CLIMATE WARMING REDUCES BLACK SPRUCE GROWTH DURING A SPRUCE BUDWORM OUTBREAK PERIOD

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Context

Climate change:

- Widespread effects on forest ecosystems worldwide
- Alters the disturbance regimes of forest

Natural disturbances:

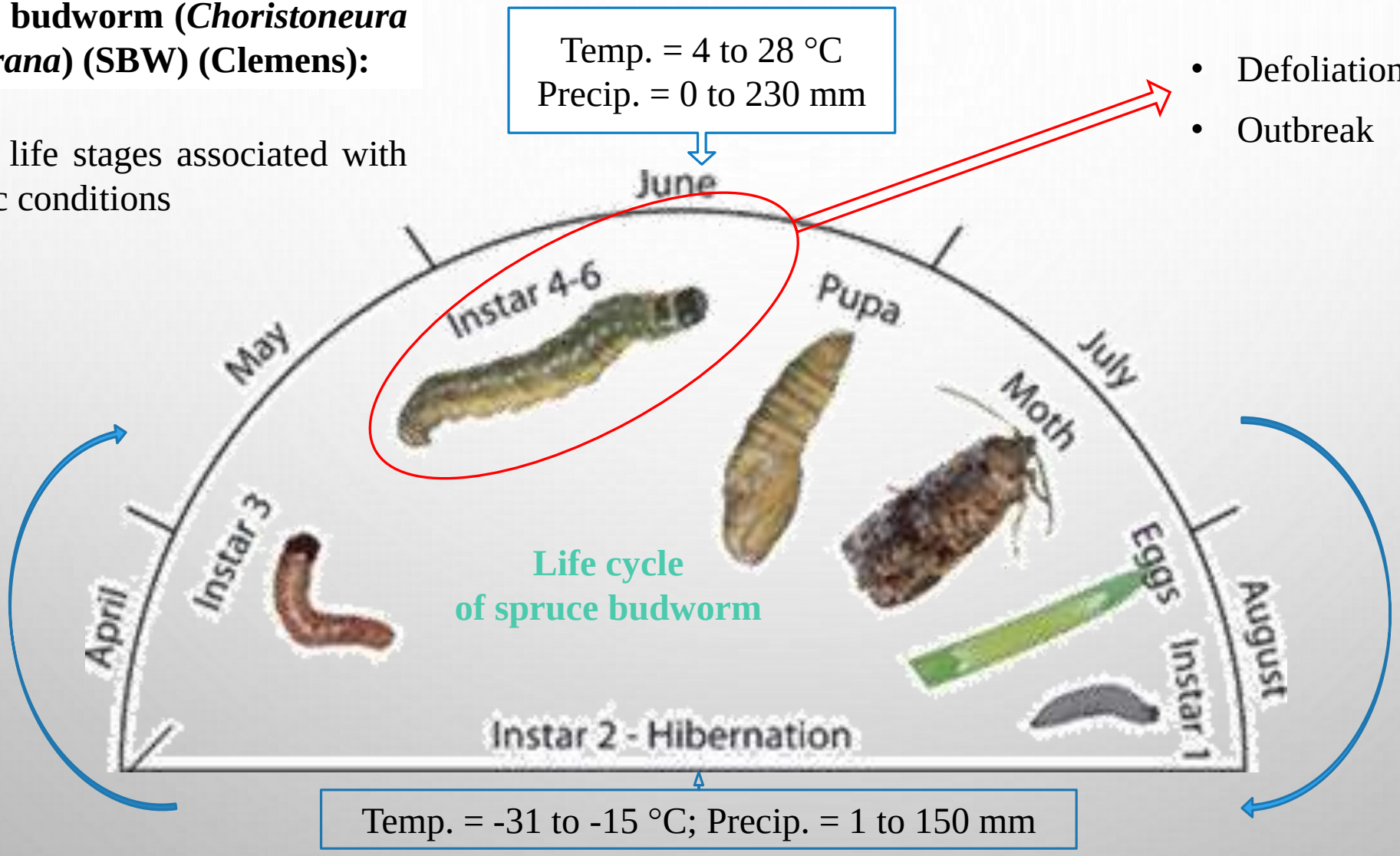
- Boreal and temperate biome prone to disturbances
- Eastern spruce budworm, a principal defoliator of North American forest, is one of the major insect disturbances in eastern Canada

