Regional adaptation of Integrated Pest Management to control invasive insects

Michael Stastny (Canadian Forest Service – Atlantic Forestry Centre)

Juan Corley (Institute for Forestry and Agricultural Research / Universidad Nacional del Comahue in Bariloche, Argentina

Jeremy Allison (CFS – Great Lakes Forestry Centre / University of Pretoria)

Invasive Forest Insects in the Anthropocene

- escalating propagule pressure & impacts
- multiple stressors on forest resources
- replicate invasions across regions

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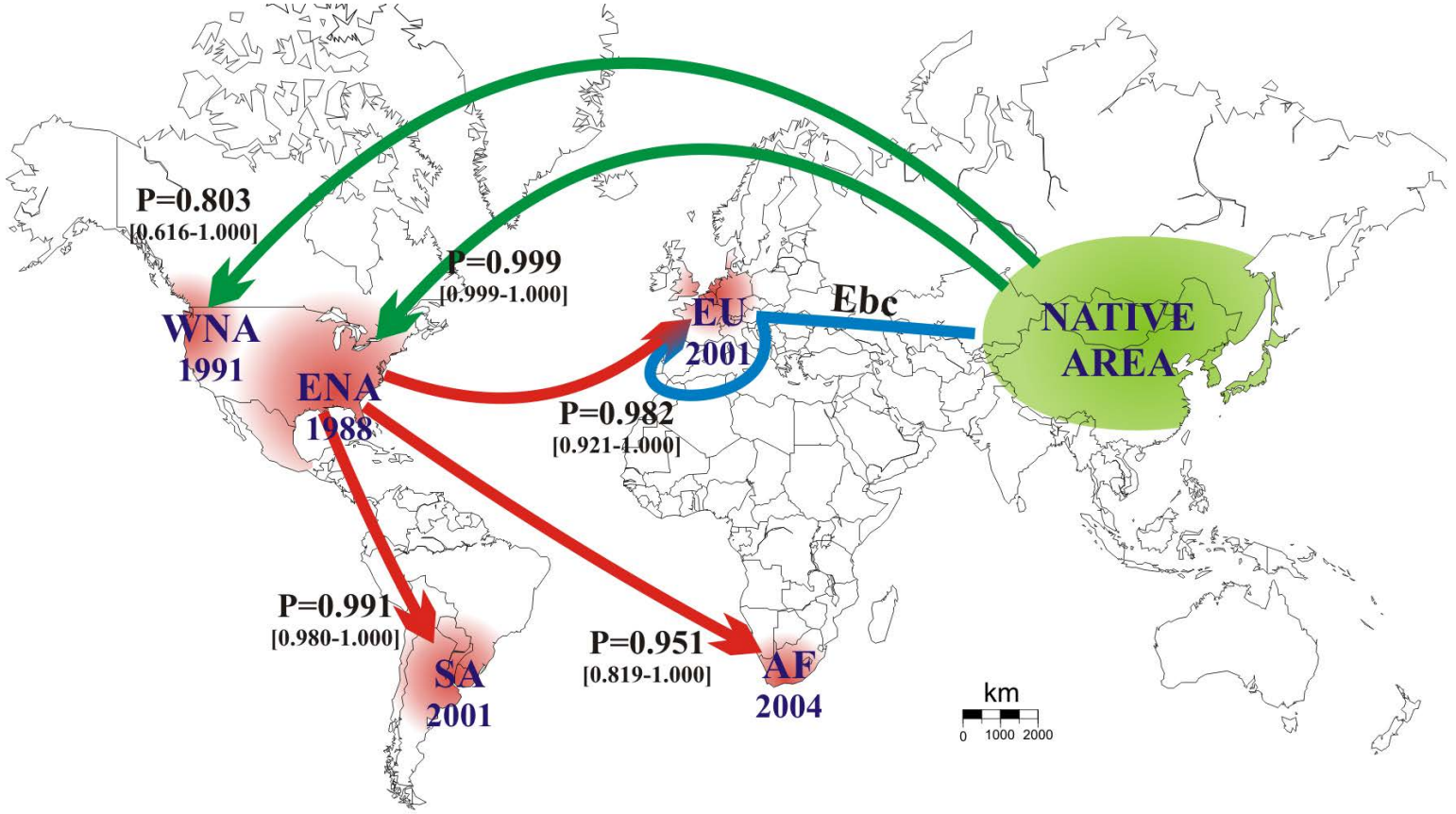

Bridgehead effect in Harlequin ladybird *Harmonia axyridis* (Lambaert et al. 2010)

Invasive Forest Insects in the Anthropocene

- escalating propagule pressure & impacts
- multiple stressors on forest resources
- replicate invasions across regions

- pressure from stakeholders to find proactive solutions
- growing recognition of ecological services
- evolving regulatory environment

Invasive Forest Insects in the Anthropocene

- escalating propagule pressure & impacts
- multiple stressors on forest resources
- replicate invasions across regions

demand for rapid integrated response, risk-based management

- pressure from stakeholders to find proactive solutions
- growing recognition of ecological services
- evolving regulatory environment

→ we adopt existing IPM programs for the same pest in multiple regions

BENEFITS:

- knowledge sharing
- collaboration & training
- more efficient implementation, regulation
- enhanced coordination across jurisdictions
- regional / global solutions & policy

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BENEFITS:

- knowledge sharing
- collaboration & training
- more efficient implementation, regulation
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- regional / global solutions & policy

RISKS:

- no guarantee the same approach works in other regions
- consequences of poor efficacy or program failure
- slower to recognize and adapt to changing pest situations

Regional adaptation of IPM

Conceptual synthesis + online survey of IPM experts (2022)

Regional adaptation of IPM

Conceptual synthesis + online survey of IPM experts (2022)

- qualitative compilation of examples
- information from grey literature
- unpublished / subjective opinion
- haphazard sample
- global coverage

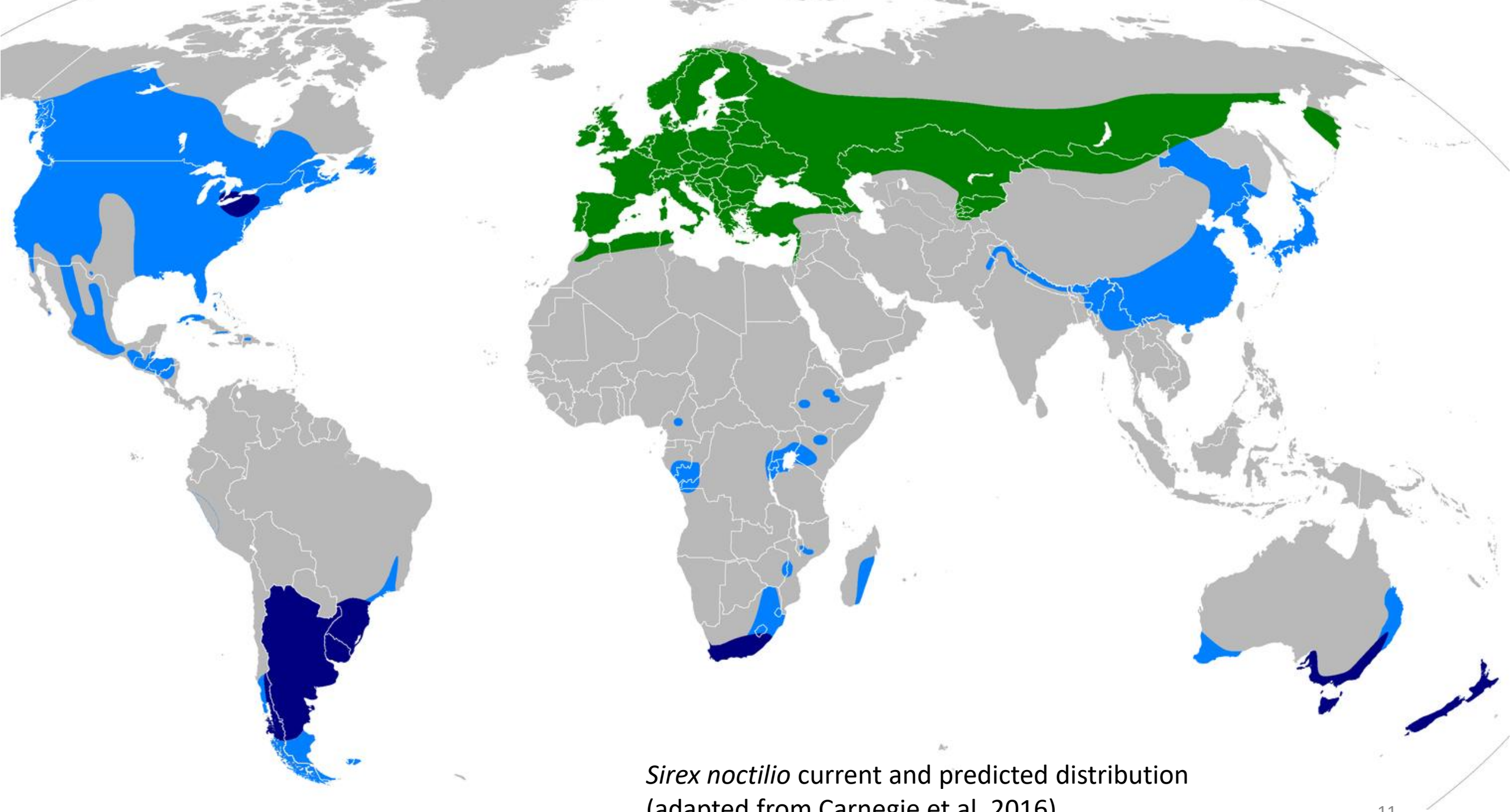
Anoplophora glabripennis
Adelges tsugae
Cameraria ohridella
Dendroctonus valens
Dryocosmus kuriphilus
Glicaspis brimblecombei
Gonipterus platensis
Gonipterus sp. 2
Ips grandicolis
Ips typographus
Leptocybe invasa
Leptoglossus occidentalis
Matsucoccus josephi
Pineus boerneri
Pityophthorus juglandis
Profenusa thomsoni
Rhynchophorus ferrugineus
Sirex noctilio
Lymantria dispar dispar
Tetropium fuscum
Thaumastocoris peregrinus
Xylosandrus crassiusculus

