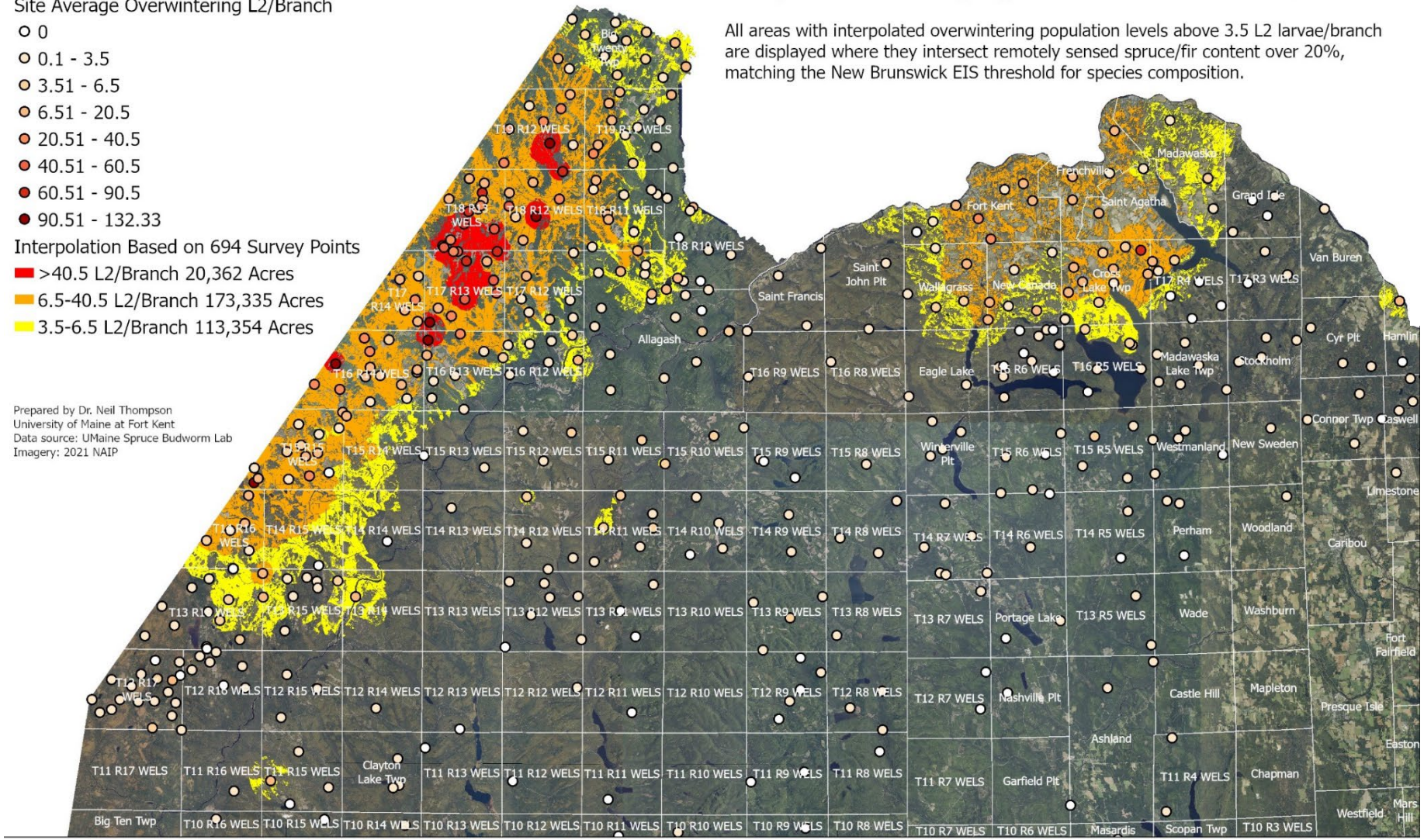


sites ≥ 7 L2s
2020: 1
2021: 0
2022: 0
2023: 2
2024: 21

1865 THE UNIVERSITY OF MAINE
Spruce Budworm Lab

2024 SBW L2 Monitoring: 307,051 acres at risk

Neil Thompson:
Associate Professor of Applied Forest Management
(UM Fort Kent)



What have our Canadian neighbors been up to?