(Turner et al., 1998; Bergeron et al., 1998, 2010; Dale et al., 2001; Seidl et al., 2017, 2020; Boucher et al., 2018; IPCC, 2019)

Context

Spruce budworm (*Choristoneura fumiferana*) (SBW) (Clemens):

All the life stages associated with climatic conditions



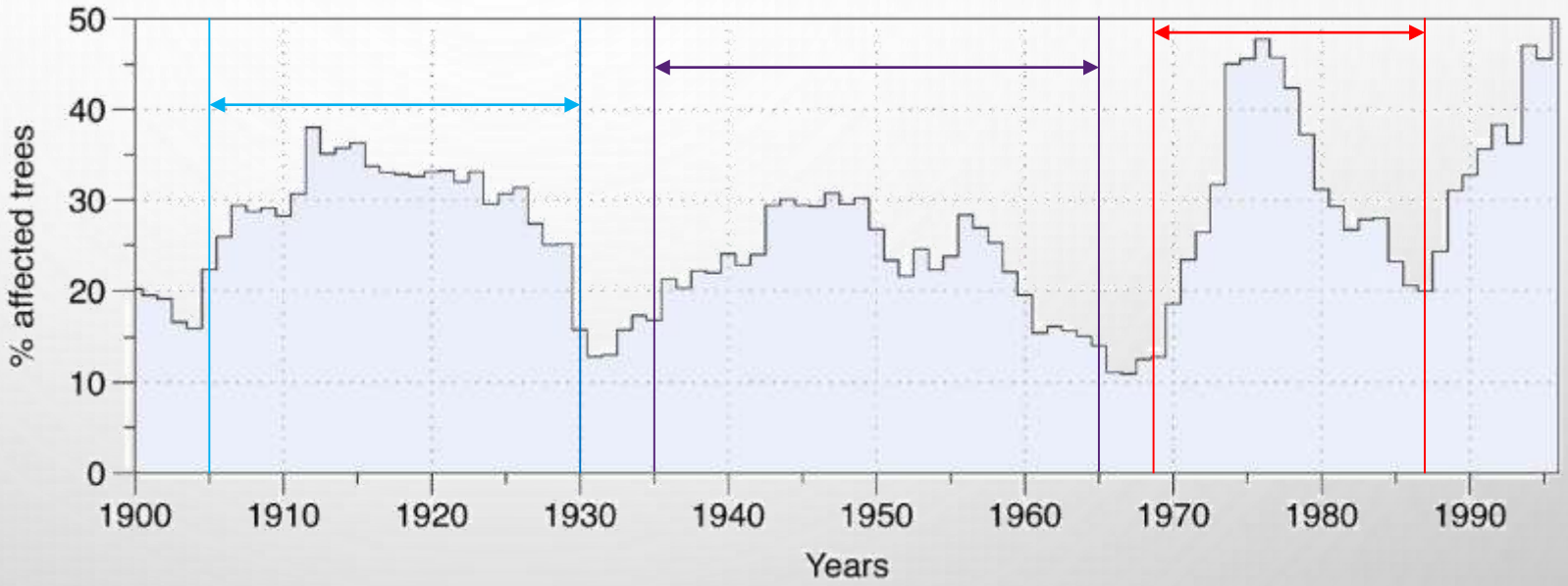
- Defoliation
- Outbreak

(Rauchfuss et al., 2011; Wellington et al., 1950; Ciesla, 2011; Gray, 2013; MFFP, 2021; Pureswaran et al., 2015)

Context

Outbreak of spruce budworm in Quebec:

- Outbreaks occurring at a cyclic pattern of 30-40 years
- Recent outbreaks are becoming shorter but more severe
- Major tree species affected are Balsam fir, White spruce, **and Black spruce**