Regional adaptation of IPM

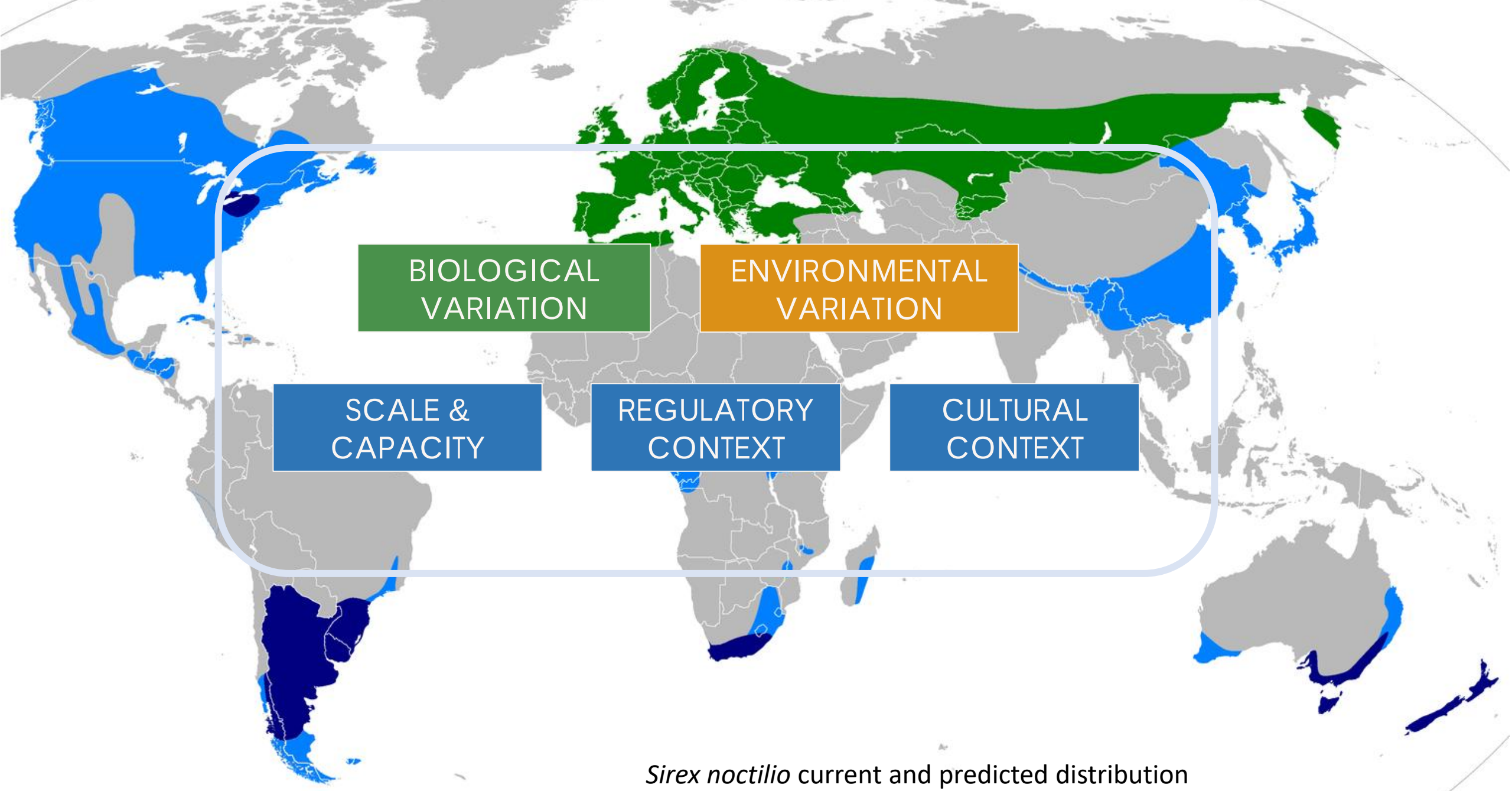
Conceptual synthesis + online survey of IPM experts (2022)

Thanks to Prof. Stephen Heard and University of New Brunswick

- Outcome if based on previous program?
- Key differences between regions?
- Research prior to or during implementation?
- Program modified?
- Impact of this modification?



Sirex noctilio current and predicted distribution
(adapted from Carnegie et al. 2016)



Sirex noctilio current and predicted distribution (adapted from Carnegie et al. 2016)

BIOLOGICAL VARIATION

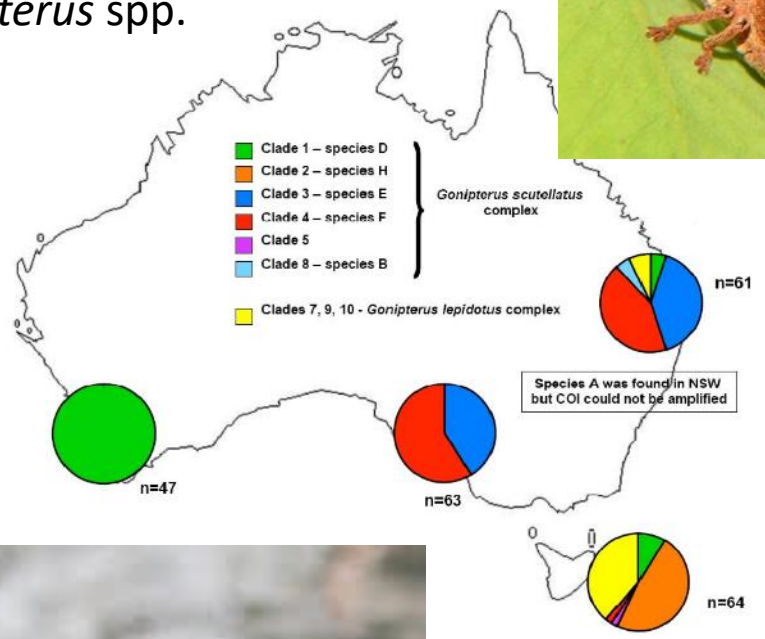
Pest ID

- Different genotypes?
- Species complex?

Natural enemy ID

- Ecotypes?
- Symbiont involved?

Gonipterus spp.



Sirex noctilio

Tetropium fuscum

BIOLOGICAL VARIATION

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Natural enemy ID

- Ecotypes?
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Tree impacts

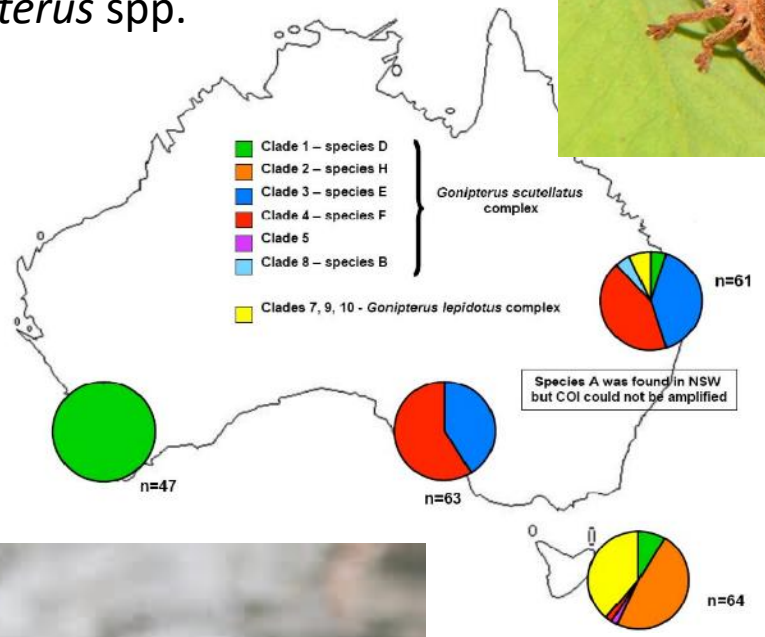
- Symptoms and severity?
- Other stressors?
- Other hosts?
- Resistant genotypes?

Ecological context

- Differences in habitats, communities?
- Related species?

Rapid evolutionary change

Gonipterus spp.



Sirex noctilio

Tetropium fuscum

ENVIRONMENTAL VARIATION

Climatic similarity

- Differences in phenology?
- Changes in voltinism?

Risks under climate change

- Impacts on natural enemies?
- Increasing host stress?

- Shifts in pest distribution?
- Novel outbreaks?

Ips typographus Jakoby et al. 2019

SCALE AND CAPACITY

Scale of problem

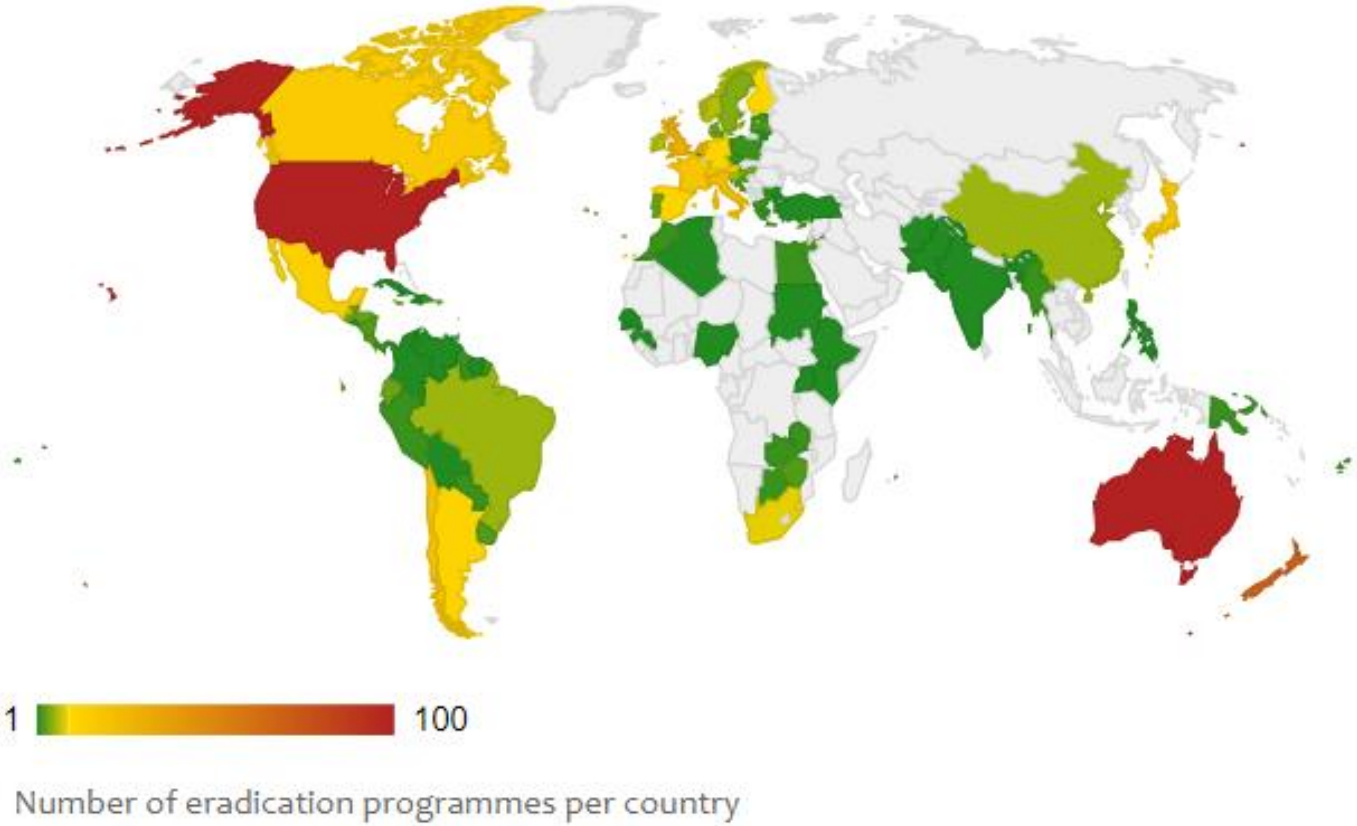
- Economic costs?
- Ecological impacts?
- Timescale and risks?

Capacity

- Resources for implementation?
- Funding for further research?
- Existing expertise?
- Adequate monitoring?

Tactics

- Partial adoption?
- Integration?