Natural Resources Canada

BOARD OF PESTICIDES CONTROL

DEPARTMENT OF AGRICULTURE, CONSERVATION & FORESTRY

Tebufenozide and BT_K: Toxicity and Risk Assessment

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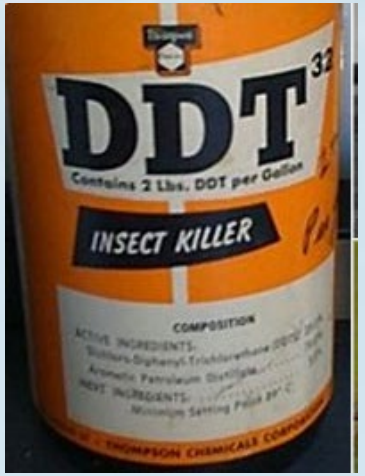
Risk considers both:

1) the hazard



2) and the likelihood of exposure to the hazard.

For pesticides, exposure includes drinking water, diet, dermal, and inhalation routes.

What makes an effective pesticide?

- Capable of solving the problem, *e.g.* spruce budworm outbreak.
  - Potency to the insect at low concentrations
  - Minimal applications

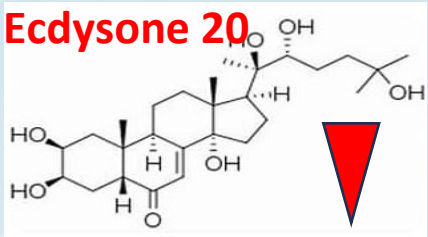
- Does not create other problems (*i.e.* adverse events).
  - Low toxicity to off-target organisms including humans, wildlife, aquatic organisms, other insects, *etc*.
    - **This is especially a consideration for endangered or threatened species.**
  - Low environmental impact. Does the pesticide volatilize, leach into groundwater, bioaccumulate, or persist in the soil?

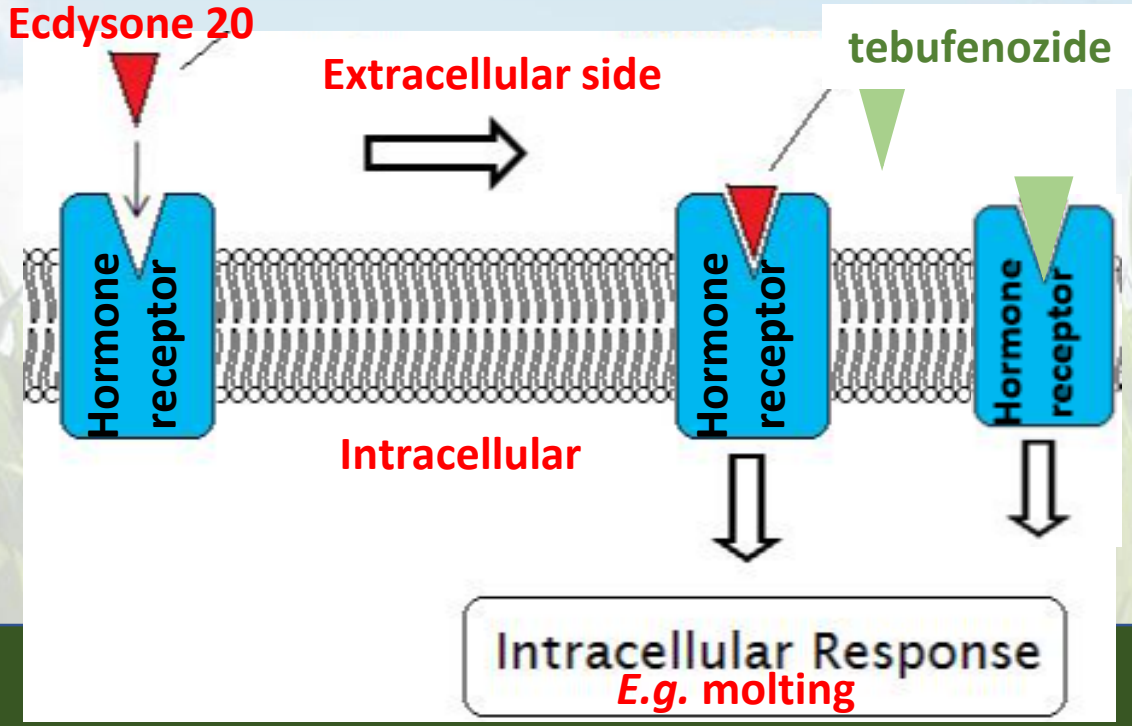
TEBUFENOZIDE

Understanding the biology of SBW guides the effective design of insecticides

- Molting is an essential developmental process in spruce budworm
  - This process is regulated by the molting hormone, ecdysone 20.
  - This hormone is highly specific to the SBW's hormone receptor.