The proportion of trees affected by outbreak conditions in Quebec

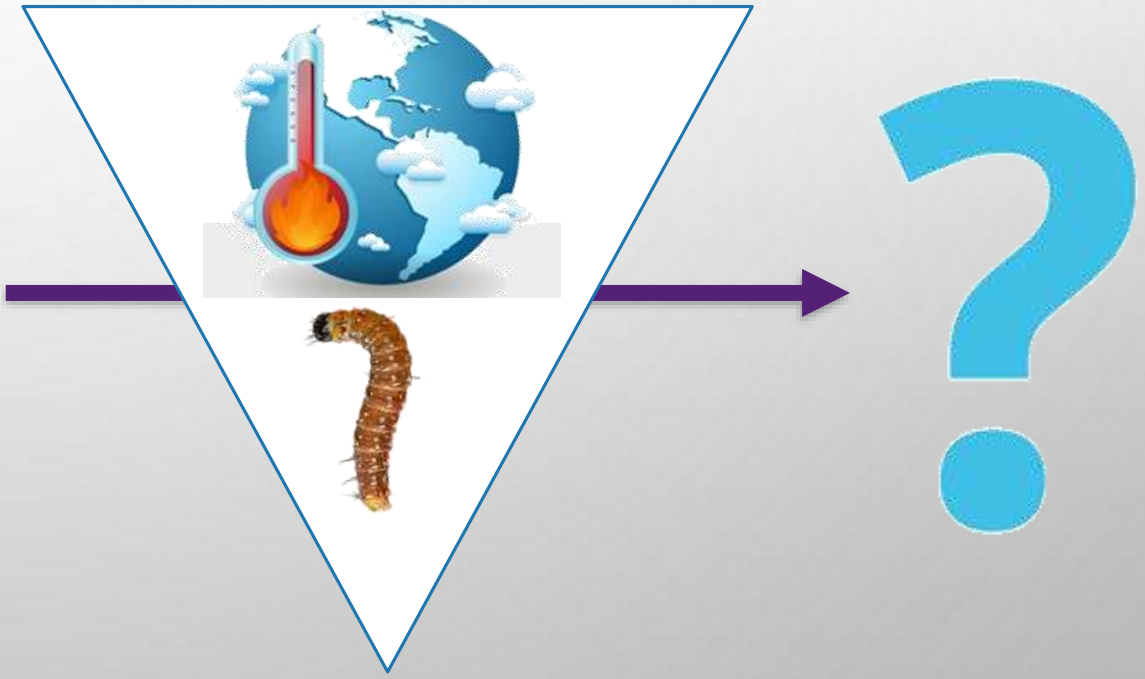
(Montoro Girona et al., 2016; Navarro et al., 2018; Pureswaran et al., 2015)

Context

Black spruce (*Picea mariana*):

Black spruce distribution

- Black spruce, yet secondary, is a good host for spruce budworm
- Growth and development of black spruce are driven by disturbances and climate



(Walker et al., 2015; Pureswaran et al., 2015, 2019; De Grandpré, et al., 2019; D'Orangeville et al., 2018)

Objectives

General objective : To evaluate the influence of climate and outbreak severity on black spruce growth during the outbreaks that have occurred in the last half-century

Specific objective: To identify climatic parameters that interact with the outbreak severity leading to growth reduction in black spruce