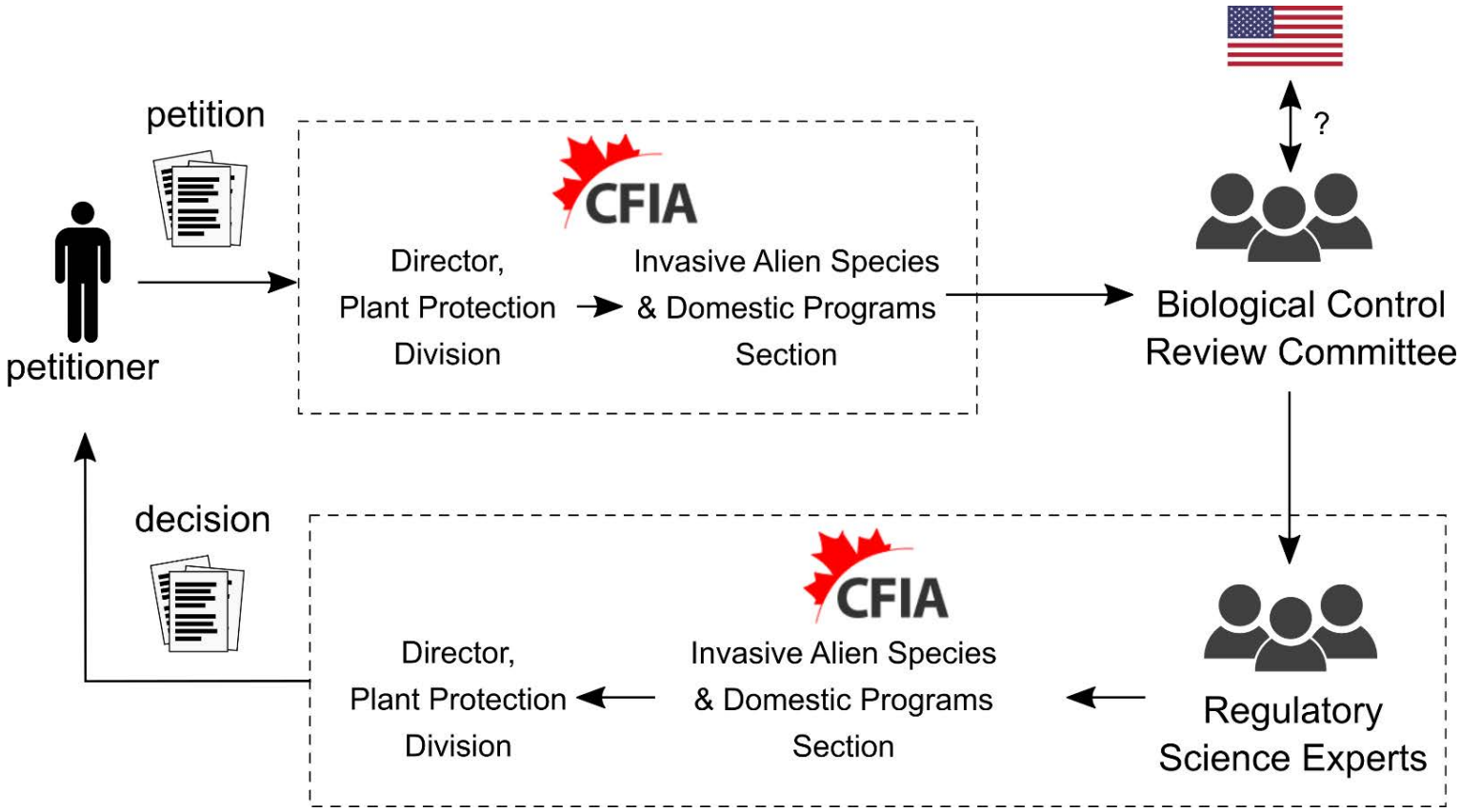
REGULATORY CONTEXT

Differences in legislation

- Available tools?
- Specific constraints?
- Timelines of approvals?

Non-target risks

- Context & perception?



Adapted by C. MacQuarrie, CFS

CULTURAL CONTEXT

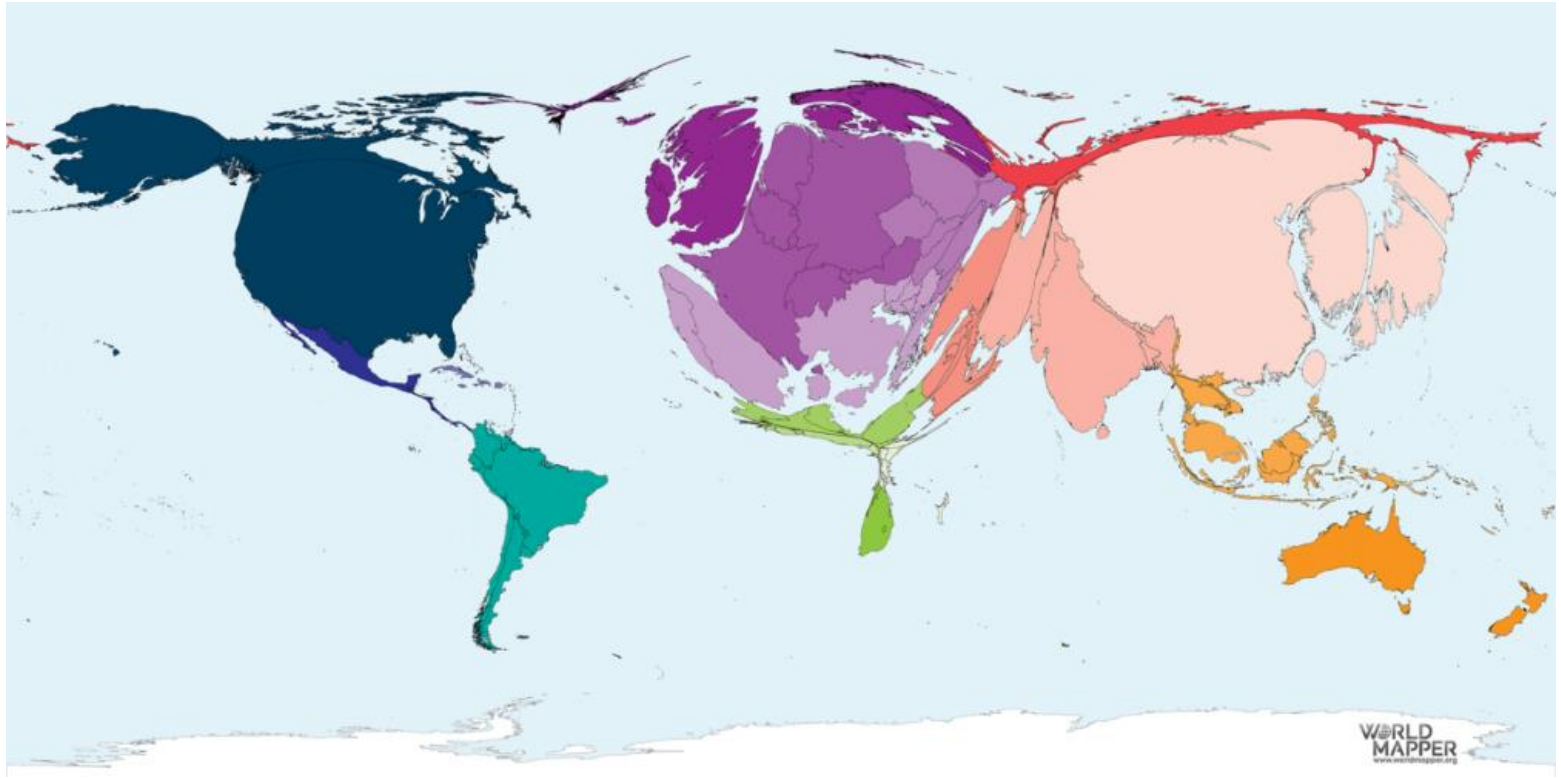
Outreach and uptake

- Communication?
- Implementation routes?
- Cultural values and biases?

Stakeholders

- Public perception?
- Funding models
- Involve social scientists

Scientific publications in 2016



Online survey summary

- biological & environmental variation ranked most important: 22 of 29 cases
- scale & capacity another major challenge:12 of 29 cases

Online survey summary

- biological & environmental variation ranked most important: 22 of 29 cases
- scale & capacity another major challenge:12 of 29 cases

- modifications already occurring: 20 of 29 cases
  (14 based on regional differences)
- programs with satisfactory / complete control: 12 of 15 cases involved modifications

  (10 report critical/significant impacts …but only 5 modified before implementation)

… in most cases, multiple factors influence outcomes

- failures are rarely studied / published
- differences / issues may be identified but fixes may not be feasible
- only some components of programs may be implemented
- monitoring & program evaluation often neglected

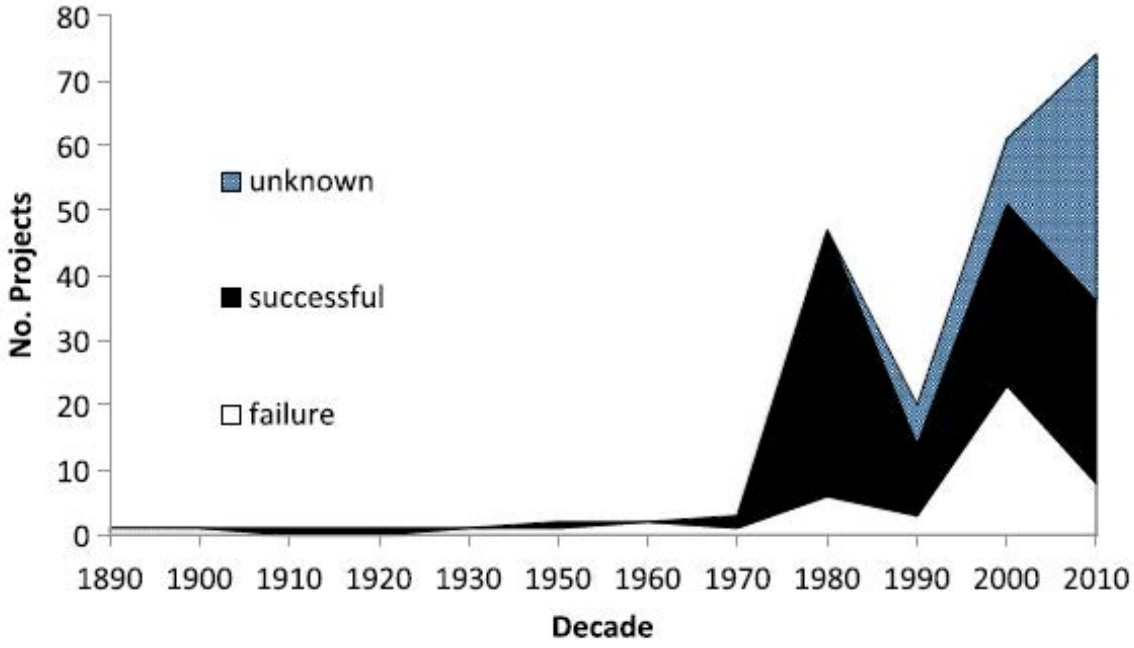


Fig. 1 Numbers of historical forest insect eradication projects by decade. Data extracted from GERDA database (Kean et al. 2018)

IPM PROGRAM EVALUATION

BIOLOGICAL VARIATION

Confirm pest ID
- Different genotypes?
- Species complex?

Confirm natural enemy ID
- Ecotypes?
- Symbiont involved?

Assess tree impacts
- Symptoms and severity?
- Other stressors?
- Additional host species?

Check for resistant genotypes

Characterize ecological context
- Differences in habitats, biological communities?
- Related species?
- Management considerations?

Consider rapid evolutionary change

ENVIRONMENTAL VARIATION

Evaluate climatic similarity
- Observed changes in phenology or voltinism?
- Climate matching modeling?

Assess risks under climate change
- Impacts on natural enemies?
- Increasing host stress?
- Shifts in pest distribution?
- Novel outbreaks?

CULTURAL CONTEXT

Consider outreach and uptake
- Implementation routes?
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Identify stakeholders
- Involve social scientists

SCALE AND CAPACITY

Evaluate scale of problem
- Economic costs?
- Ecological impacts?
- Timescale and risks?

Evaluate capacity
- Resources for implementation?
- Funding for further research?
- Existing expertise?
- Adequate monitoring?

Select tactics
- Partial adoption? Integration?

REGULATORY CONTEXT

Identify differences in legislation
- Available tools?
- Specific constraints?

Non-target risks?

