"Natural disturbances, global changes and forest dynamics of boreal ecosystems".

Dan Kneeshaw, Sylvie Gauthier, Yves Bergeron, Frederik Doyon, Frederic Raulier, H. Morin, Louis DeGrandpre, Deepa Pureswaran, B. Harvey, Martin Girardin, Changhui Peng, Alain Leduc & lots of others

Natural disturbances

- The CEF is a leader in research on natural disturbance dynamics and putting them into the context of global changes

- Researchers at the CEF have been active in incorporating this knowledge into forest management

Centre d'étude de la forêt

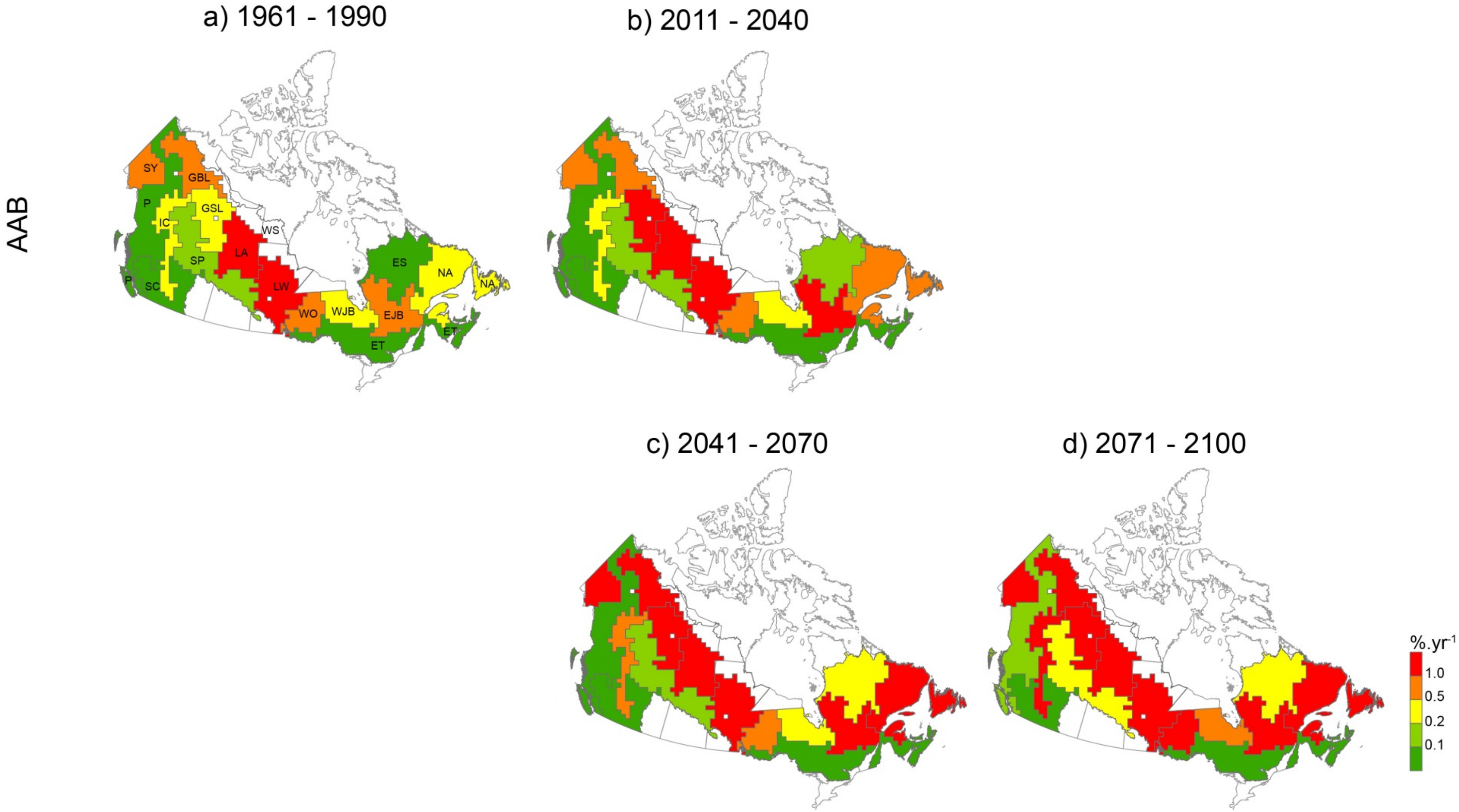
Natural disturbances & the CEF

- Disturbances studied:
- Fire (Gauthier, Bergeron, Girardin and collaborators)
- Insect disturbances (especially spruce budworm – Kneeshaw, DeGrandpre, Pureswaran and collaborators)
- Windthrow (Doyon, Ruel, Kneeshaw and collaborators)
- Gap dynamics (not discussed here)
- Incorporating disturbance risk (Raulier, Leduc et al)

Fire

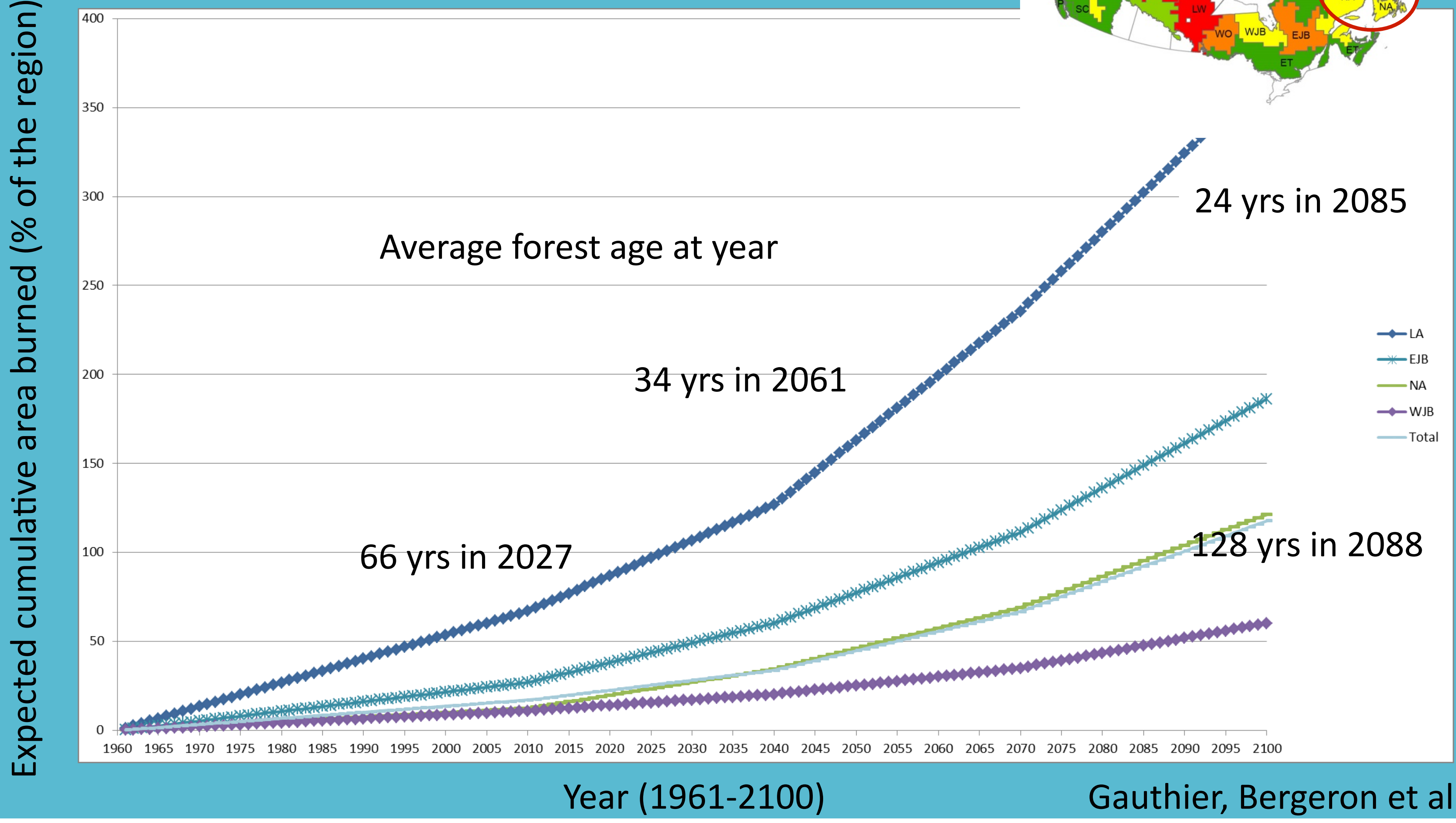
- The following is an example of some recent work from Gauthier, Bergeron & collaborators linking climate change effects on forest management risk