Hypothesis

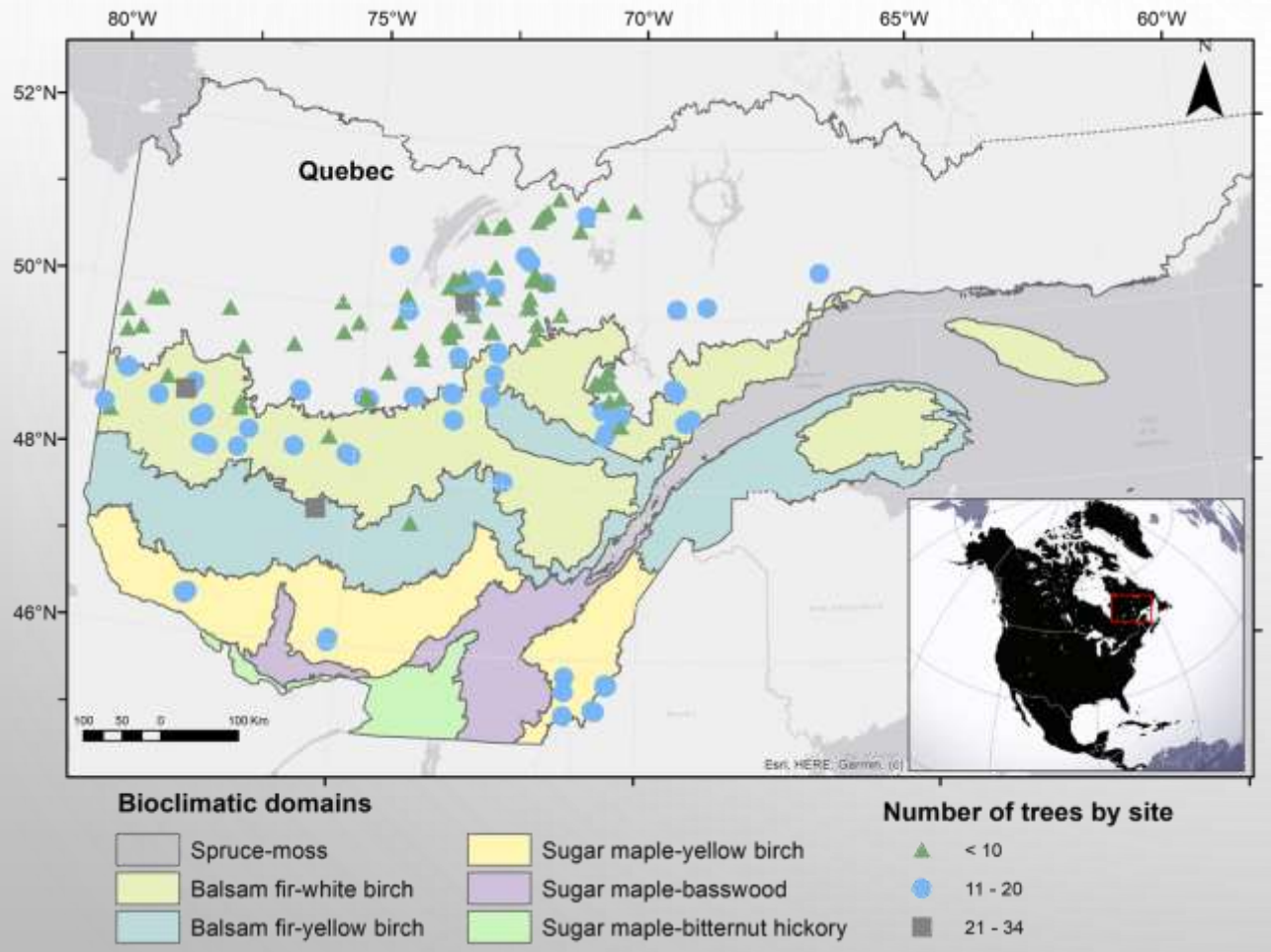
H1: High temperature and precipitation in the previous spring and summer reduces the current year growth of black spruce due to increased defoliation severity

H2: Temperature of June has more influence on the growth-rings reduction than precipitation during an outbreak period

(*Walker et al., 2015; Pureswaran et al., 2015, 2019; D'Orangeville et al., 2018b*)