Ecdysone 20





Tebufenozide has greater affinity to the hormone receptor compared to Ecdysone 20. This initiates premature molting. The disruption of the physiological and developmental process in SBW causes lethality.

TEBUFENOZIDE

Risk Assessment for humans and mammals

Toxicity is determined by LD_{50} assays in laboratories

- lethal dose for 50% of the individuals
- these data inform thresholds for human toxicity

Examples of LD_{50} data in rats

	rat (mg/kg)
cyanide	3.6
DDT	87
aspirin	250
table salt	3000
Tebufenozide	>5000

Table 2. Categories of Toxicity for Terrestrial Organisms

Oral dose LD_{50} (mg/kg-bw)	Toxicity Category
< 10	Very highly toxic
10 - 50	Highly toxic
51 - 500	Moderately toxic
501 - 2000	Slightly toxic
> 2000	Practically nontoxic

Conclusion: practically non-toxic to mammals, including humans.
It is also practically non-toxic to birds, earthworms, and reptiles.

TEBUFENOZIDE

Risk Assessment for other organisms

LD_{50} for honey bees is 234 ug/bee

Table 3. Categories of Toxicity for Bee

Bee Acute Contact LD_{50} (µg/bee)	Toxicity Category
<2	Highly toxic
2 – 10.99	Moderately toxic
≥ 11	Practically nontoxic

- In contrast, LD_{50} assays indicate that tebufenozide is slightly to moderately toxic to aquatic life (*e.g.* trout, water fleas, lobster, *etc*).

- However, the risk to aquatic organisms is minimal because:
  - the applied concentration is lower than the LD_{50} conc. (⬇toxicity)
  - risk of exposure is low (risk for lobsters < trout < water fleas)
    - 100 foot setback from streams and water surfaces.

- Non-target caterpillars will succumb to tebufenozide if consumed.

Environmental Risk Assessment

The chemical properties of tebufenozide <u>prevents:</u>

- Volatilization- movement into the atmosphere
- Leaching- movement into the groundwater
- Persistence in the soil- 90% is broken down in 100 days
- Bioaccumulation in the food chain
  - 90% is excreted in fish after 15 days.
  - In trout, less than 0.5% of ingested tebufenozide would remain in edible tissue after 15 days. No risk to anglers.

Additional information about Tebufenozide

- No evidence that it is carcinogenic, neurotoxic, or an endocrine disruptor in humans.

- Recipient of EPA's first Green Chemistry Award in 1998.

BTk

- Bt_k contains spores of the naturally occurring bacterium *Bacillus thuringiensis*, subspecies *kurstaki* (Btk).

- Spores contain a dormant endotoxin that is only activated in caterpillars upon consumption.

- Used to control insects for > 50 years.

- Used on organic crops in Maine.

BTk

Organismal Risk Assessment for BT_k

- Even less toxic than tebufenozide.

  - EPA has waived the maximum residue limit on crops and food.
  - LD50 in rats is >5000. It is practically nontoxic to mammals, birds, aquatic organisms, and most insects.
  - However, it will be toxic to nontarget caterpillars if consumed.

BTk

Environmental Risk Assessment

- Half-life on leaves is 2-4 days.
- Low-persistence in soil (10-fold decrease after 2 weeks).
- Low risk of leaching (trapped in the top 3 inches of soil and quickly degrades).
- No risk of bioaccumulation in the food chain.

Conclusions

- Environmental risks associated with tebufenozide and BTk are anticipated to be minimal.
- Risks of tebufenozide and BTk to most organisms is low at the expected environmental concentrations.
- Anticipated low risk to birds that prey upon caterpillars; foraging habits might be altered.
- Applications of both insecticides will be lethal to nontarget caterpillars if consumed.