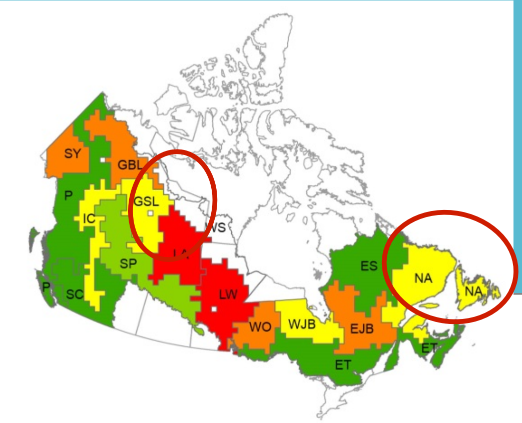
Projected change in area burned



Boulanger, Gauthier, Bergeron et al. submitted

Rate of change by HFR





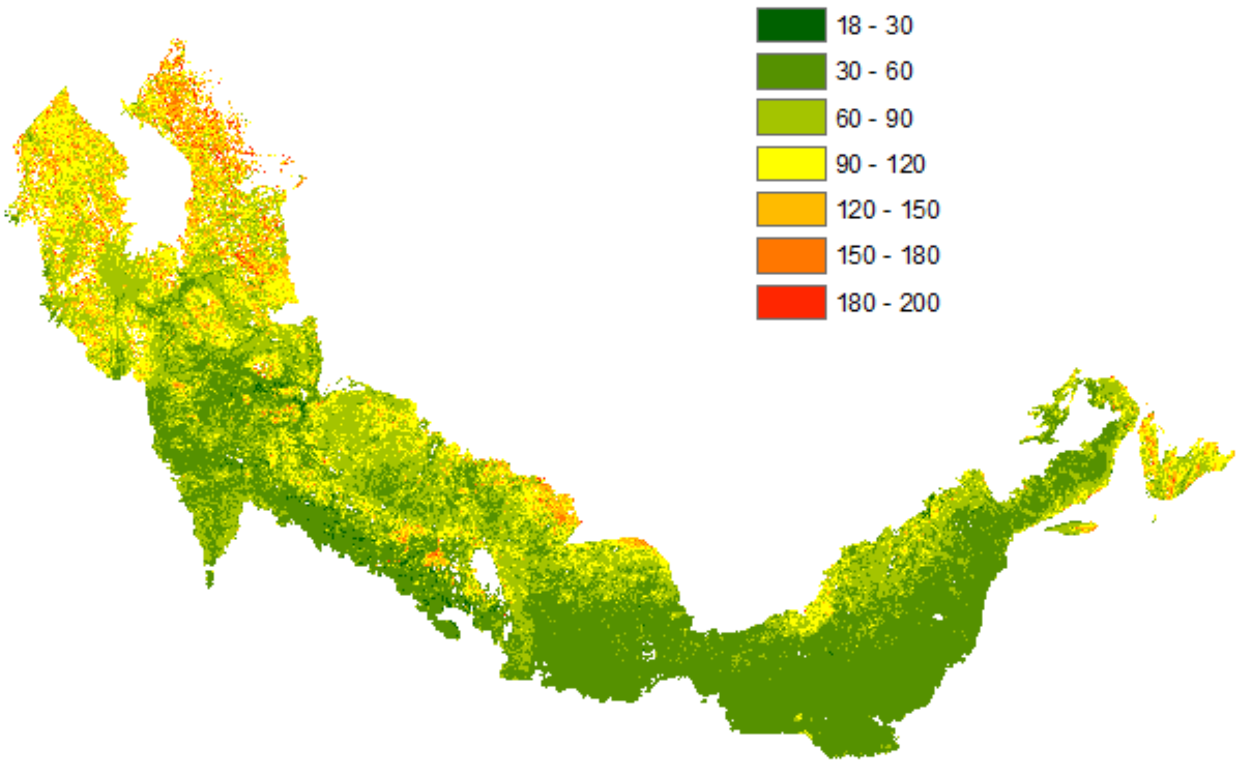
Gauthier, Bergeron et al

Analysis of growth to commercial suitability:

Time to reach 50 m^3/ha of merchantable timber

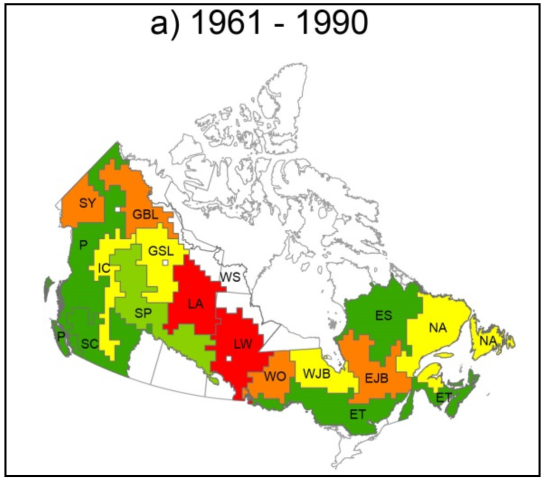
Managed boreal forest only

Units in years



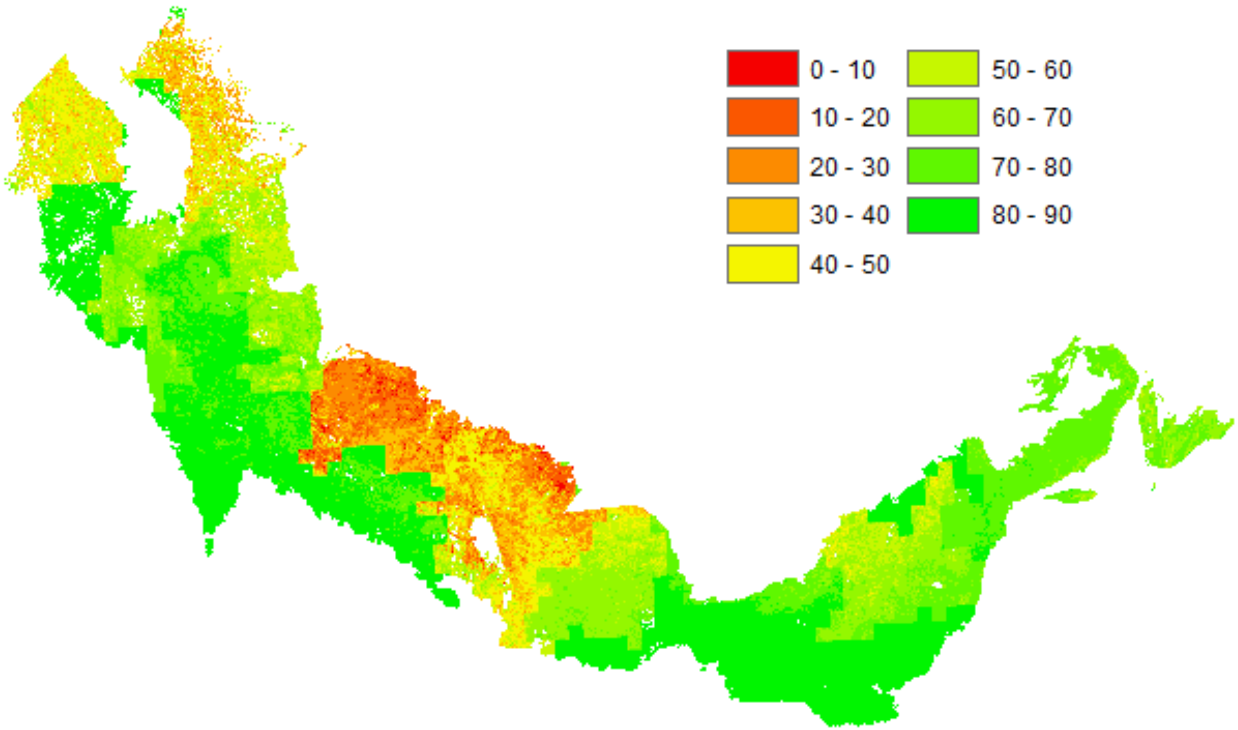
Gauthier, Bergeron et al

Analysis of risk to commercial timber:



Probability of reaching 50 m^3/ha of merchantable timber without burning.

1961-1990 fire regime

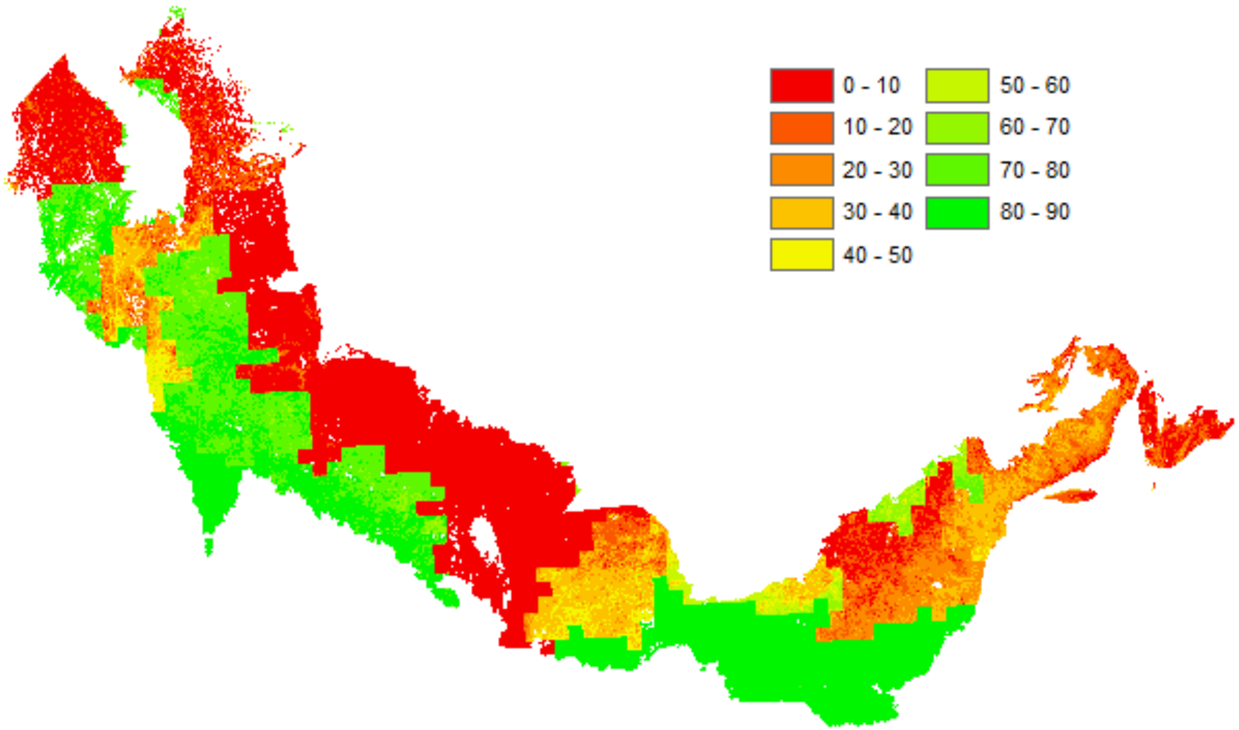


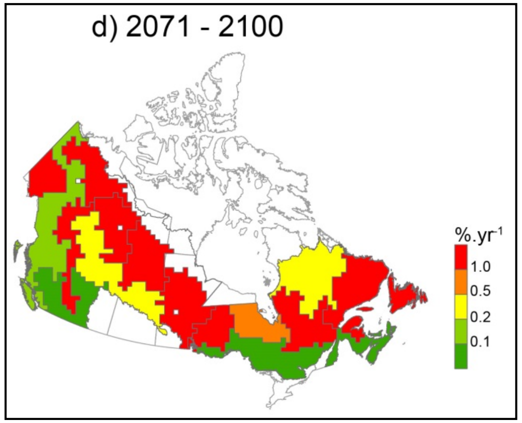
Gauthier, Bergeron et al

Analysis of risk to commercial timber:

Probability of reaching 50 m³/ha of merchantable timber without burning.