PERIODIC REASSESSMENT

IPM PROGRAM EVALUATION

BIOLOGICAL VARIATION

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REGULATORY CONTEXT

- **Identify differences in legislation**
  - Available tools?
  - Specific constraints?
- **Non-target risks?**

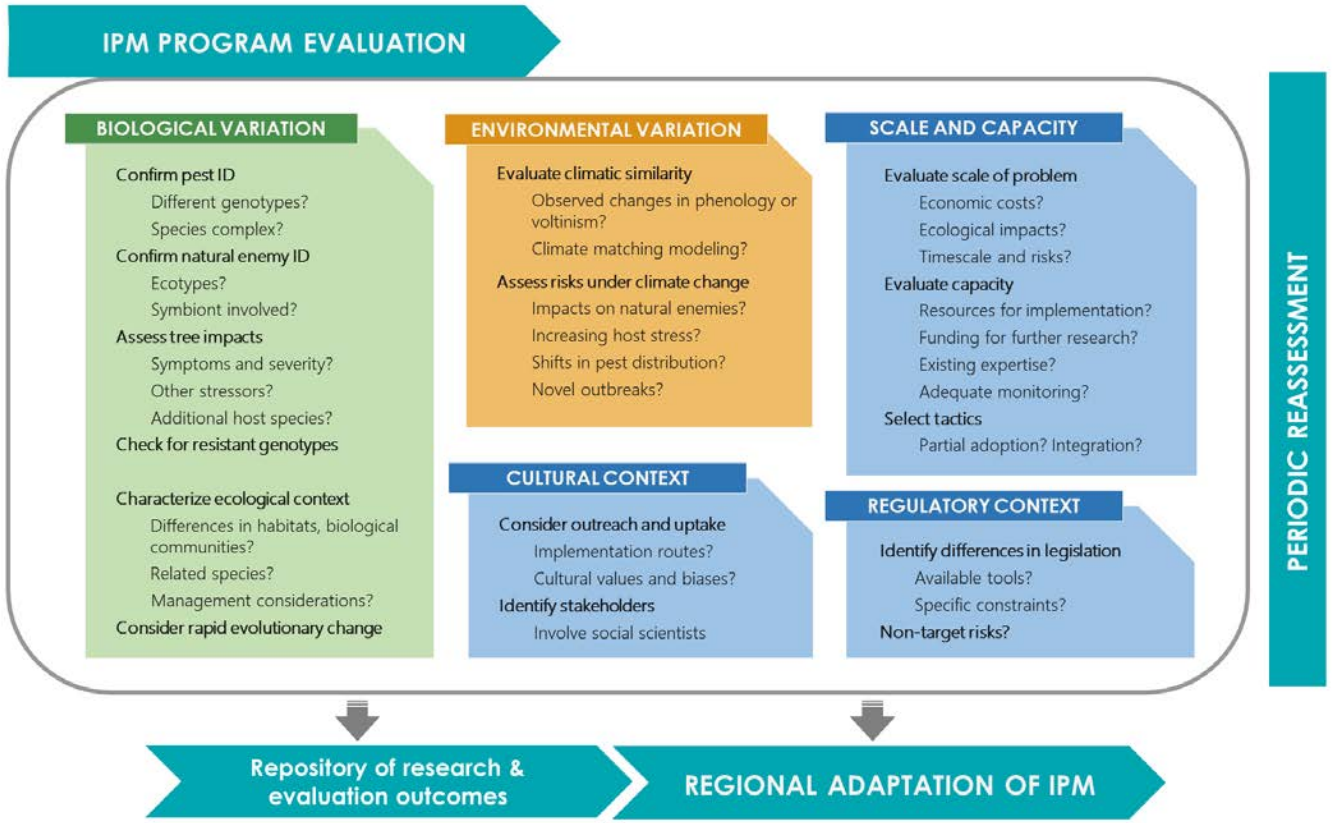
PERIODIC REASSESSMENT

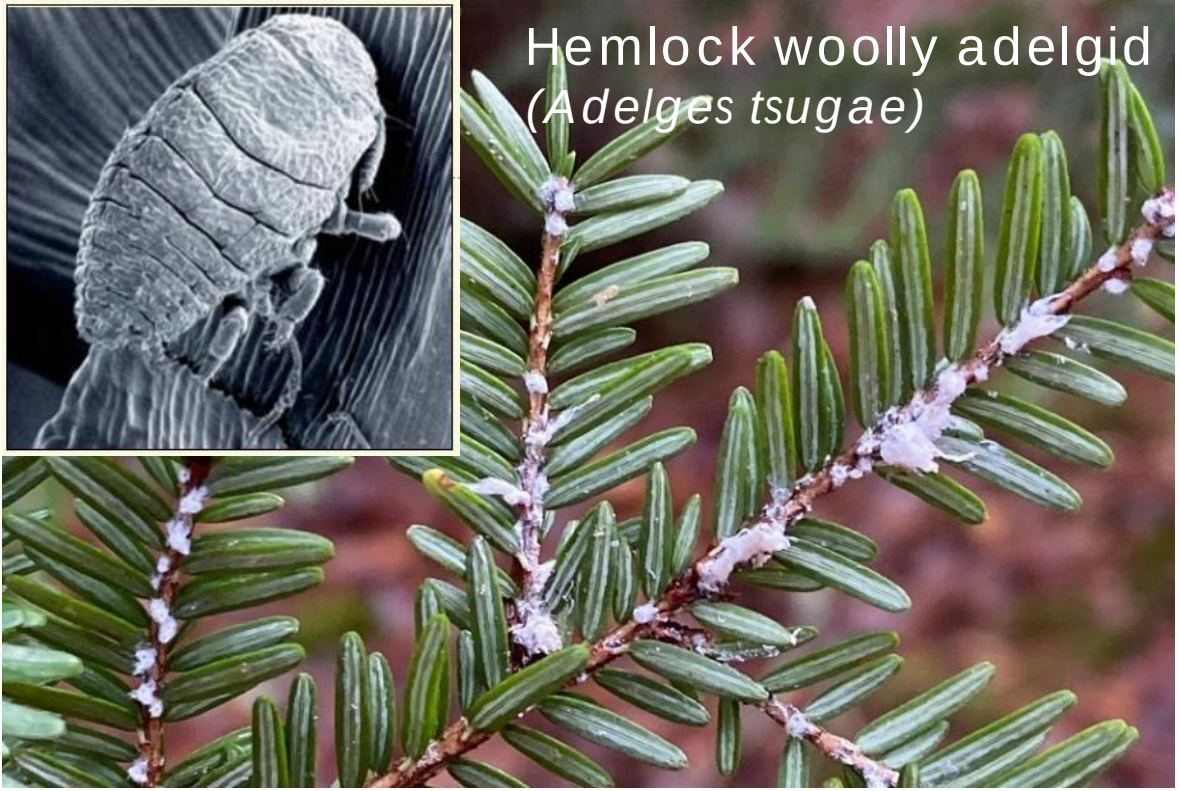
Repository of research & evaluation outcomes

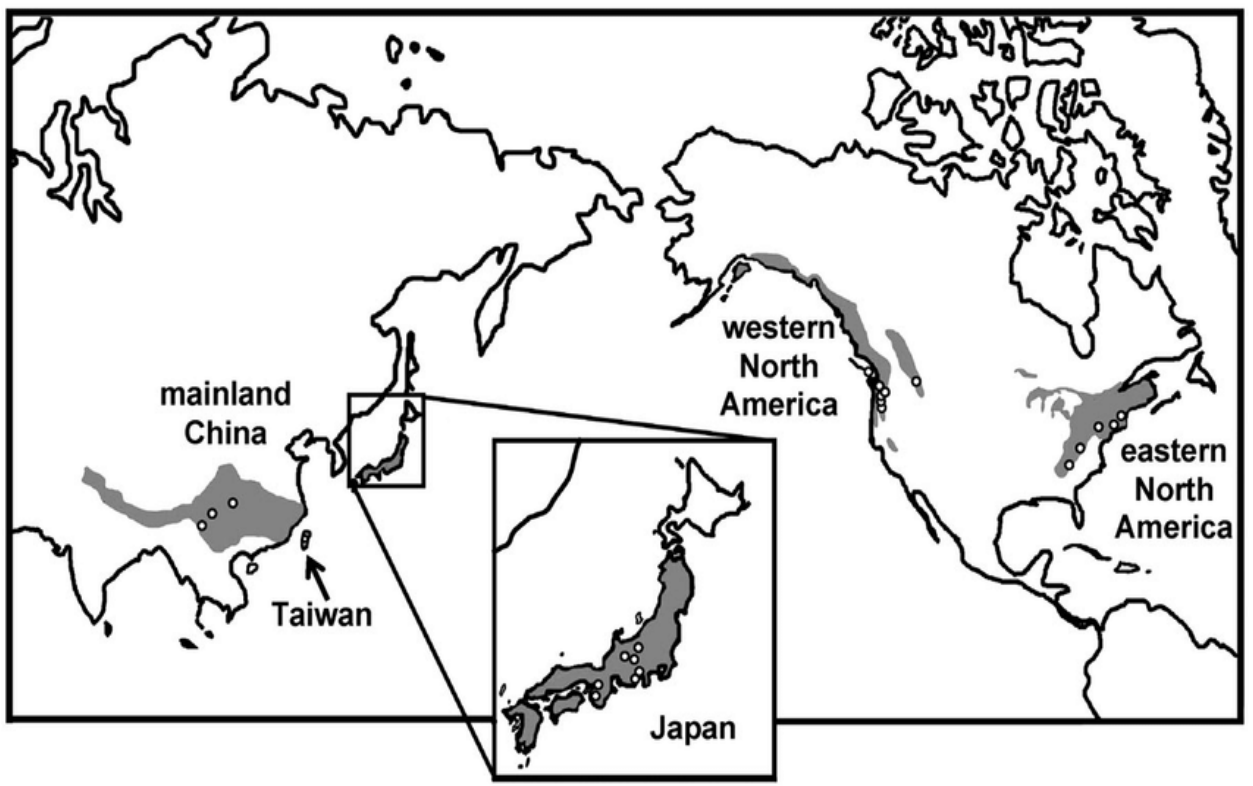
REGIONAL ADAPTATION OF IPM

Regional adaptation of IPM in agricultural systems?

- simpler ecological context
- relative ease of monitoring
- emphasis on resistance breeding
- trade & food security implications
- cultural dimension