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Maine Budworm Response Coalition

Alex Ingraham
Chair of MBRC

Ked Coffin
Co-Chair Tactical Team

*Photography Credit: Dr. Neil Thompson

The Time to Act is Now

PROJECTED NEGATIVE IMPACTS OF A SEVERE SPRUCE BUDWORM OUTBREAK IN MAINE

494,000 cords

of annual wood supply reduction

$794 M

of annual economic impact

3,865 jobs

direct and indirect job losses

Source : Spruce Budworm Task Force Report

The Solution:

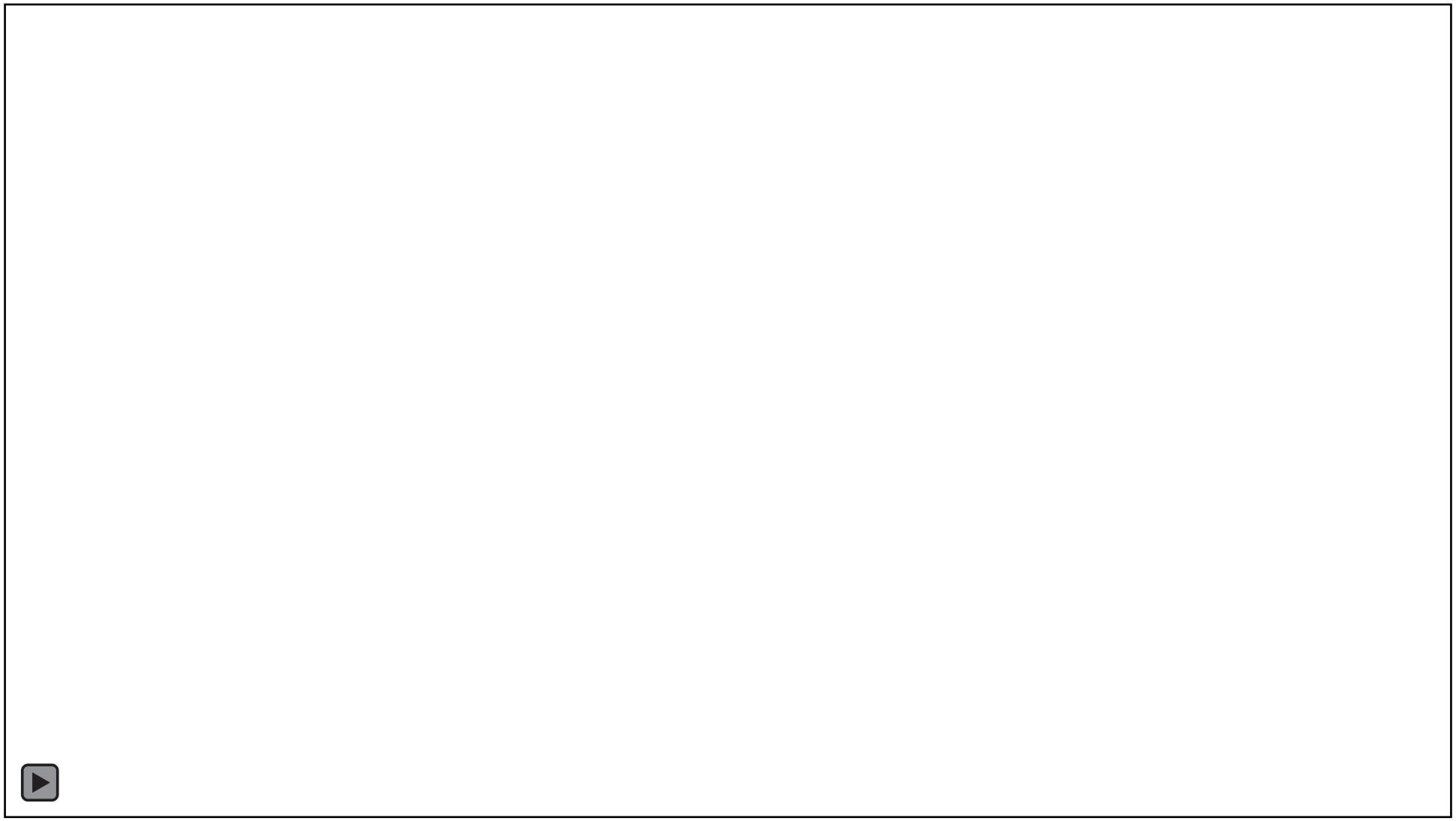
Early Intervention Strategy (EIS)

A simple but effective strategy to combat a large-scale spruce budworm outbreak in Maine.

Includes:

1. **Early Detection** - Monitors populations to detect hot spots.
2. **Early Intervention** - Targets insecticide treatment to prevent spread.
3. **Communication** - Proactive communications and engagement with stakeholders on project activities and results.