2071-2100 fire regime





Gauthier, Bergeron et al

Forest fires

Fire regime changes with climate change

Influence of topography on fires

Emulating fire effects in forest management

Risk analysis in time

Modeling

And much more…..

Gauthier, Bergeron, Girardin, Leduc, Harvey, Raulier, many students and other collaborators

Response of the boreal forest to eastern spruce budworm outbreaks under a changing climate

Deepa Pureswaran, Louis De Grandpré, Dan Kneeshaw, H. Morin and students

Canadian Forest Service
Université du Québec à Montréal

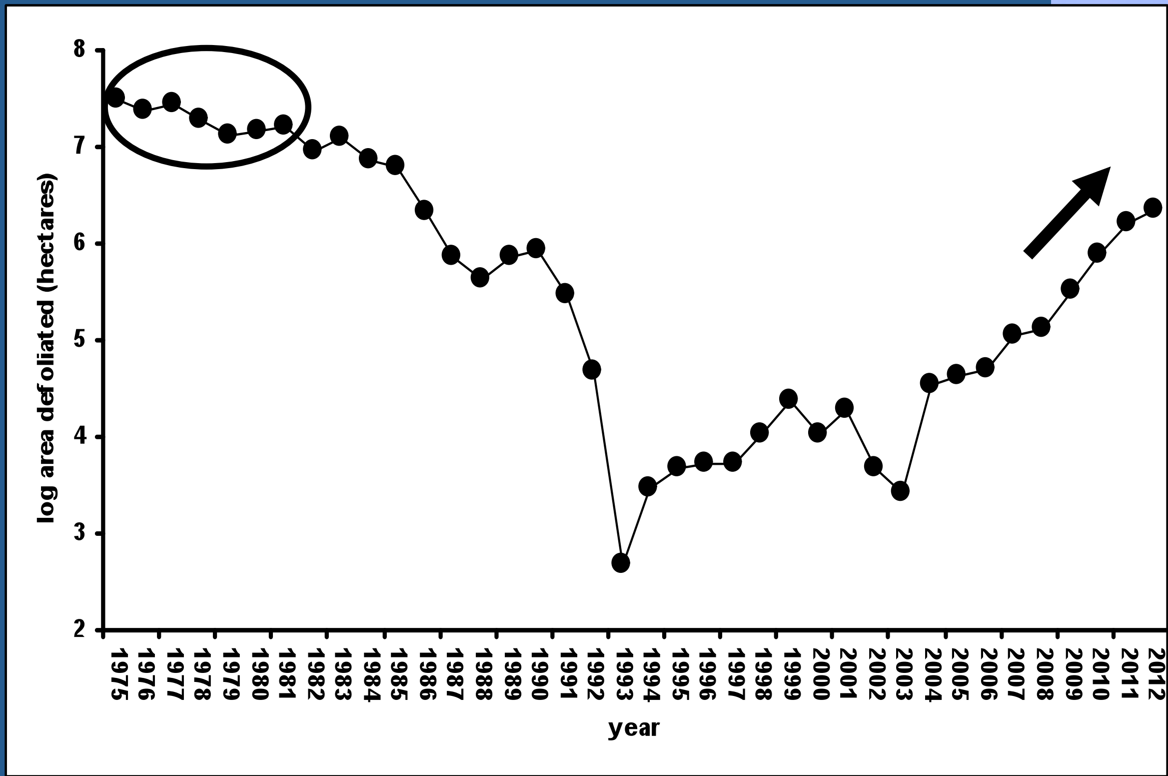
The spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae)

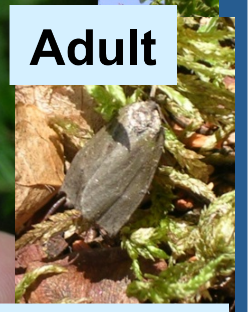
Our changing climate - Impacts on plants and insects

- **Changes in distribution, abundance and phenotypes of species worldwide**
- **Changes in phenology and voltinism in moths and bark beetles**
  - **Sudden rather than gradual**
  - **Adaptation to new host species**
- **Magnitude of insect outbreaks unprecedented in history**

Eastern spruce budworm in Quebec – A growing outbreak!

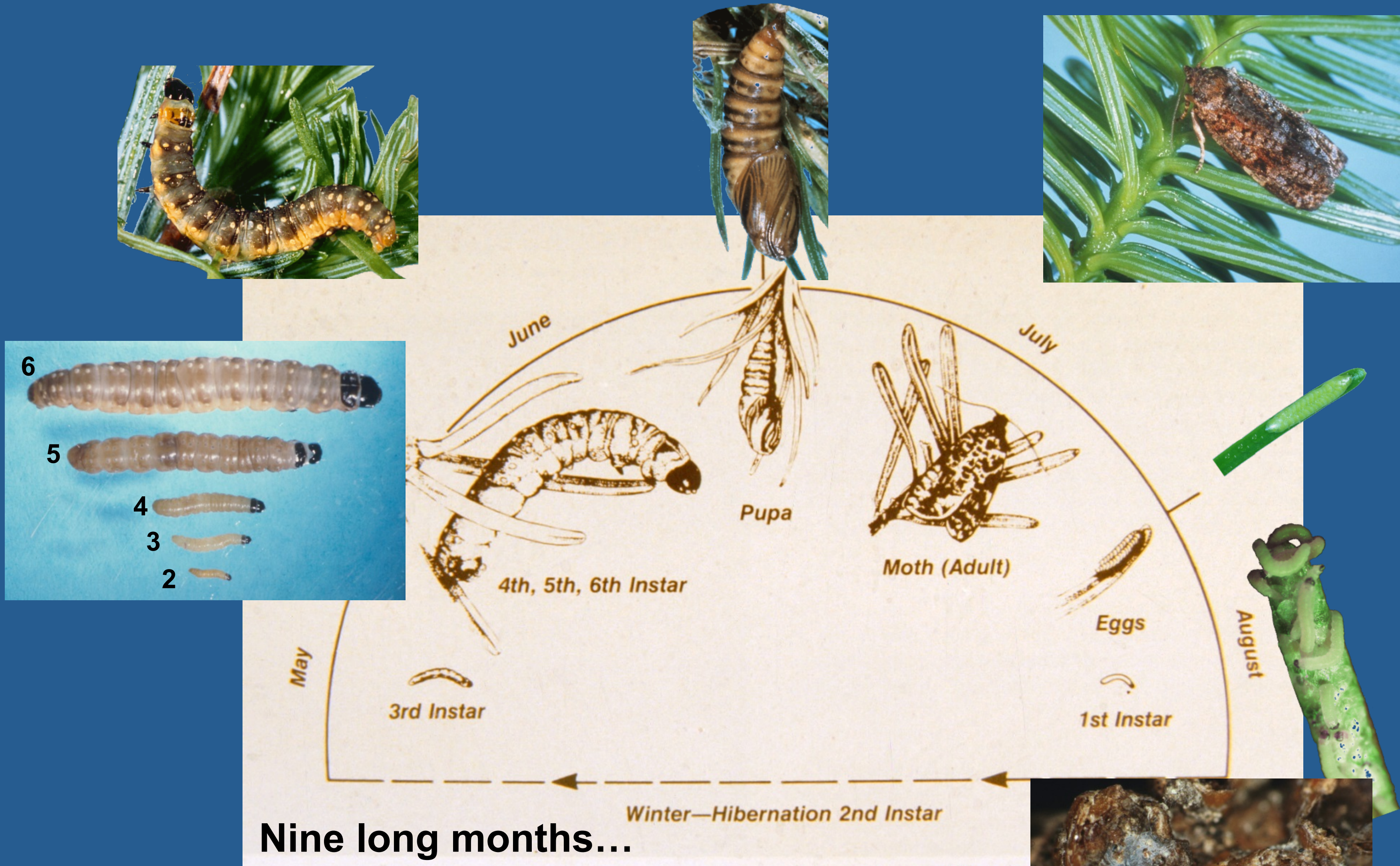
- Rising population in Quebec since 2006