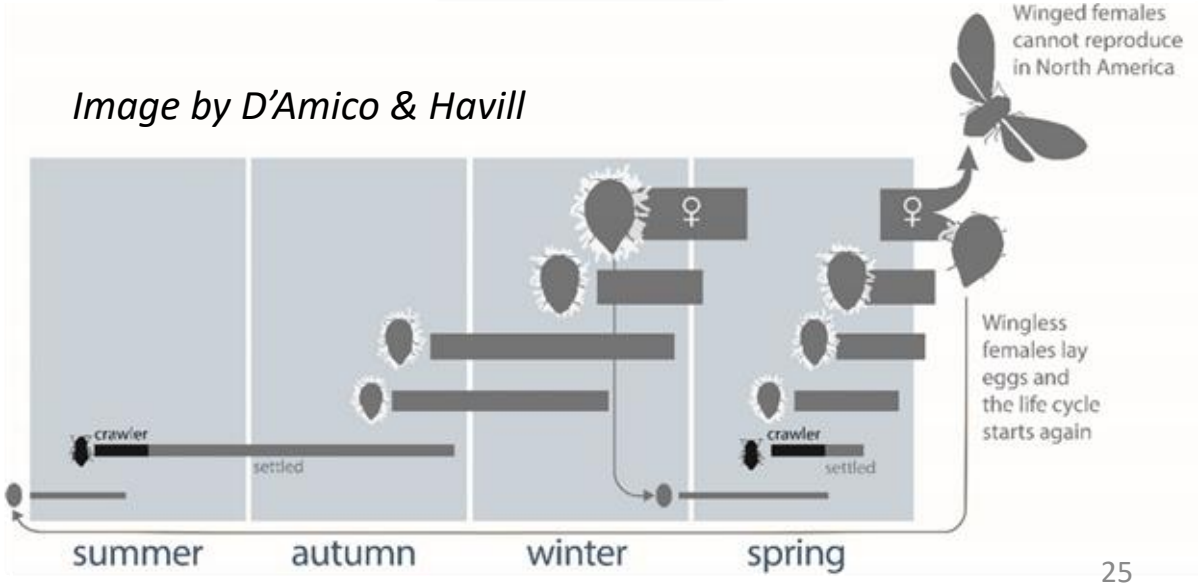


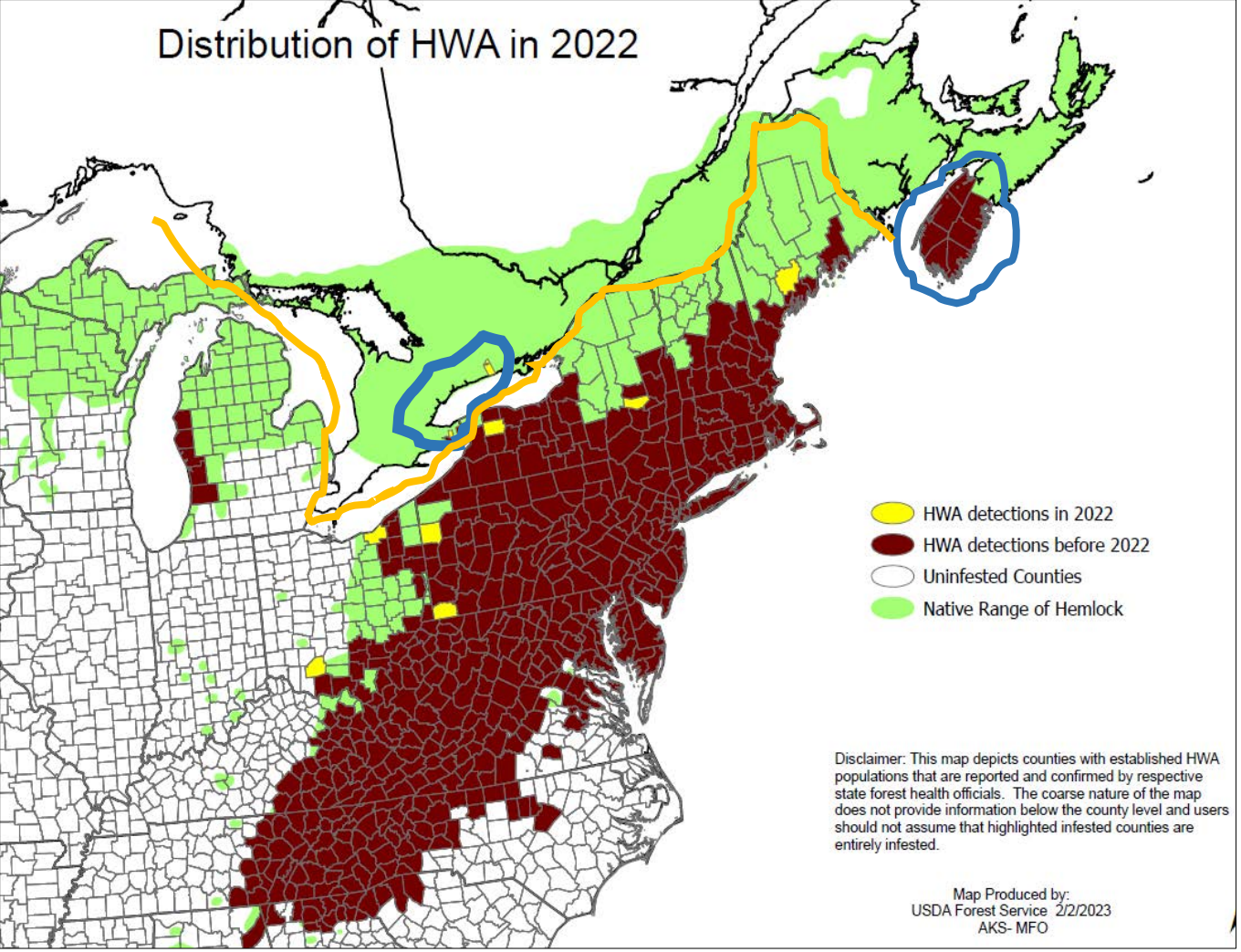


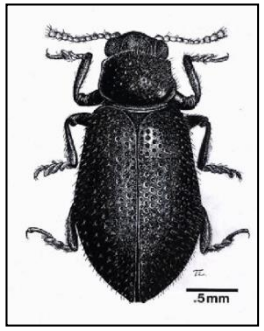


- complex life cycle with 2 all-female generations
- passive long-distance dispersal, parthenogenetic
- symptoms: tree decline, death in 3-10 years
- increased cold tolerance during invasion

Image by D'Amico & Havill







→ 30+ years of basic & applied research

→ IPM program in USA relies on:

1) chemical control

- neonicotinoids (every ~2-4 years)
- prevent hemlock mortality
- slow spread

2) biological control

- 2 *Laricobius* beetles (Western NA, Japan)
- 2 *Leucotaraxus* silver flies (Western NA)

3) silviculture (tests ongoing)

- stand thinning to promote tree resilience

BIOLOGICAL VARIATION

Pest ID

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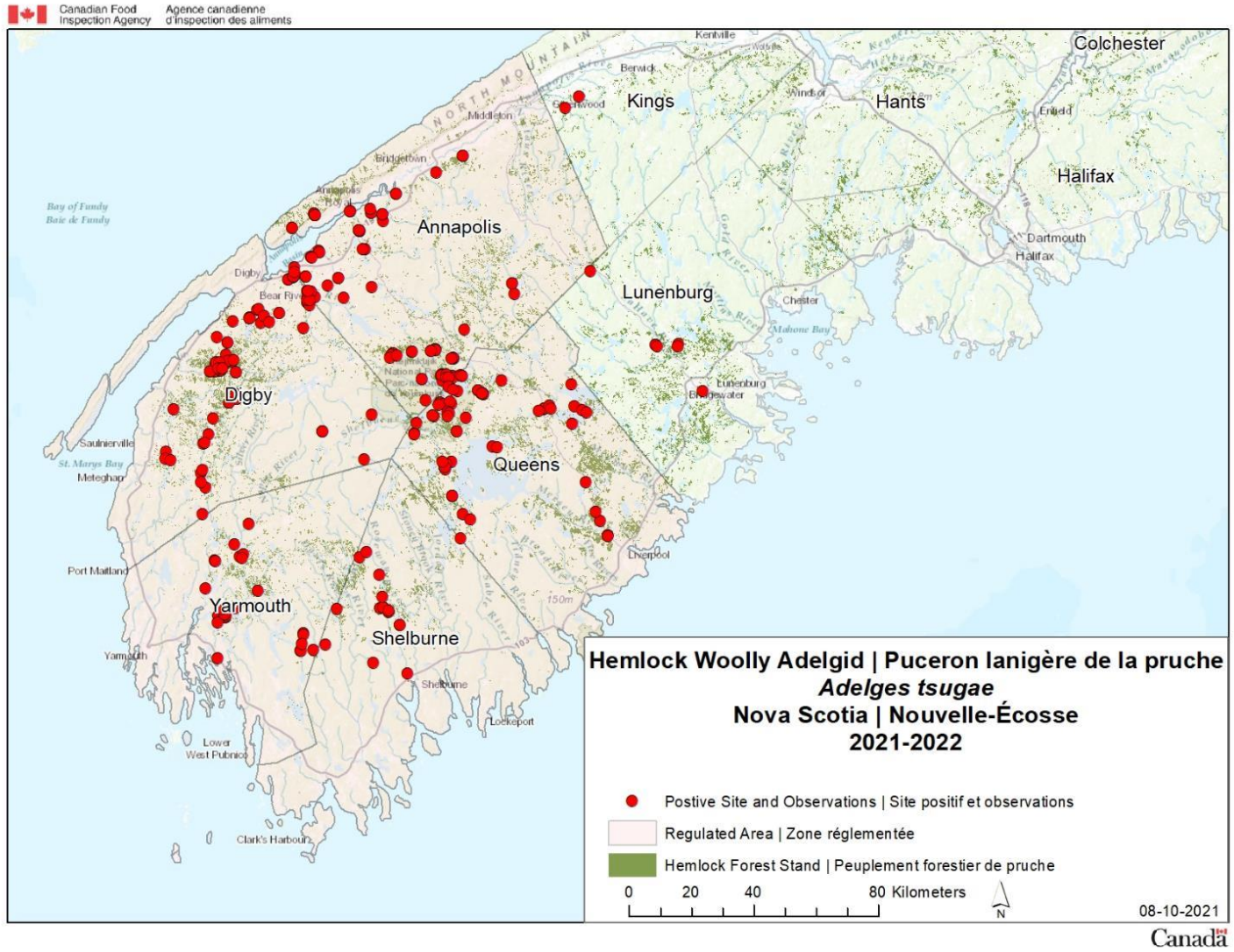
Rapid evolutionary change



HWA invaded range in Nova Scotia

ENVIRONMENTAL VARIATION

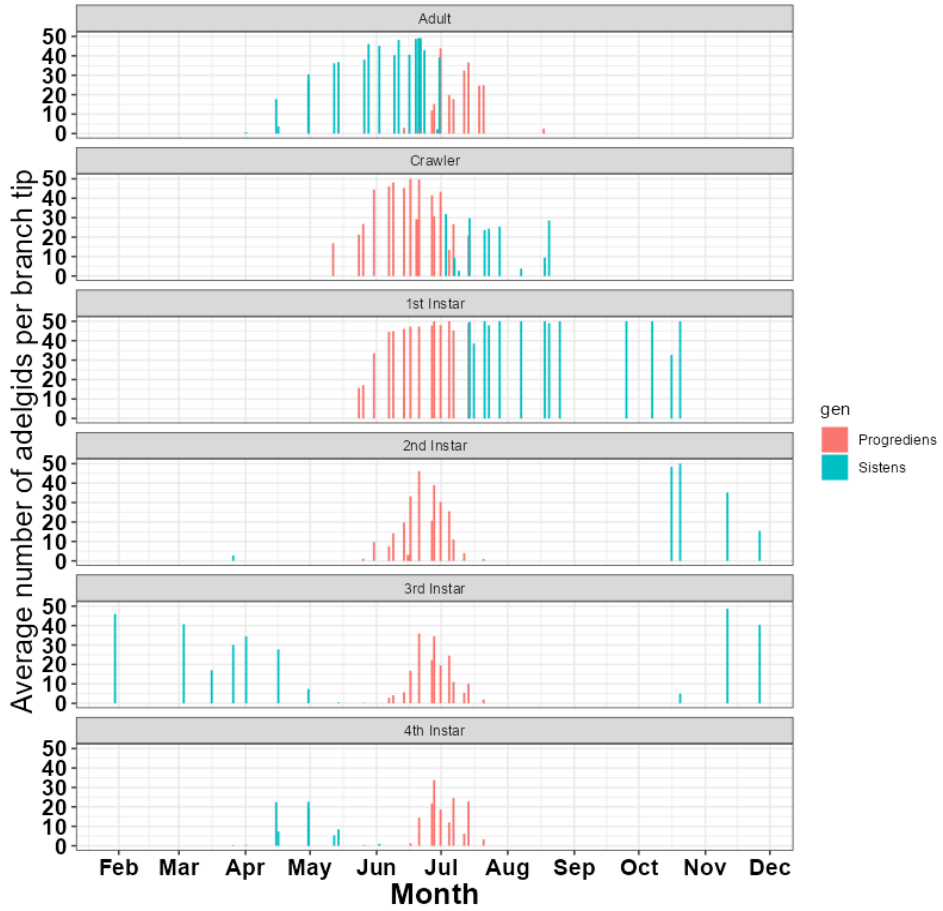
Climatic similarity

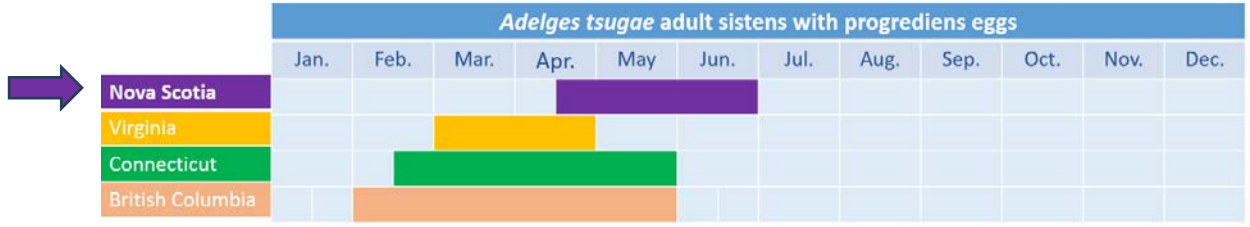
- Differences in phenology?
- Changes in voltinism?