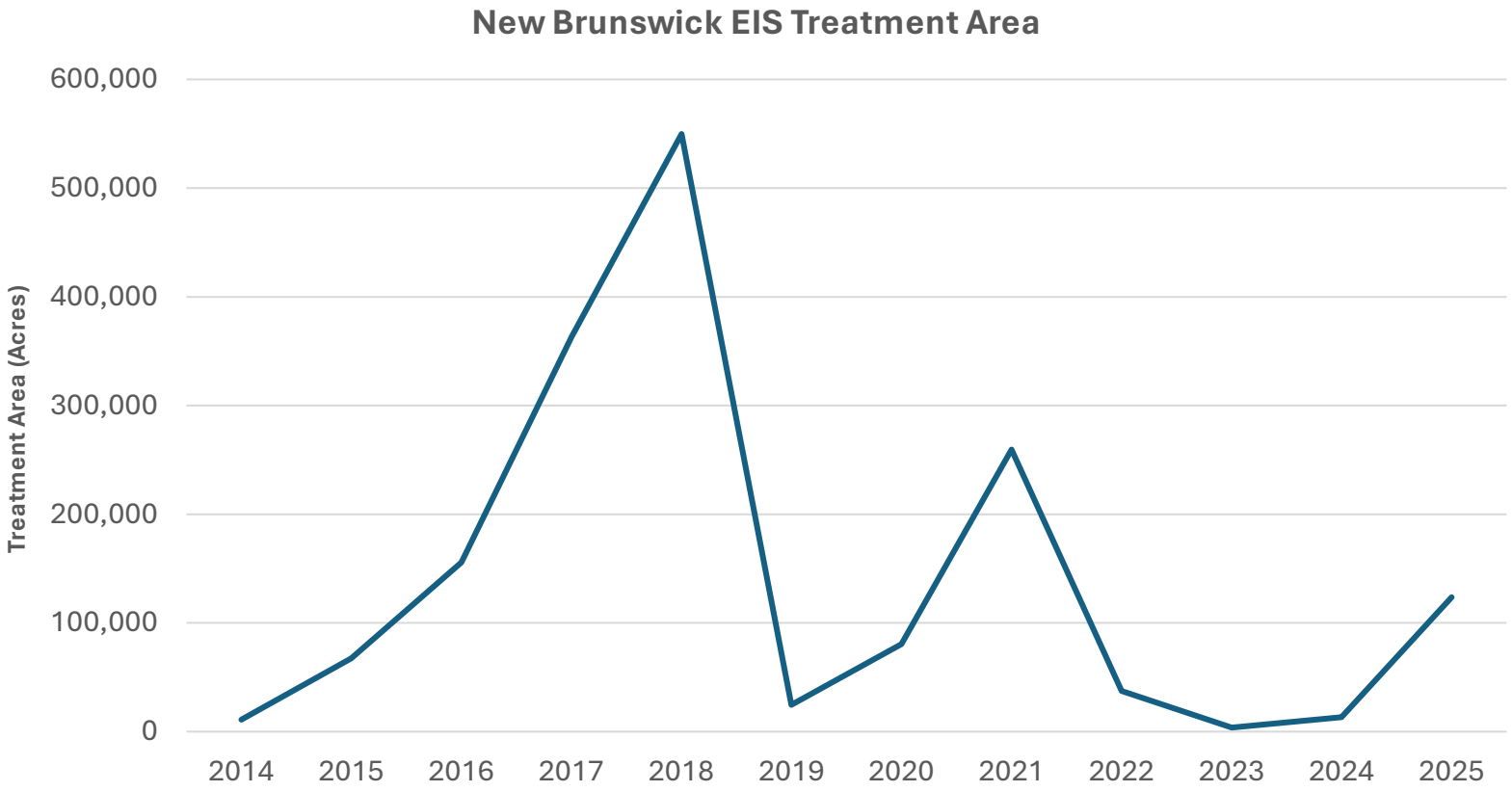
Is it working?