National Forestry Database: http://nfdp.ccfm.org/data/comp_41e.html

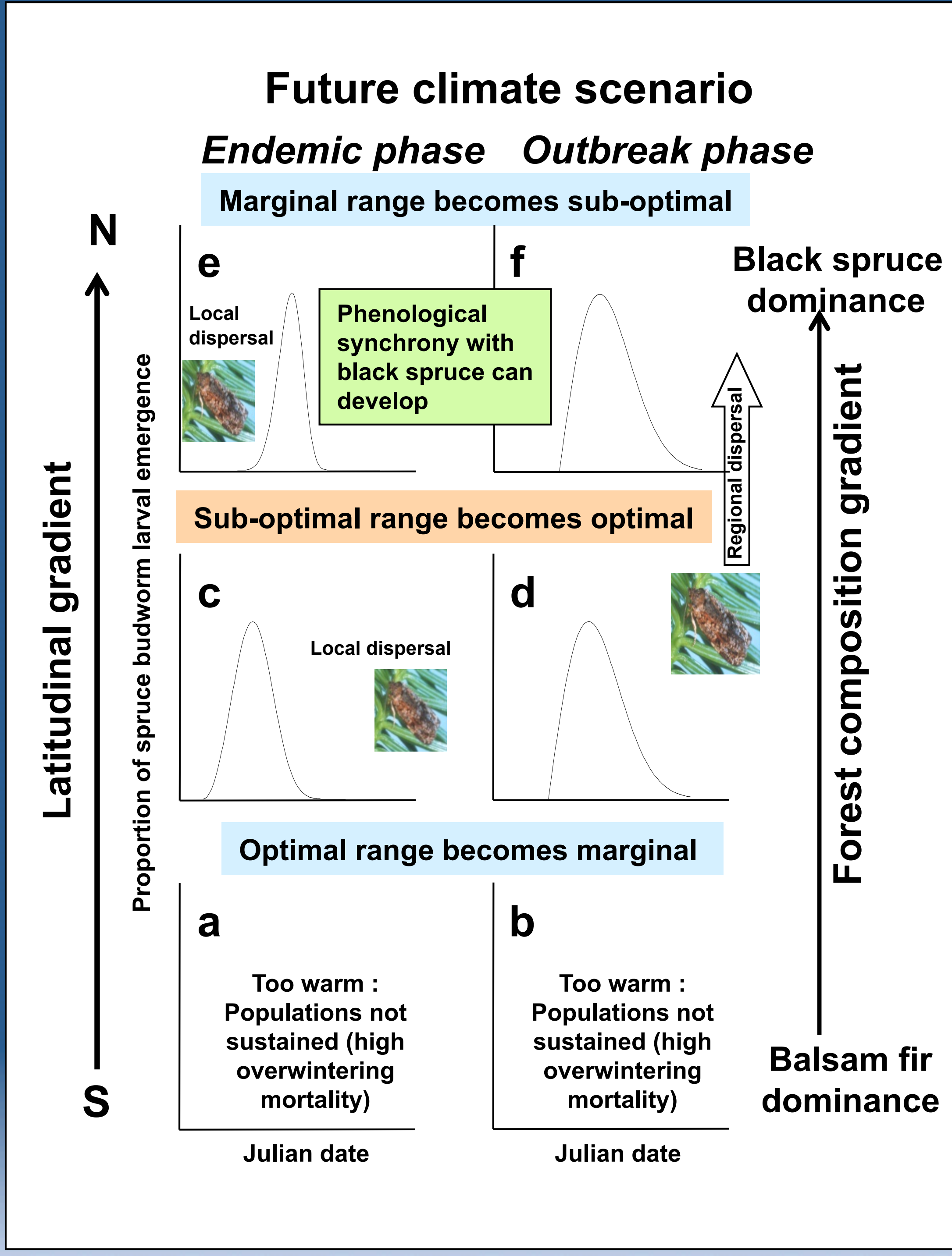
The spruce budworm in eastern Canada



A highly cold-adapted species!

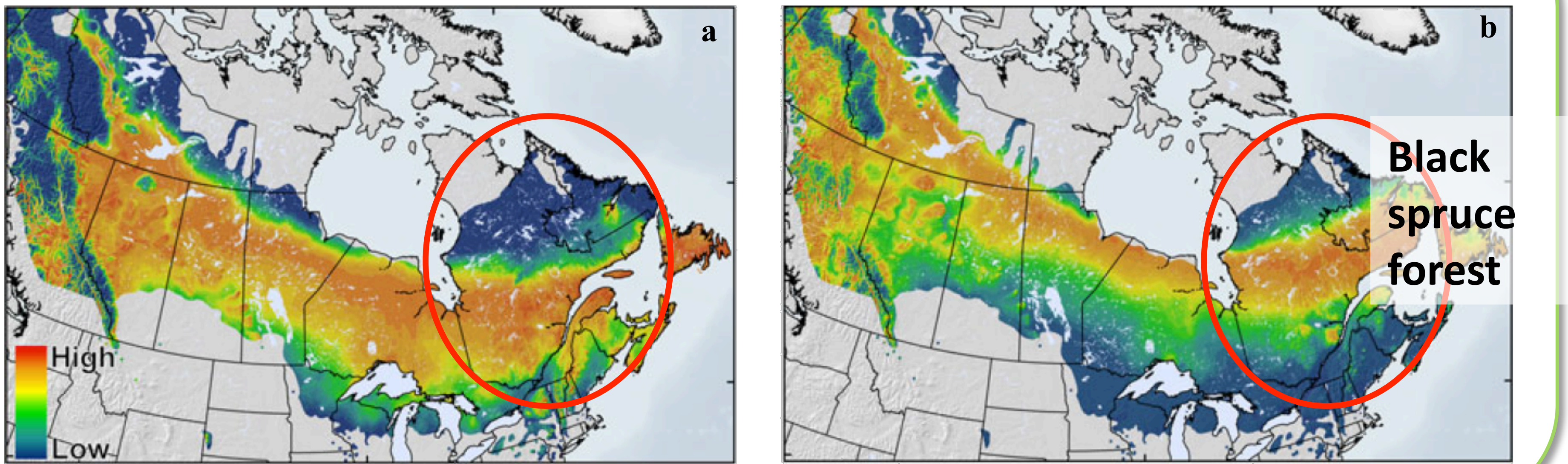
Range shift and outbreak severity in the black spruce zone

- Southern portions of the range would become too warm to sustain high population levels
- Longer summers will make northern latitudes more suitable for completion of life cycle
- Advance in budburst phenology would make black spruce a more suitable host
- Increase defoliation and outbreak severity in the boreal black spruce zone



Maps of potential SBW population growth rate over the distribution of its host plant under different climates

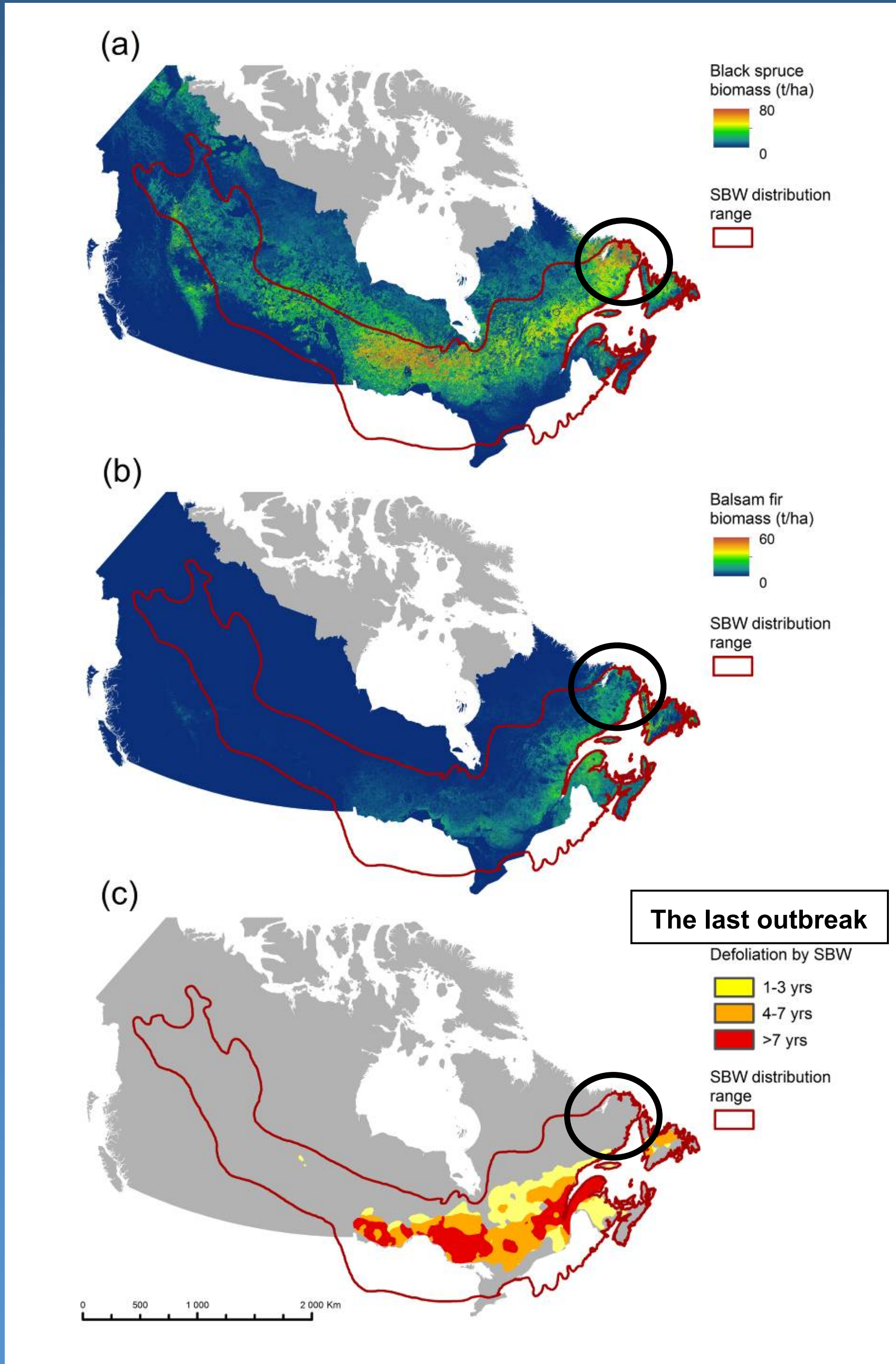
(a) current climate (1971-2000) and (b) future climate (2041-2070)



shift in distribution of the spruce budworm by about 3°N over the next 50 years

Southern forests will be spared but northern forests will now be the new salad bar

(Régnière *et al.* 2010)



Distribution range of host species and spruce budworm

- **Black spruce present across the continent - high densities in the north**
- **Balsam fir is often found mixed with black spruce**
- **Spruce budworm outbreaks have ample potential to shift further north**

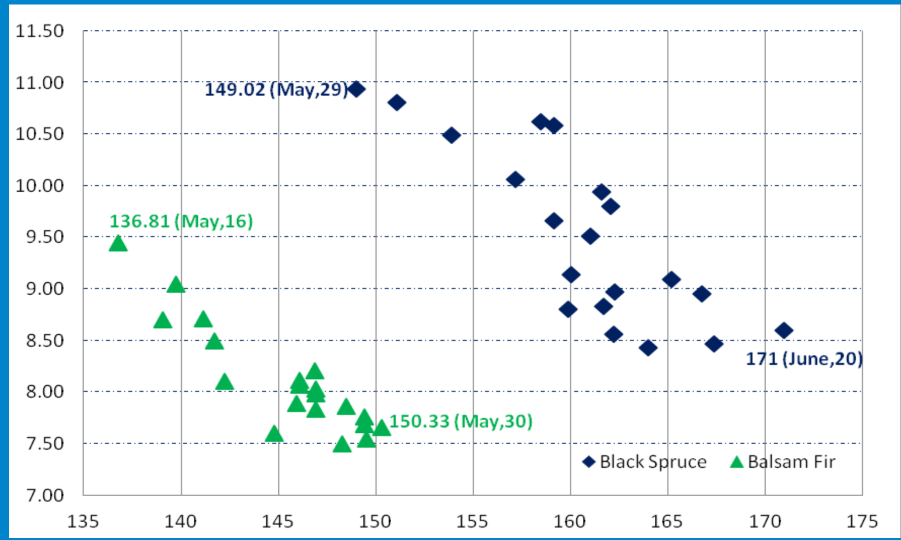
Plasticity in budburst phenology and overwintering larval emergence