Methodology

Study area

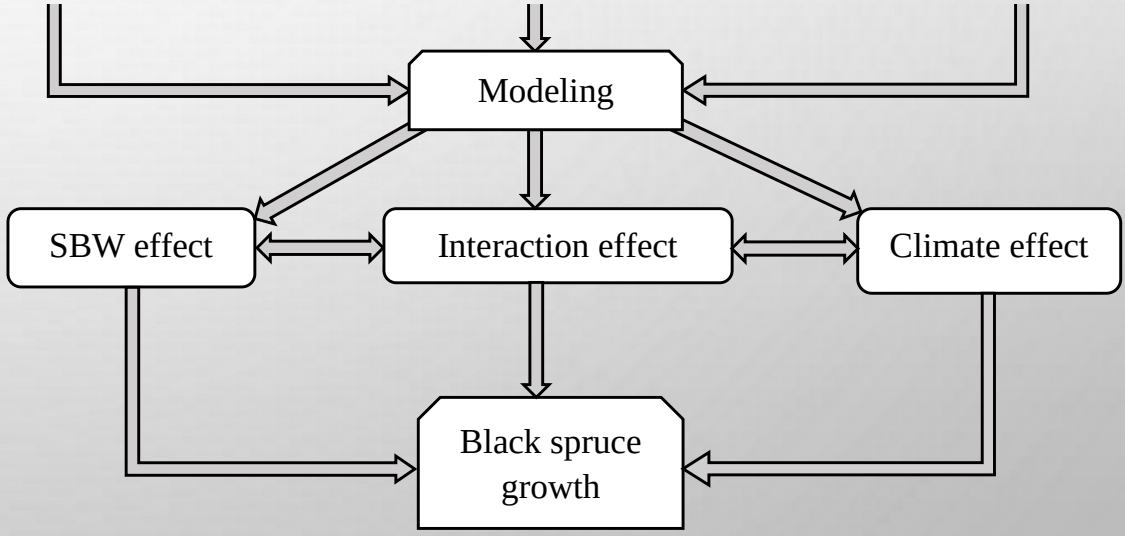


The location of study sites in Quebec

1. Dendro-chronological data

2. Defoliation data

3. Climate data



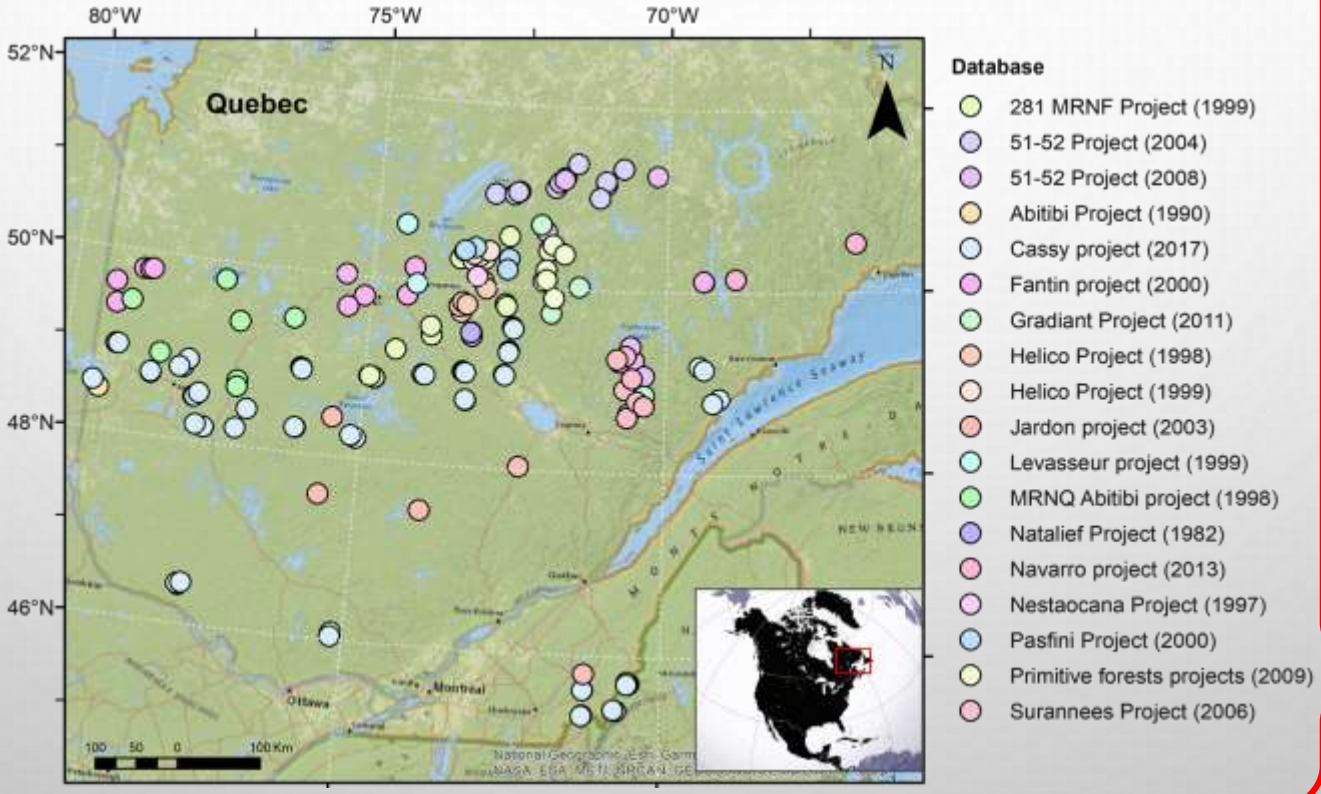
Methodology