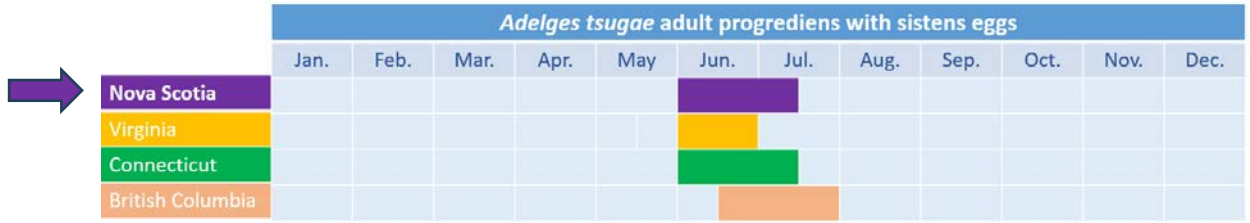
Risks under climate change

- Impacts on natural enemies?
- Increasing host stress?

- climatic matching of predators
- abiotic mortality → population dynamics







SCALE AND CAPACITY

Scale of problem

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- Resources for implementation?
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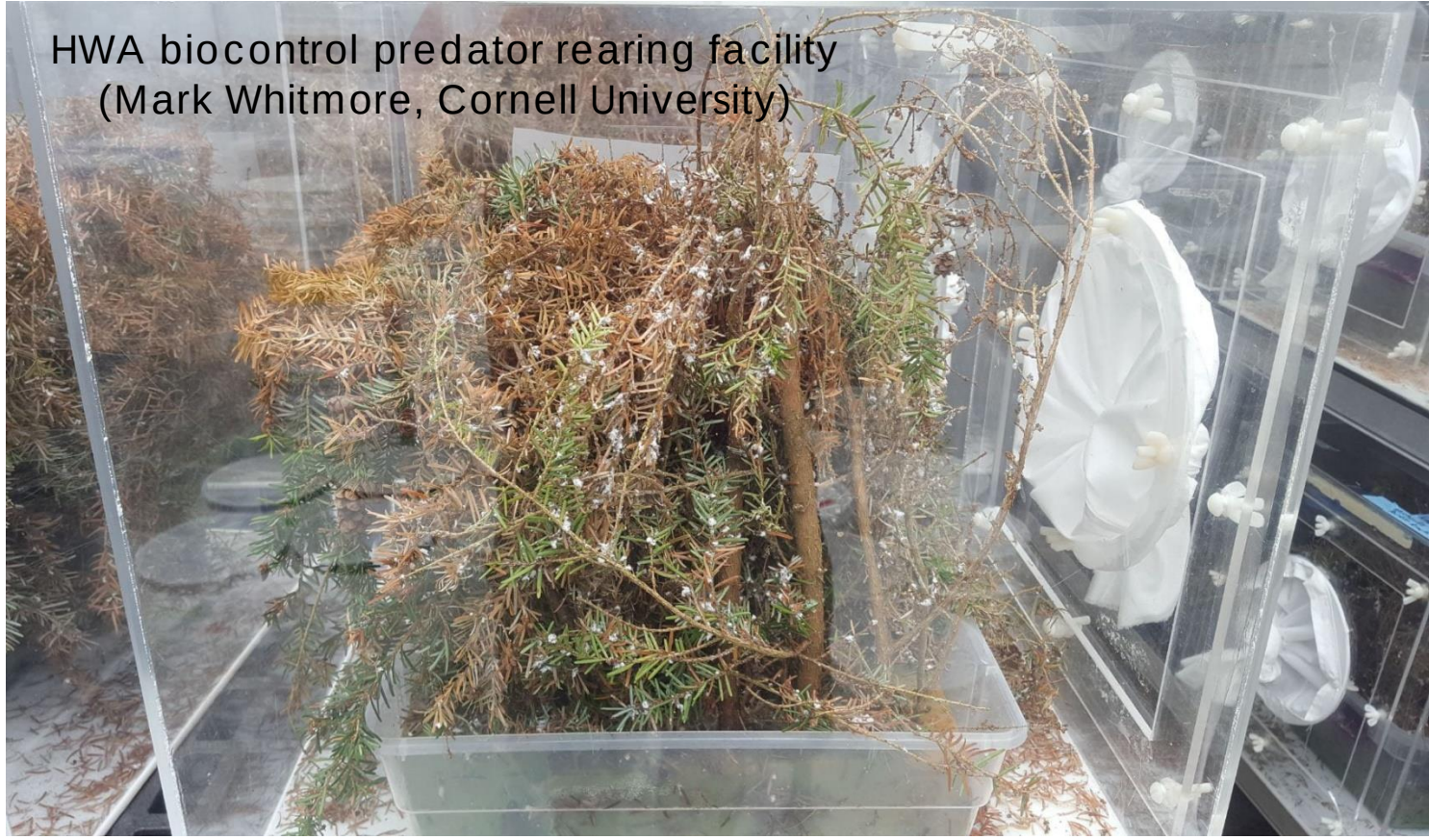
Tactics

- Partial adoption?
- Integration?



ELSEVIER

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

A decision framework for hemlock woolly adelgid management: Review of the most suitable strategies and tactics for eastern Canada

Caroline E. Emilson[a,*], Michael Stastny[b]

[a] Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen St. E., Sault Ste. Marie, ON P6A 2E5, Canada
[b] Natural Resources Canada, Canadian Forest Service, Atlantic Forestry Centre, 1350 Regent Street South, Fredericton, NB E3B 5P7, Canada

REGULATORY CONTEXT

Differences in legislation

- Available tools?
- Specific constraints?
- Timelines of approvals?

Non-target risks

- Context & perception?

- some insecticide applications not allowed/available
- consultations with First Nations, conservation groups
- sources of biocontrol agents
  → same species but requires petition if from USA

CULTURAL CONTEXT

Outreach and uptake

- Communication?
- Implementation routes?
- Cultural values and biases?

Stakeholders

- Public perception?
- Funding models
- Involve social scientists

Hemlocks & Hardwoods Trail, Kejimkujik NP (R Rodriguez Jr)

- aesthetic & recreational value, urban forests
- private versus public forests
- national versus regional strategy

ENVIRONMENTAL VARIATION

Risks under climate change

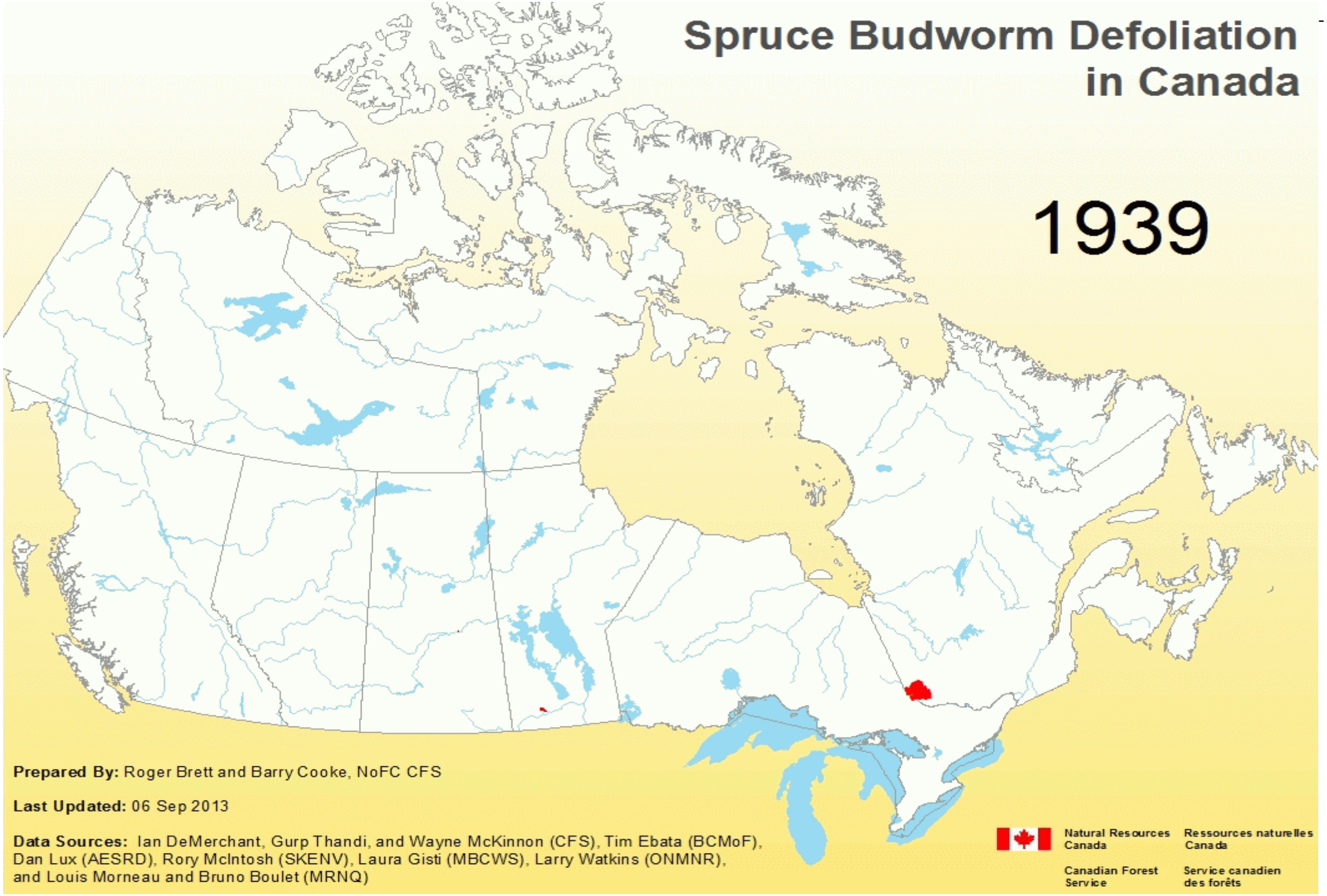
- Shifts in pest distributions?
- Changing population dynamics?
- Novel outbreaks and impacts?

Emerging issues in *native* forest insect pests in the Anthropocene

Spruce budworm / SBW *(Choristoneura fumiferana)*

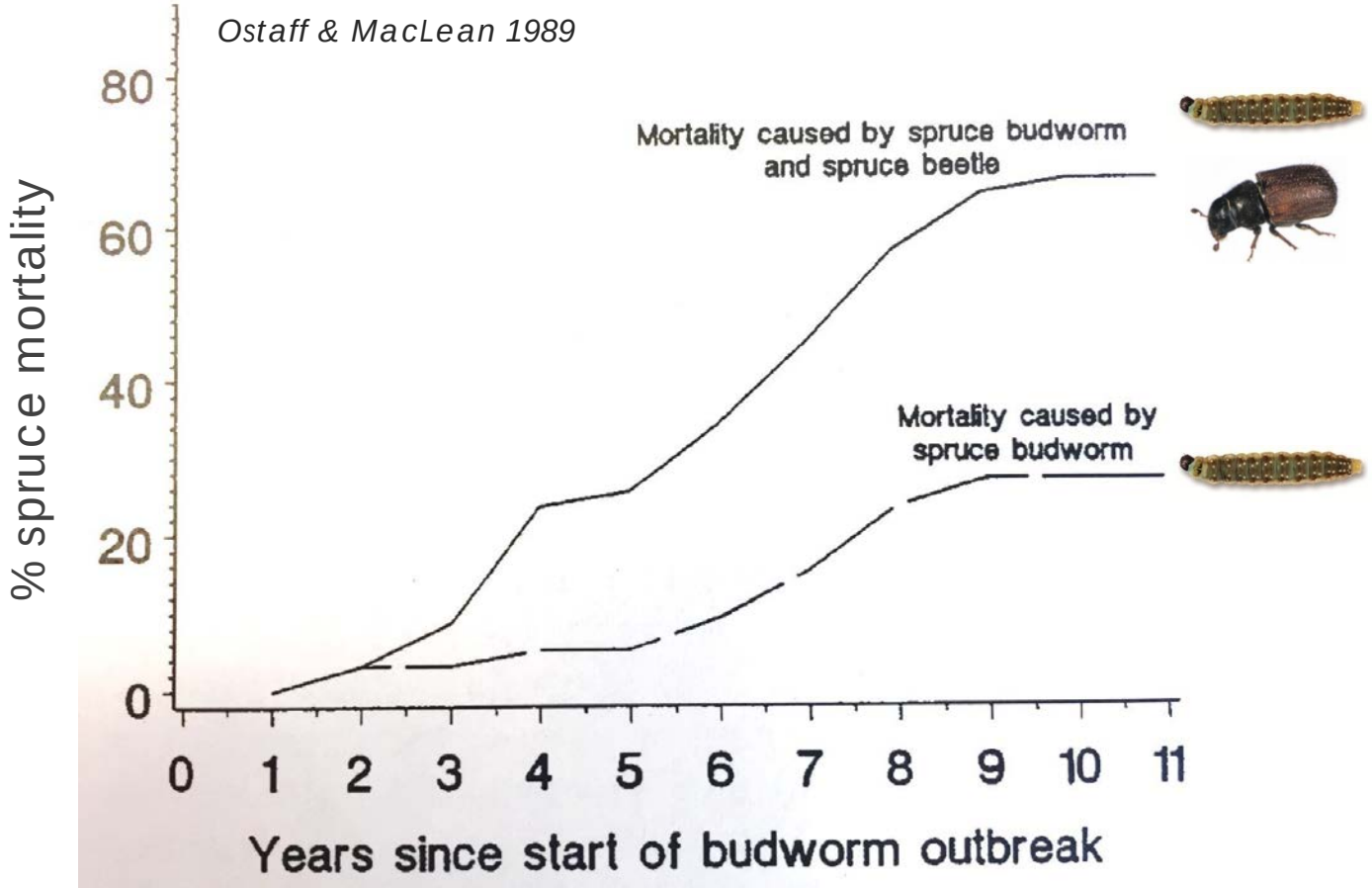
Two stages of white spruce (Picea glauca) apical bud break: (left) stage 4, translucent bud; (right) stage 5, split bud. (Dhont et al. 2010)