- **Budburst phenology = Earlier onset in warmer temperatures**
- **Better phenological synchrony in warmer temperature regimes**

Black spruce can become more suitable with climate warming

Neau, Pureswaran, Kneeeshaw, DeGrandpre

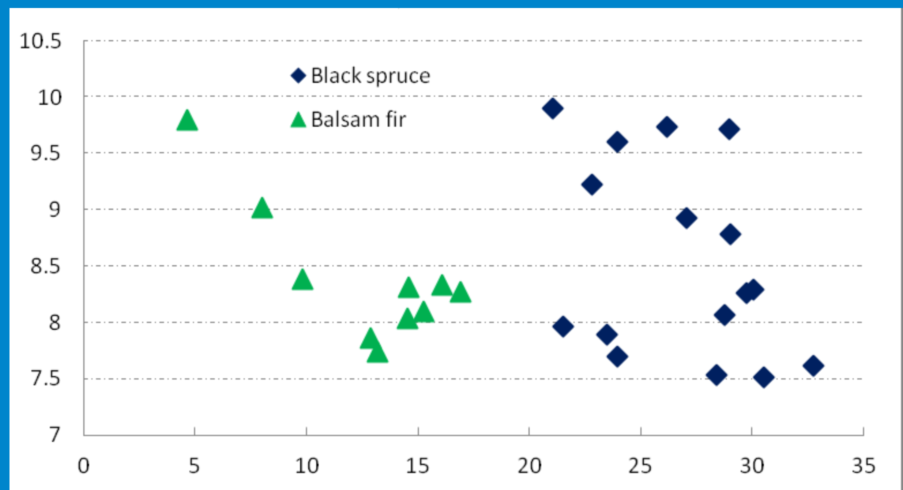
Variation in onset of budburst in relation to temperature



Temperature °C

Julian date

Phenological synchrony (host-budworm) in relation to temperature

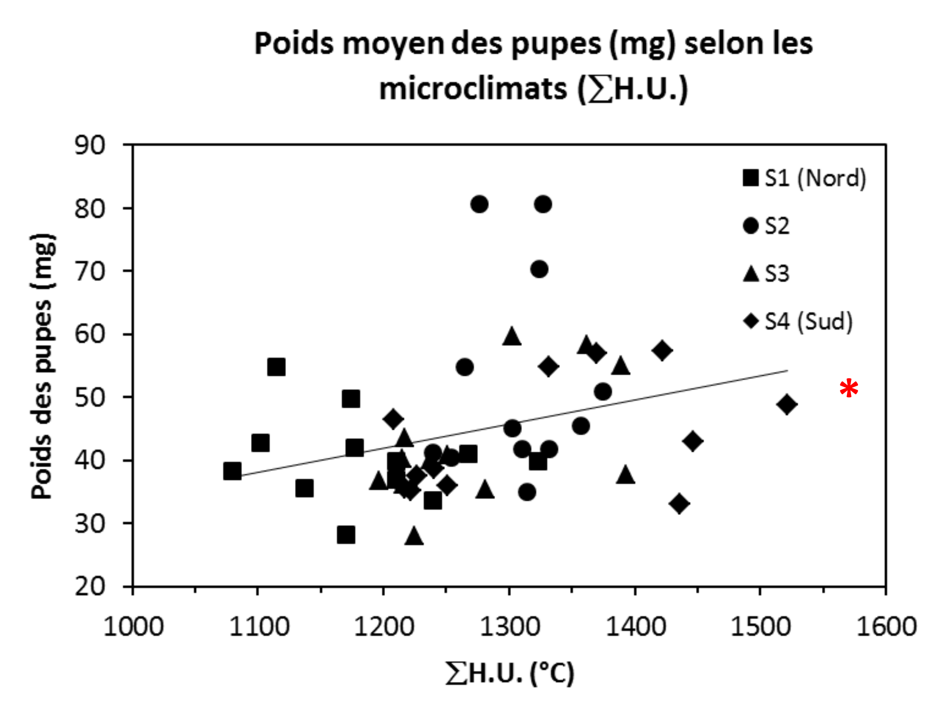


Lag (no. days) between onset of budburst and emergence of overwintering larvae

Pupal weight (as an indication of fitness) in different microclimates

Hypotheses : given that food is available sooner on fir than spruce, pupa should be larger on fir in warmer microclimates.

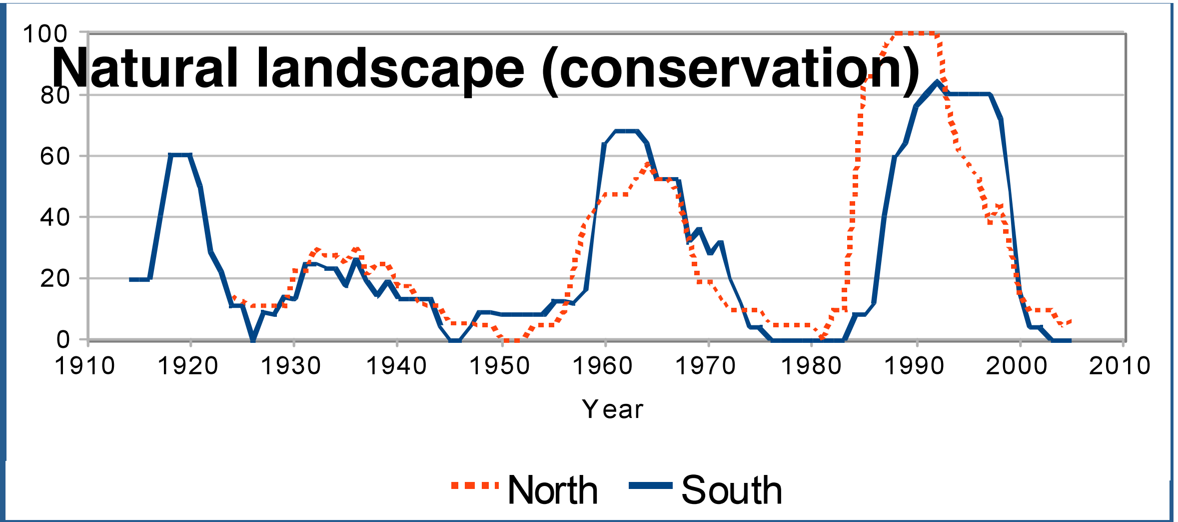
Effet	DDL num.	DDL den.	F-value	P-value
Espèce	1	1	0.5739	0.4528
Température	1	1	4.0963	0.0491*
Espèce*Température	1	1	0.6627	0.4200

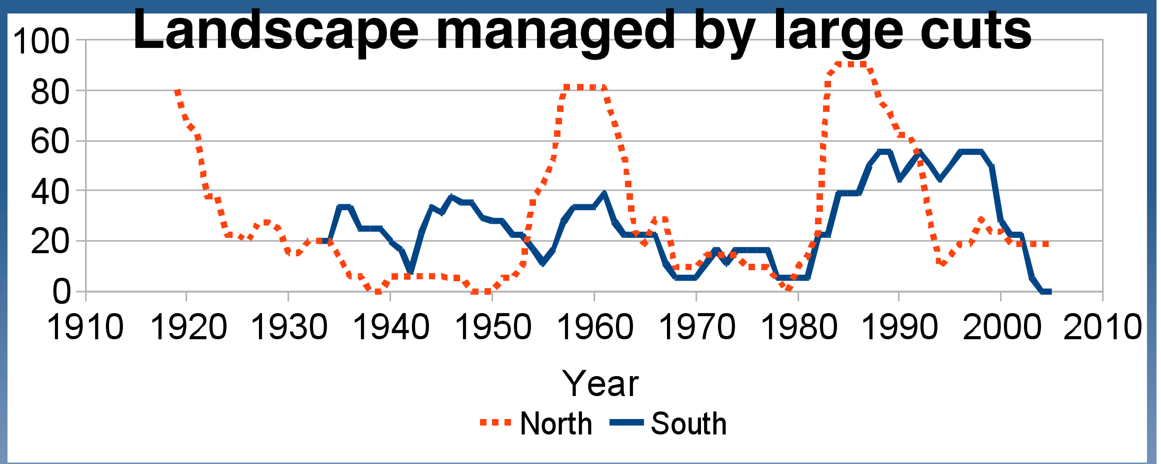


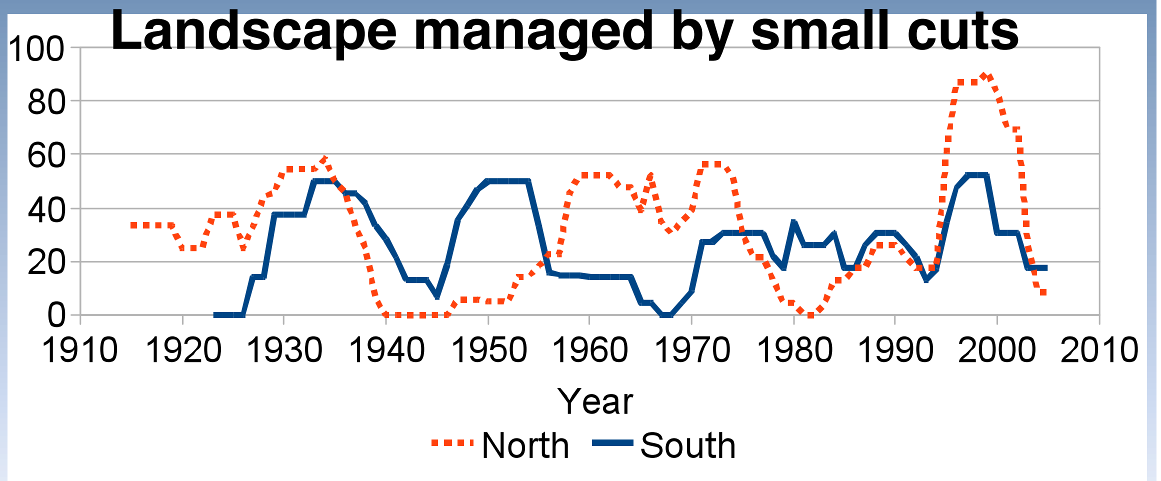
⇒ Pupal weight is influenced only by temperature and not by species.