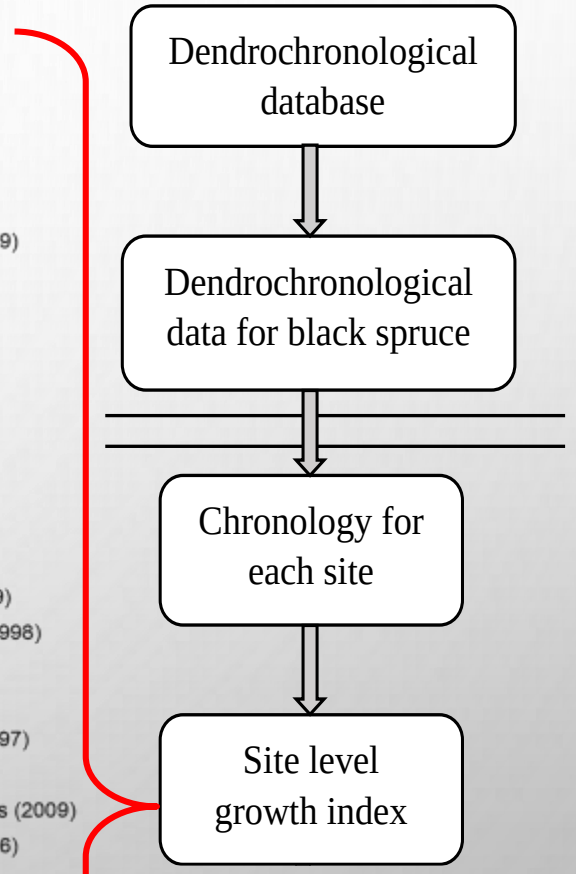
Dendrochronological data

- 18 dendro-projects; 164 sites; 2271 growth series

- **Standardization:** Removing all other signals except defoliation and interannual climate variation