- most important native insect pest in forests of eastern Canada
- endemic to epidemic (~10+ years in duration) every ~35 years
- current outbreak in QC has affected >13 million hectares since 2008


Spruce Budworm Defoliation in Canada
1939
Prepared By: Roger Brett and Barry Cooke, NoFC CFS
Last Updated: 06 Sep 2013
Data Sources: Ian DeMerchant, Gurp Thandi, and Wayne McKinnon (CFS), Tim Ebata (BCMoF), Dan Lux (AESRD), Rory McIntosh (SKENV), Laura Gisti (MBCWS), Larry Watkins (ONMNR), and Louis Morneau and Bruno Boulet (MRNQ)
Natural Resources Canada
Ressources naturelles Canada
Canadian Forest Service
Service canadien des forêts

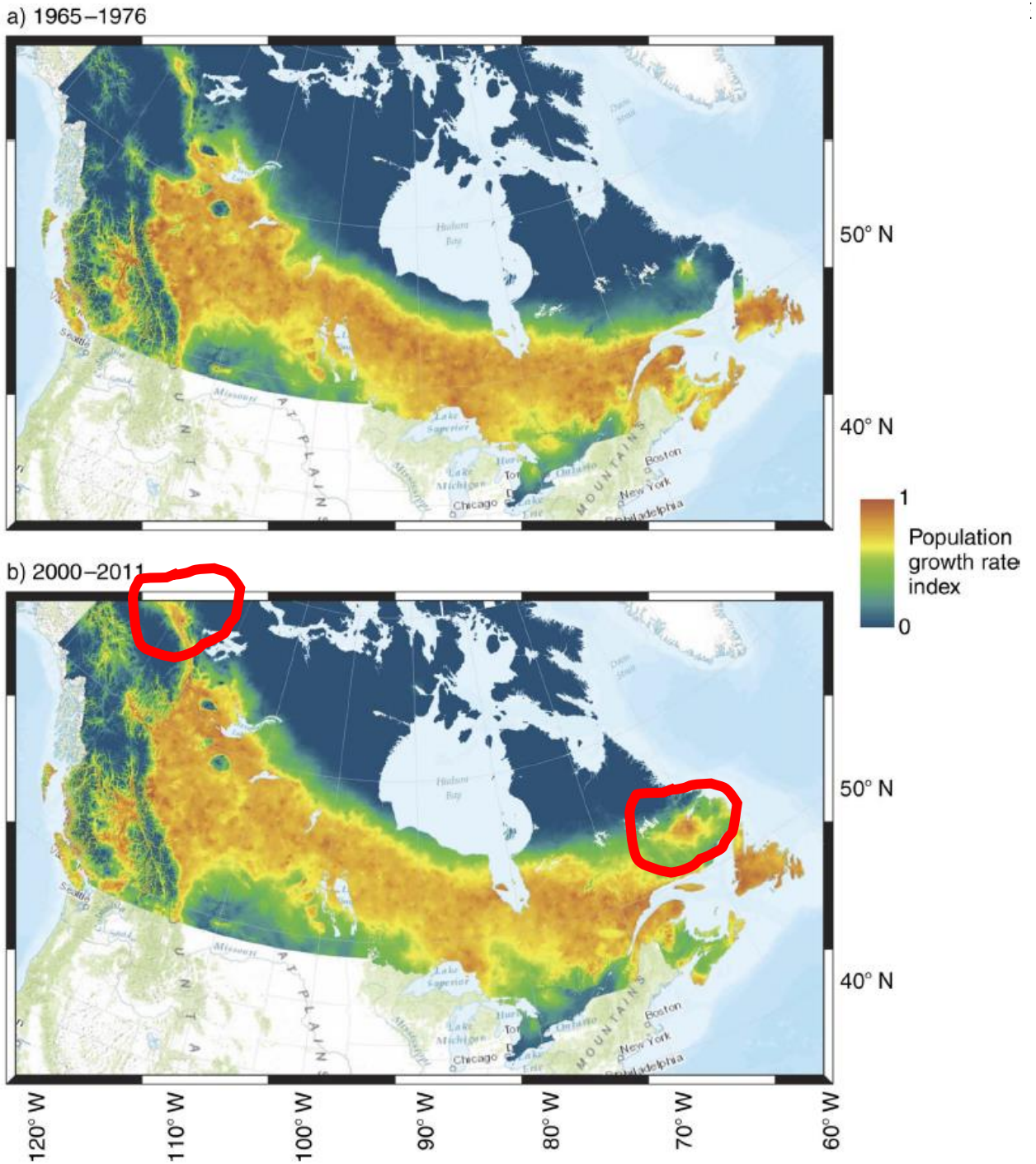
Secondary pests and diseases

Ostaff & MacLean 1989



Are outbreaks shifting north?

- evidence for increased population growth in previously marginal regions
- current outbreak has reached new locations



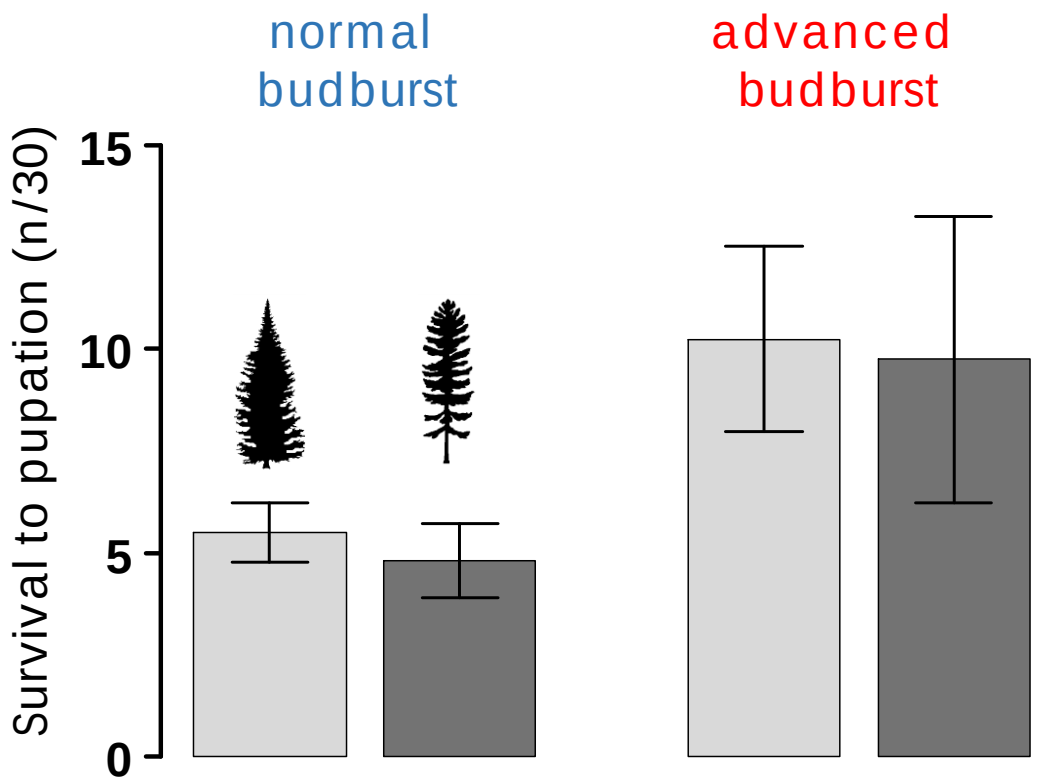
Pureswaran et al. 2015

What are the consequences of phenological asynchrony between insect and host trees?

- some evidence that earlier budburst improves larval performance

- but, greater impact on insect emergence than on host budburst?

- black spruce becoming a better host (e.g. Pureswaran et al. 2019)



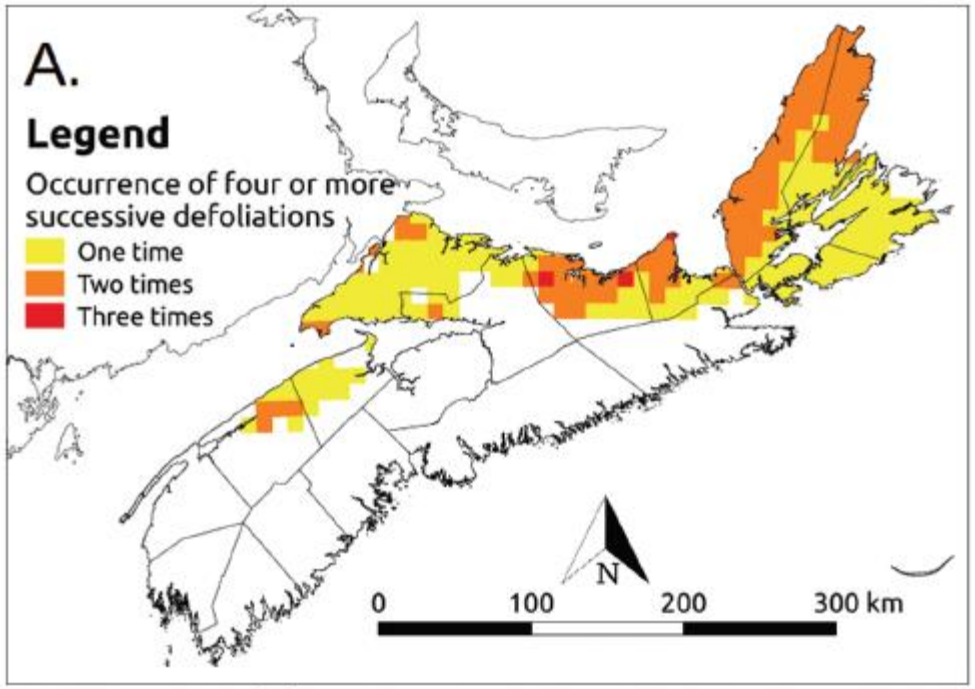
Is the southern range edge less likely to outbreak?