⇒ Weight increases at sites with higher heat accumulation (H.U.)

Forest management at the landscape scale affects SBW outbreaks







Landscape

Natural Coarse Fine

Synchronous ⟶ Asynchronous

High Severity ⟶ Low severity

Not frequent ⟶ More frequent

Long duration ⟶ Short duration

Robert et al. 2012 CJFR

Take home messages –

- Evidence for advance in budburst phenology of balsam fir and black spruce in warm microclimates
- Better phenological synchrony with black spruce in warmer microclimates
- Persistence of spruce budworm and increased outbreak severity in boreal black spruce is a new disturbance regime
- Landscape level modifications to the forest affect insect outbreaks
- Plus research on effects on biodiversity, effects of salvage logging, harvest scheduling, protection etc

Caracterising windthrow and extreme winds

Edith Bégin
Frédérik Doyon, P. Nolet (UQO, IQAFF),
Daniel Kneeshaw (UQAM)
JC Ruel (U Laval)

UQÀM
INSTITUT QUÉBÉCOIS D'AMÉNAGEMENT DE LA FORÊT FEUILLUE
Université du Québec en Outaouais

Introduction

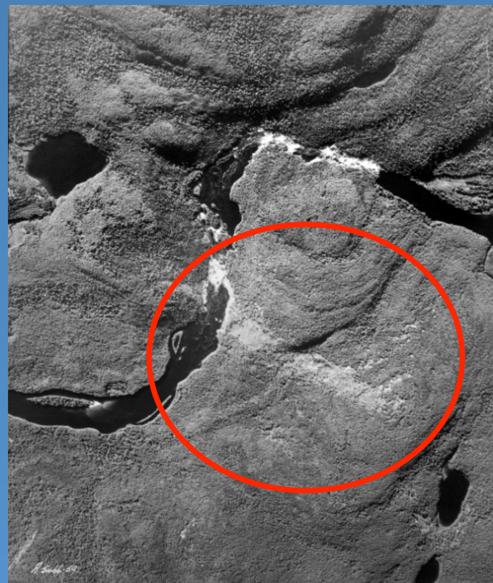
Windthrow

Snapping

Uprooting

Stand level

Landscape level



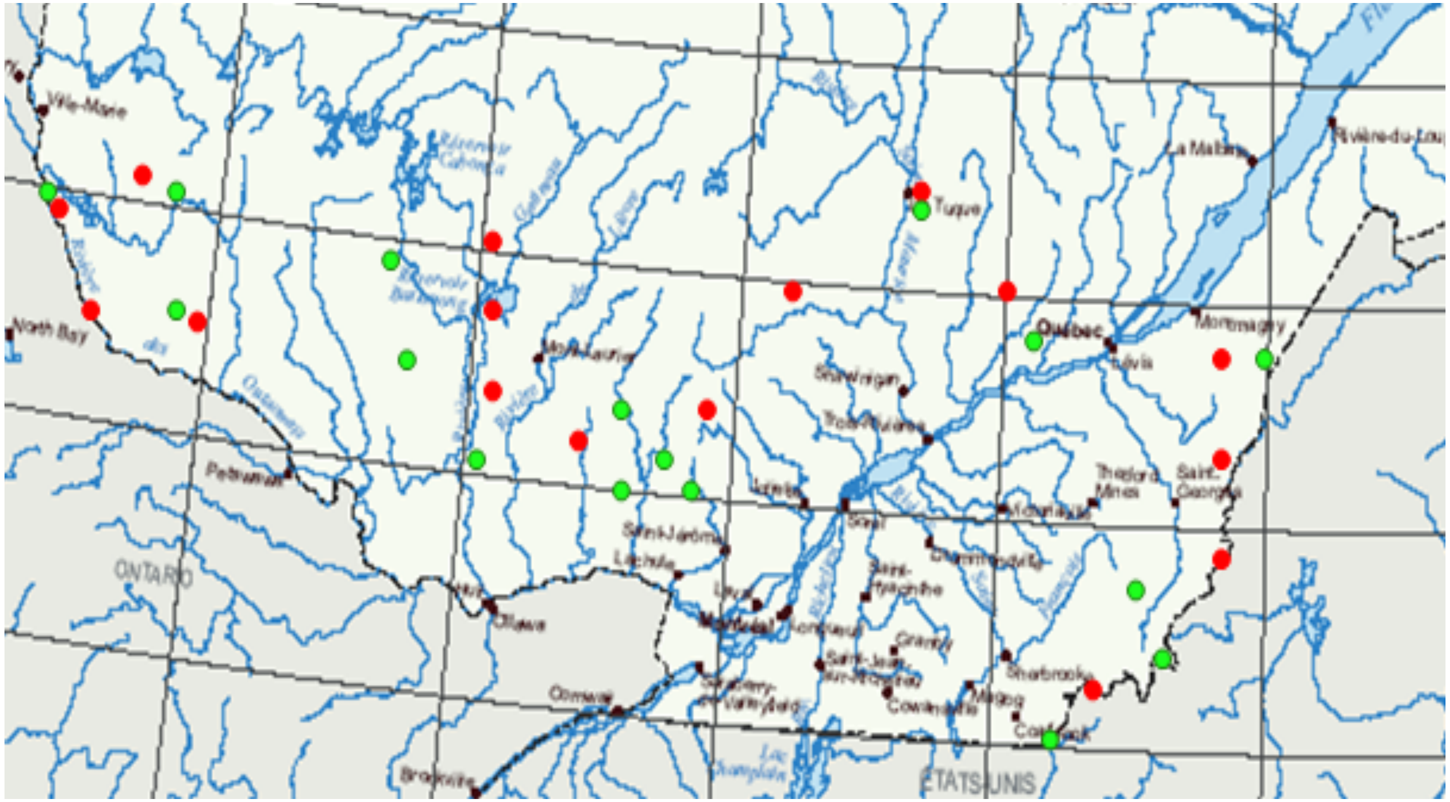
Begin, Doyon, Kneeshaw

Principal Objective

Caracterise windthrows and evaluate the role of meteorological events

Begin, Doyon, Kneeshaw

4 160 km2 landscapes sampled over four decades

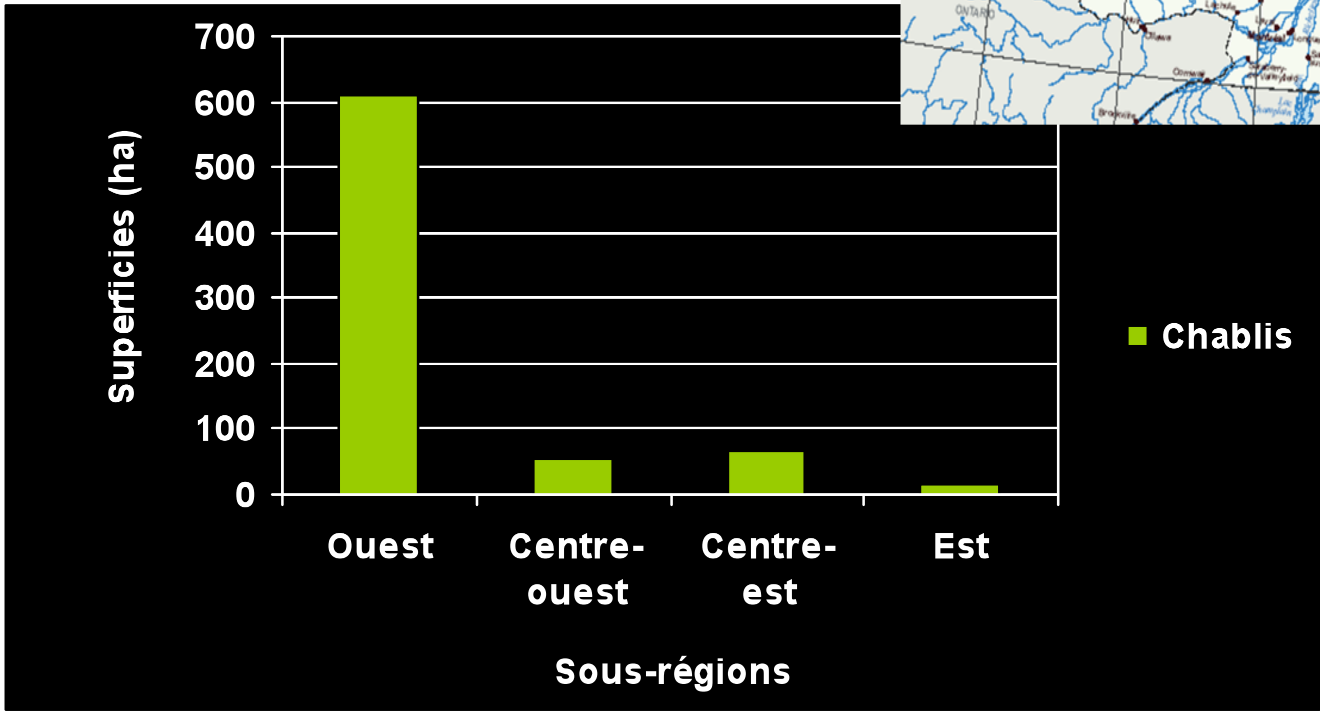


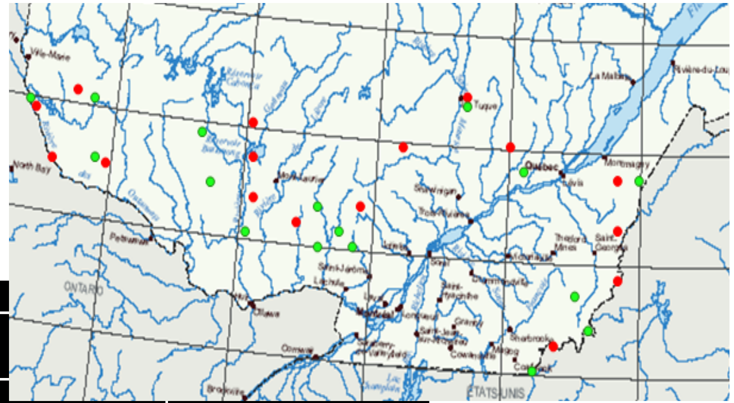
1926-1936 & 1970-1980

1945-1955 &2000-2009

Begin, Doyon, Kneeshaw

Results - area of windthrow



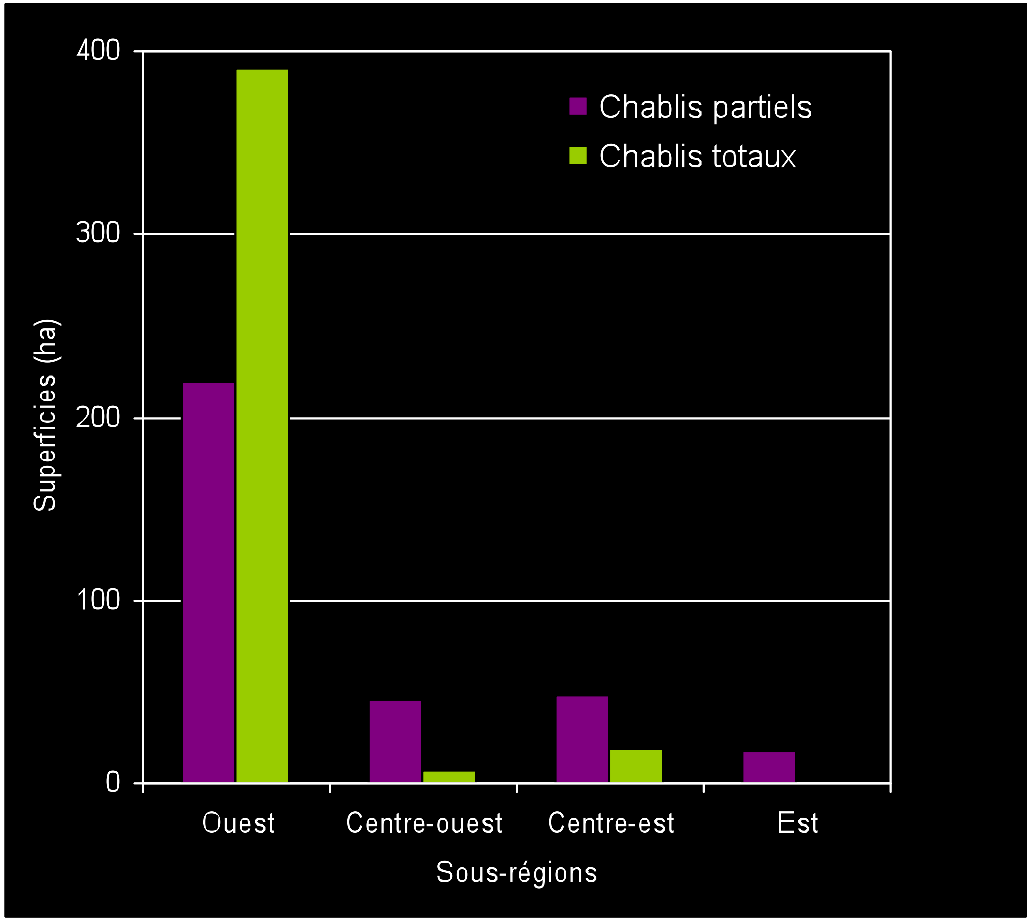


Little windthrow in eastern part of study area most in western Quebec

possible cause → **importance of downbursts**

Begin, Doyon, Kneeshaw