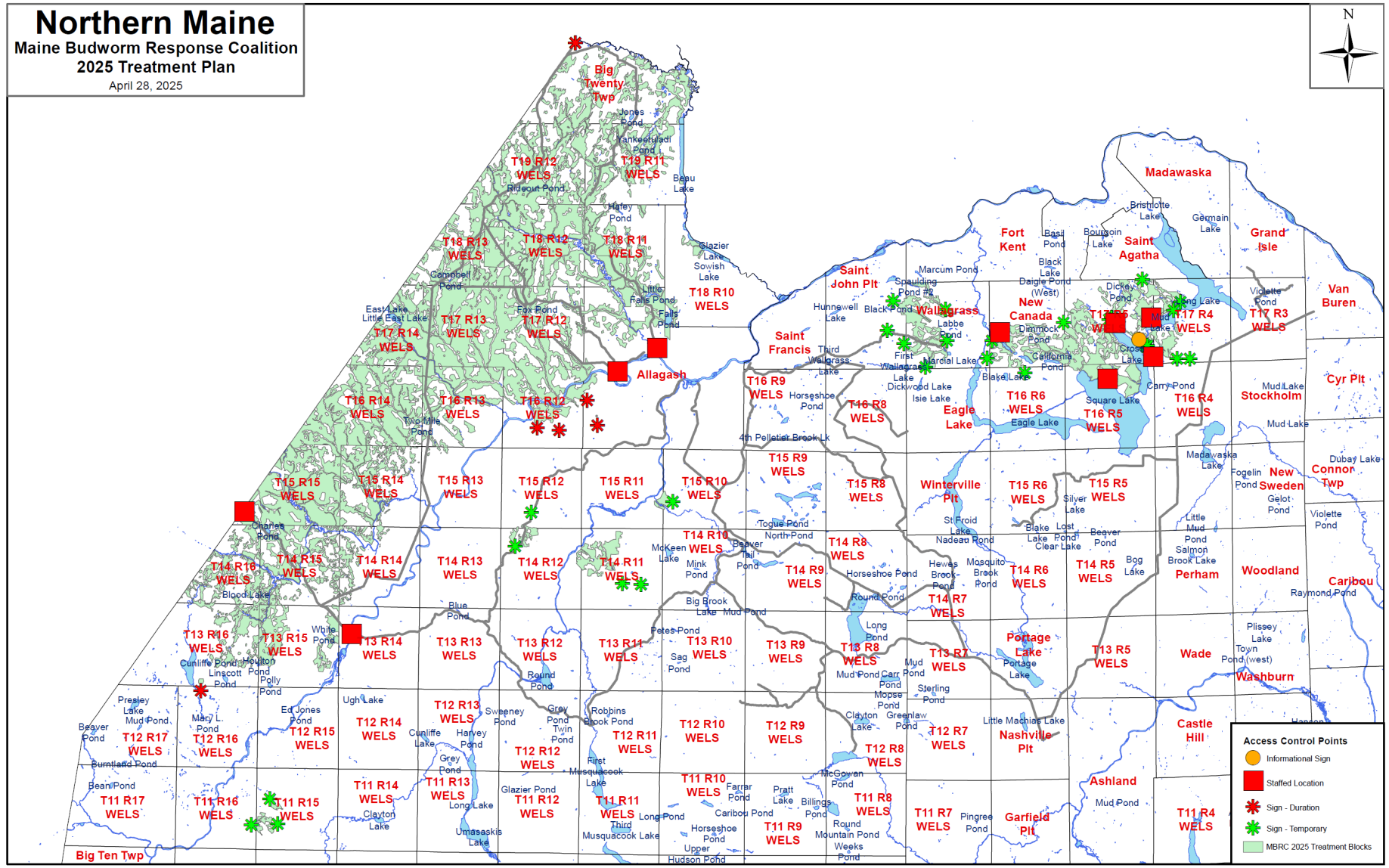
New Brunswick EIS Treatment History

Since 2014 New Brunswick has treated 1.6 M acres (160,000 acres per year on average) using the early intervention strategy.

During the past outbreak in the 1980's, **1-3 M acres were treated annually** using a foliage protection strategy.



Spruce Budworm Treatment Area



The Solution:

Early Intervention Strategy (EIS)

MAINE'S FORESTS ARE AT RISK.

Balsam fir and spruce are important tree species in Maine. A budworm outbreak would cause mass devastation, heavily impacting the forest health, the industry, and the tourism sector.

EARLY INTERVENTION IS WORKING.

Treating hotspots as they occur has successfully stopped budworm at Maine's borders. Making use of available tools, including 2 approved insecticides, Tebufenozide and Btk, will ensure we continue to stop the spread.

THE TIME TO ACT IS NOW.

Funding and commitment from all partners for the 2025 early intervention plan is secured and will ensure we avoid the massive outbreaks seen in the past ensuring a healthy forest and healthy economy.

Thank you for joining us today!