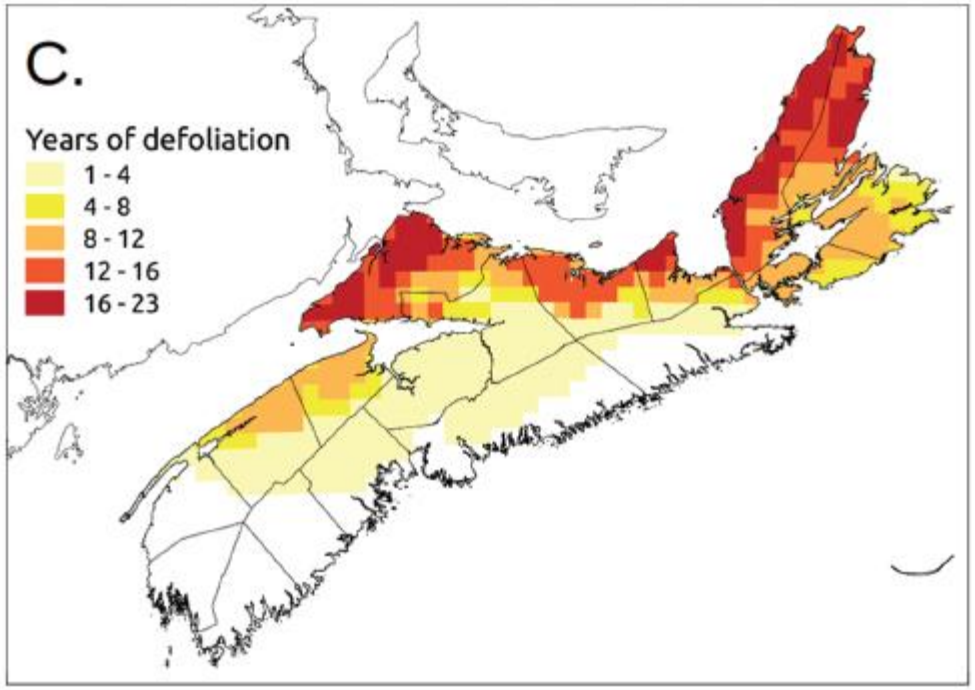
- warmer and more variable fall / winter may be impacting larval overwintering

  → metabolic reserves during diapause

- possible clues from historical outbreaks in Nova Scotia?

Taylor et al. 2020





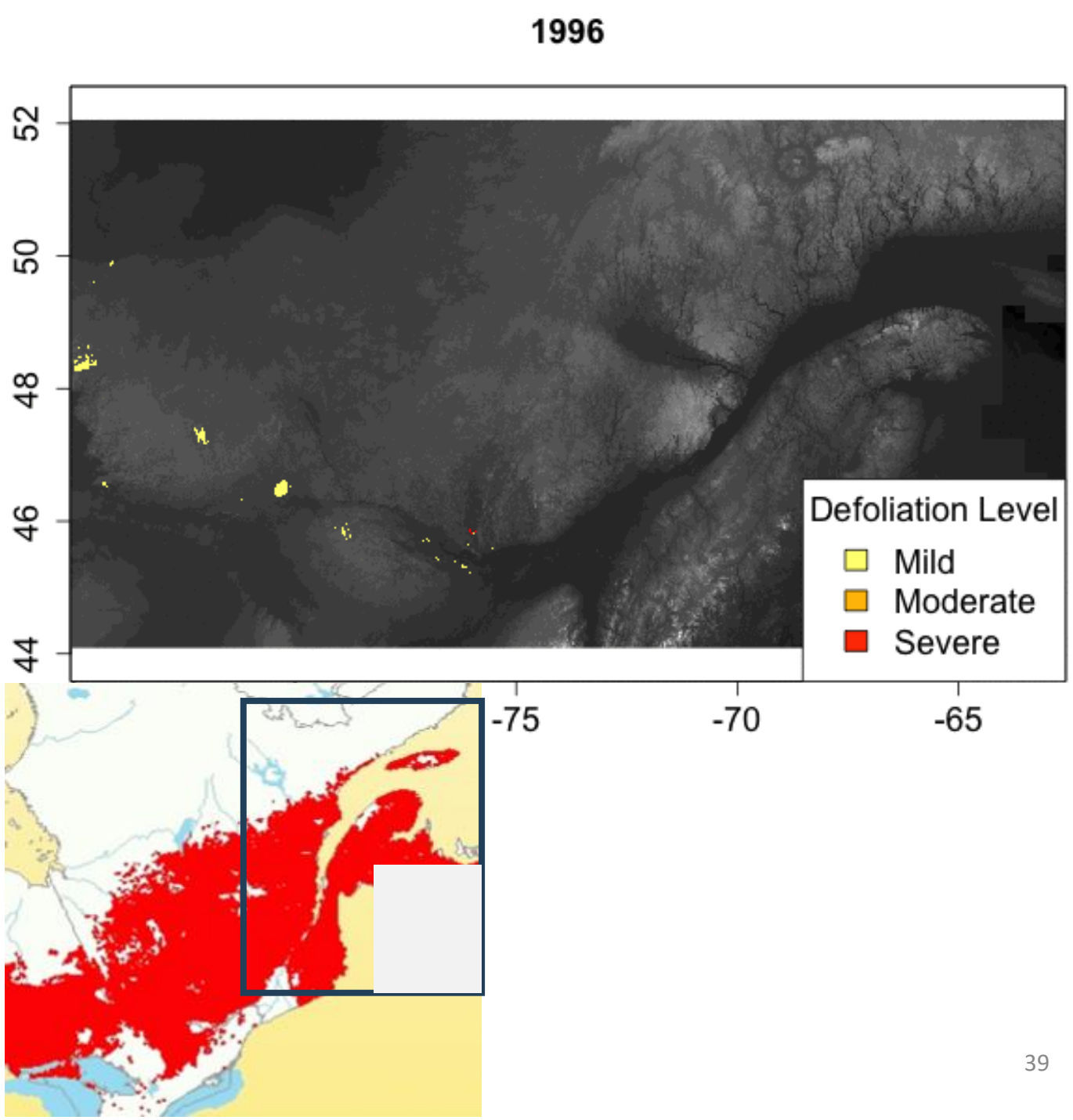
Are magnitude, duration, and frequency of outbreaks changing?

- difficult to attribute to climate change…

  → forests, management are also different…

- large-scale dynamics, dispersal

- new management approach in some areas of eastern Canada



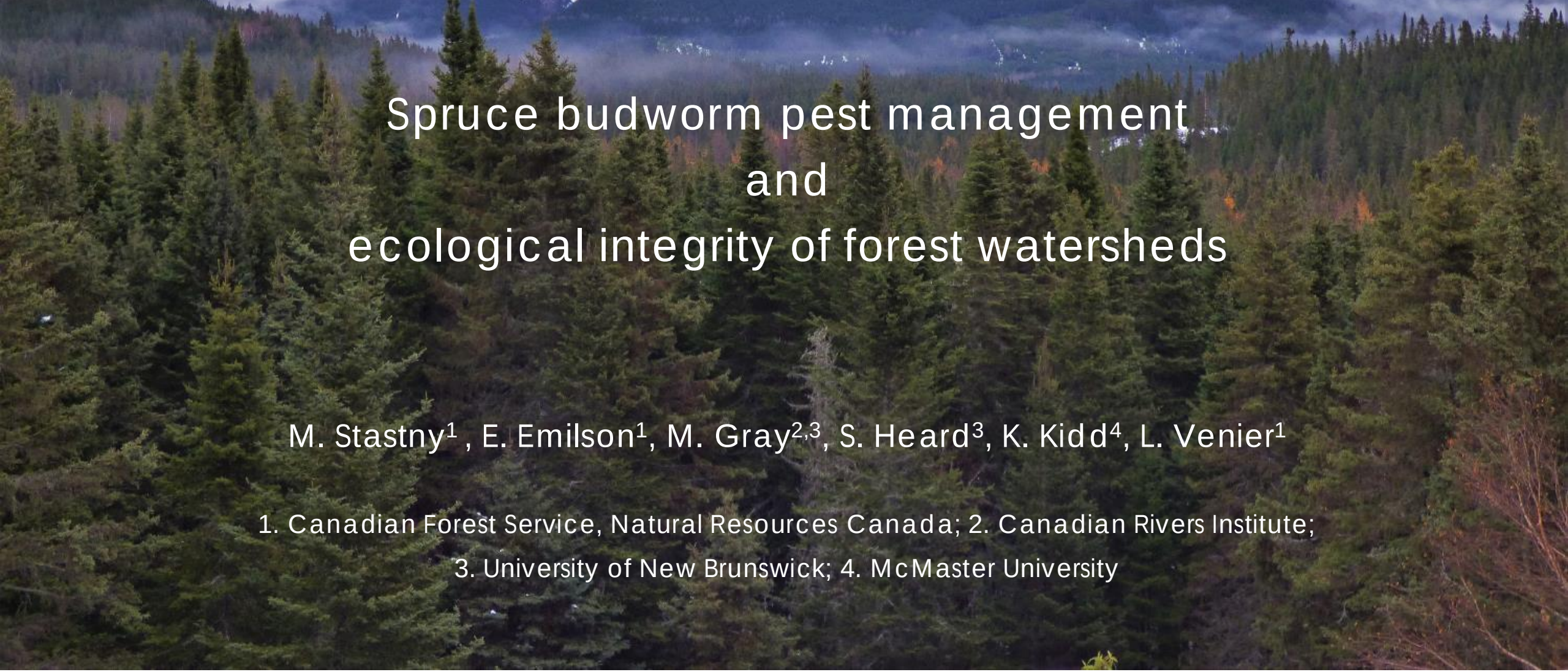
Spruce budworm management: scale & capacity?

Foliage Protection in Quebec, Ontario

versus

Early Intervention Strategy in New Brunswick, Newfoundland

Salvage harvesting following multiple years of moderate to severe defoliation



Spruce budworm pest management and ecological integrity of forest watersheds

M. Stastny[1] , E. Emilson[1], M. Gray[2,3], S. Heard[3], K. Kidd[4], L. Venier[1]

1. Canadian Forest Service, Natural Resources Canada; 2. Canadian Rivers Institute;
3. University of New Brunswick; 4. McMaster University

budworm frass

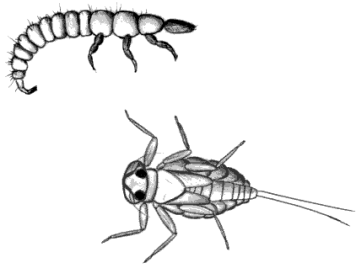
defoliation / needle fall

soil carbon & nutrients

runoff / hydrology

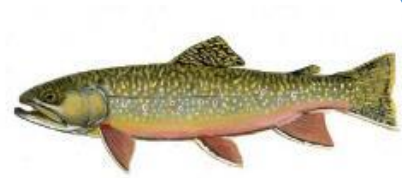
critical forest habitat

water chemistry & nutrients



benthic food webs

stream biofilms & microbes



fish community & diet

IPM PROGRAM EVALUATION

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- **Confirm natural enemy ID**
  - Ecotypes?
  - Symbiont involved?
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  - Differences in habitats, biological communities?
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  - Management considerations?
- **Consider rapid evolutionary change**

ENVIRONMENTAL VARIATION

- **Evaluate climatic similarity**
  - Observed changes in phenology or voltinism?
  - Climate matching modeling?
- **Assess risks under climate change**
  - Impacts on natural enemies?
  - Increasing host stress?
  - Shifts in pest distribution?
  - Novel outbreaks?

CULTURAL CONTEXT

- **Consider outreach and uptake**
  - Implementation routes?
  - Cultural values and biases?
- **Identify stakeholders**
  - Involve social scientists

SCALE AND CAPACITY

- **Evaluate scale of problem**
  - Economic costs?
  - Ecological impacts?
  - Timescale and risks?
- **Evaluate capacity**
  - Resources for implementation?
  - Funding for further research?
  - Existing expertise?
  - Adequate monitoring?
- **Select tactics**
  - Partial adoption? Integration?

REGULATORY CONTEXT

- **Identify differences in legislation**
  - Available tools?
  - Specific constraints?
- **Non-target risks?**

PERIODIC REASSESSMENT