Windthrow severity (partial vs total)

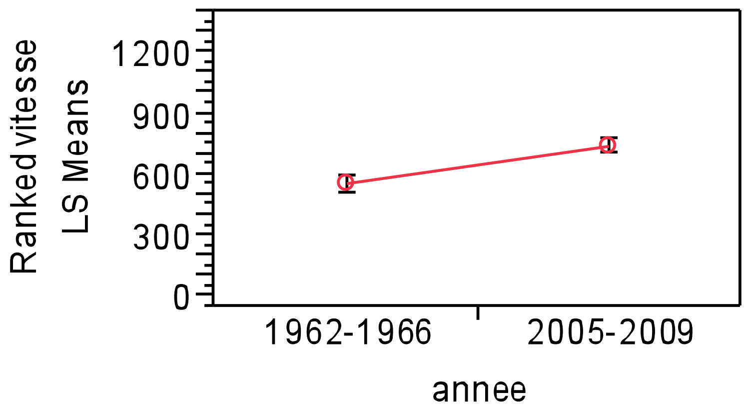


All windthrow severities greater in Western Quebec

Begin, Doyon, Kneeshaw

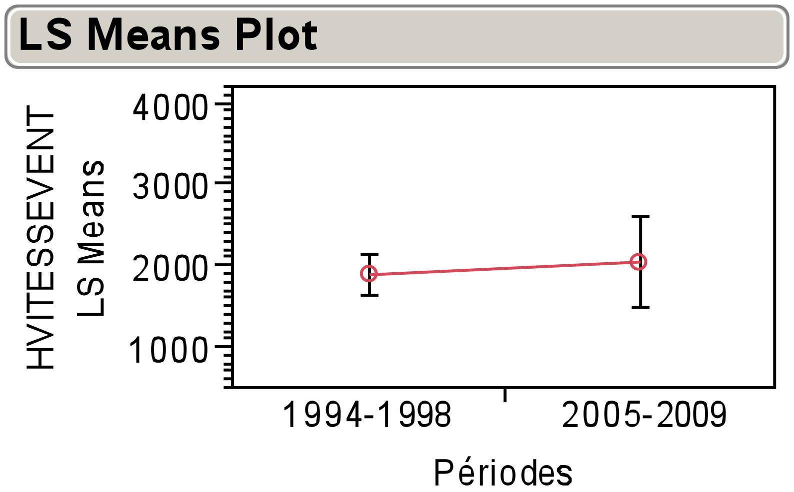
Moderate to extreme windspeeds

Increase of moderate winds of 10.1 %



Prob>F = <0.0001

Increase of extreme winds = 8.3%



Prob>F = 0.6139

Begin, Doyon, Kneeshaw

Windthrow return intervals

Period	Sub-regions			
	West	Centre-west	Centre-east	East
1926-1936	129 737	n.d.	33 706	n.d.
1945-1955	111 986	152 182	n.d.	n.d.
1970-1980	7822	57 684	n.d.	n.d.
2000-2009	1731	17 856	20 505	48 488
All periods	5387	62 297	50 528	1 99 012

Conclusion

- Windthrow hard to predict
- Number of windthrows has increased over the last century
- Windthrow greater in continental climates in western Qc
- Since 1970, windthrows cause more damage in terms of severity and areas affected

Begin, Doyon, Kneeshaw

Windthrow
- Risk Factors

- Stands
  - Composition: Hemlock, Shade-Intolerant hardwoods, Spruces, Fir
  - Age Classes: 50, 70, 90
  - Dense & tall
- Sites
  - Surficial soil deposit: R1A, 1AM, 1AY, (moyen et minces)
  - Decrease with altitude
  - Steep slope
- Context
  - Topex:
  - Region: gradient east to west

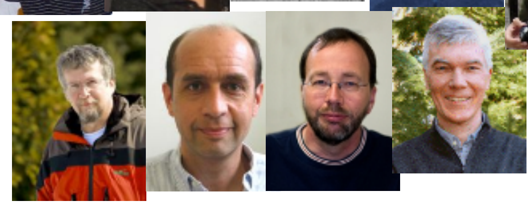
Doyon, Nolet et al

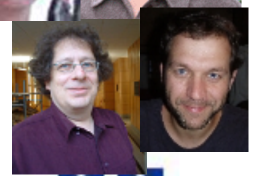
Gap dynamics

- Increased senescence (i.e. due to increased drought & tree stress (C. Peng)
- Changes across landscapes (Kneeshaw, Bergeron, etc)

Managing risk factors for AAC calculations

Raulier and many others





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Fonds de recherche sur la nature et les technologies Québec

Research Context

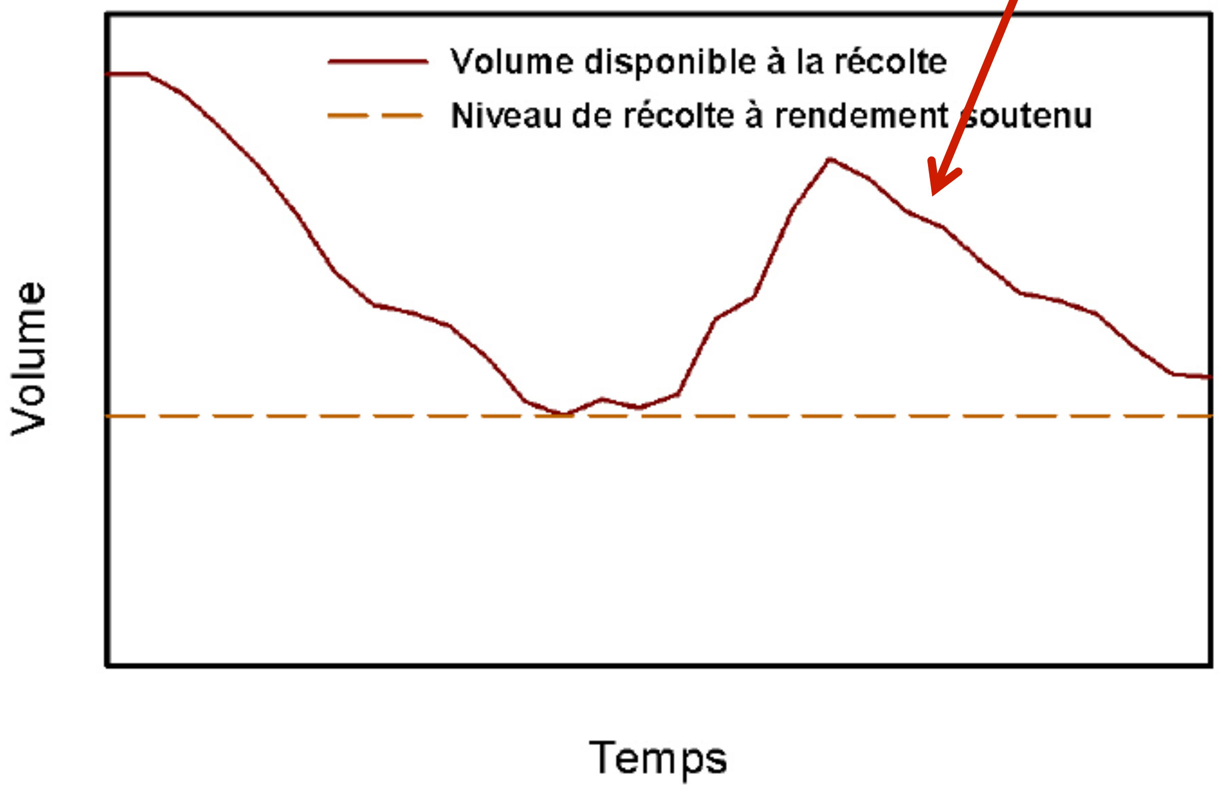
Models to calculate AAC are deterministic:

- The future is treated as certain (i.e. predictable)

Raulier et al

Research Context Sustainability= Sustained Yield (2018)

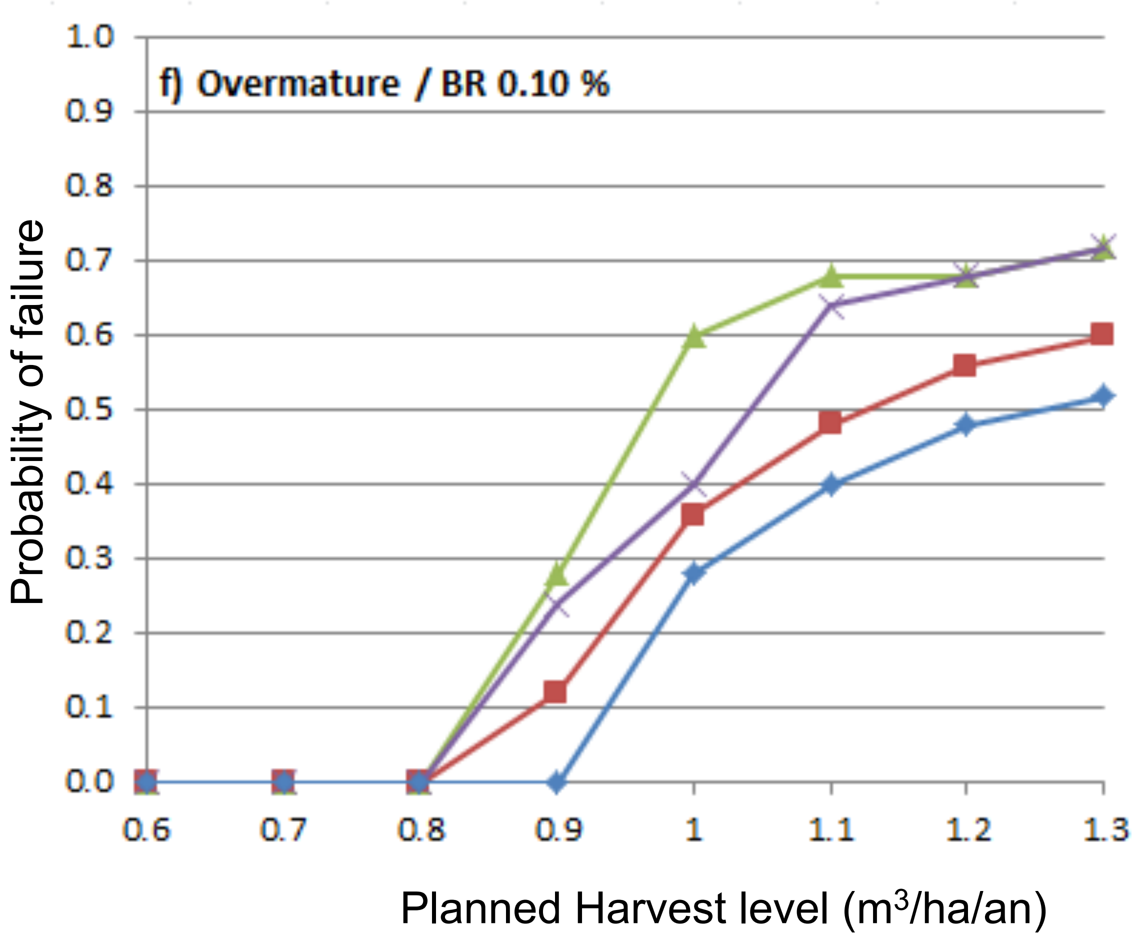
No estimation of uncertainty

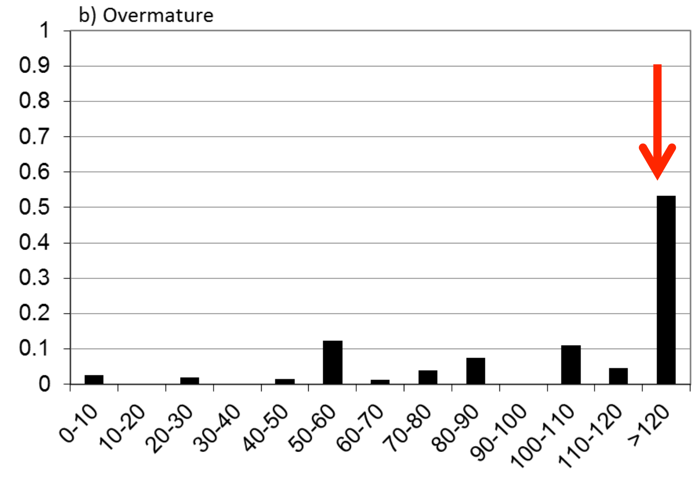


http://forestierenchef.gouv.qc.ca/

Salvage and tolerance

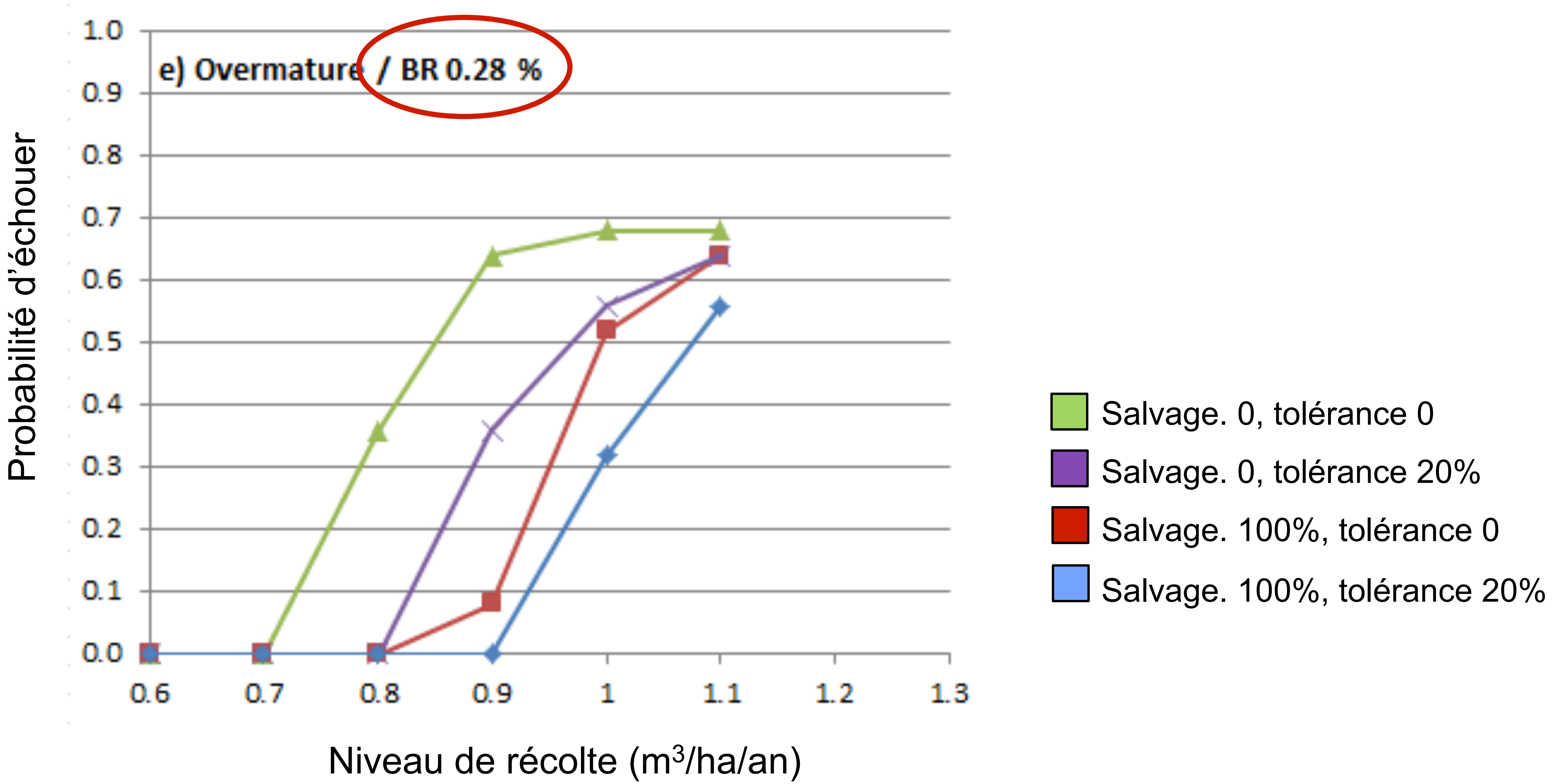
Black spruce average productivity





Leduc, Raulier, Gauthier et al

R1 – Salvage and tolerance



Leduc, Raulier, Gauthier et al

CEF, Natural disturbances and Forest management

Knowledge development on different disturbances regimes

Evaluations and predictions on how global change (in this presentation mostly climate change) affect disturbance regimes

Early work on emulating natural disturbance, now also includes work on interaction of natural disturbances, global change and forest management risk factors & thus possible mitigations

CEF, Natural disturbances and Forest management

Tests of different management approaches (TRIADE – Messier et al), 3 cohort (Bergeron, Harvey, et al)

Modeling biocomplexity, resilience etc (Messier, Munson, etc)

And effects on other processes and organisms ….