- Basal Area Increment (BAI) = $\pi r_t^2 - \pi r_{t-1}^2$



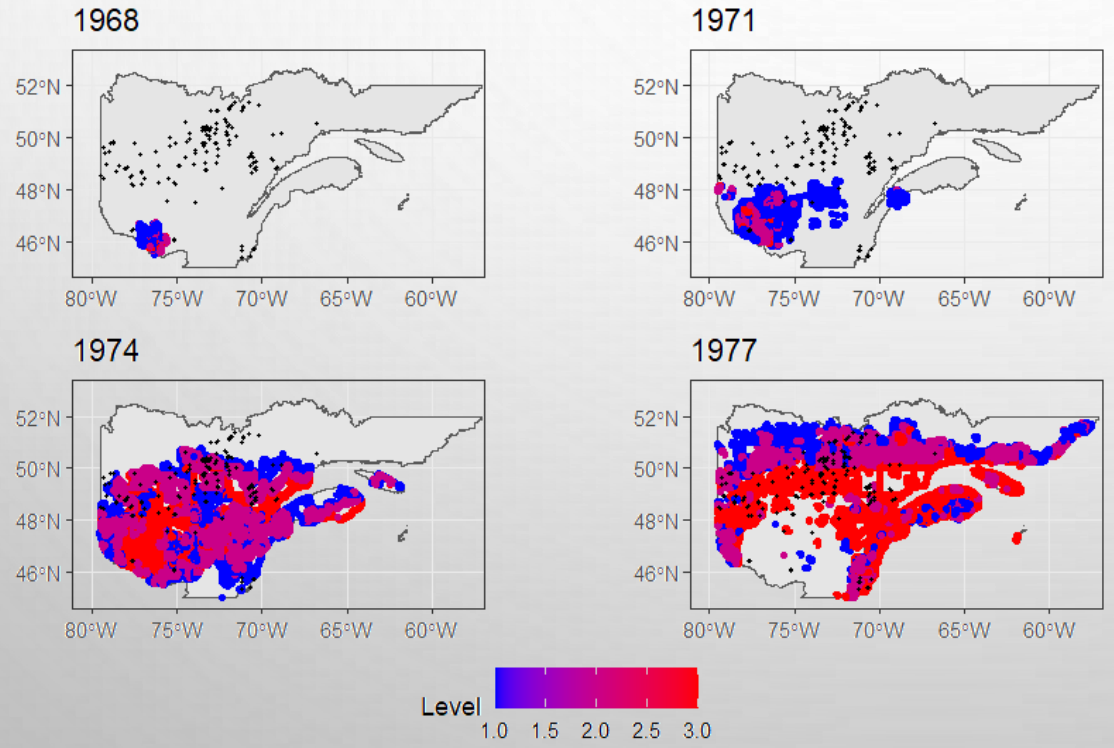


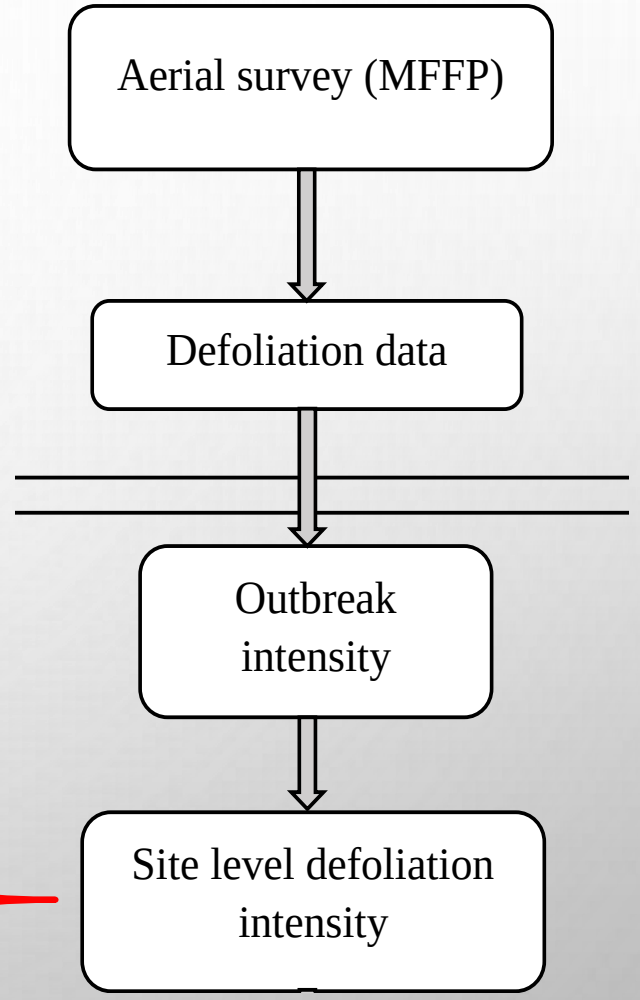
18 projects distributed within study sites in Quebec

Methodology

Defoliation survey

- Aerial information about defoliation by MFFP on yearly basis since 1968
- Defoliation: light (1-35%), moderate (36-70%), & severe (71-100%)
- Time series of outbreak severity within the area





The defoliation level [light (1) to severe(3)] from 1968-1977 in Quebec

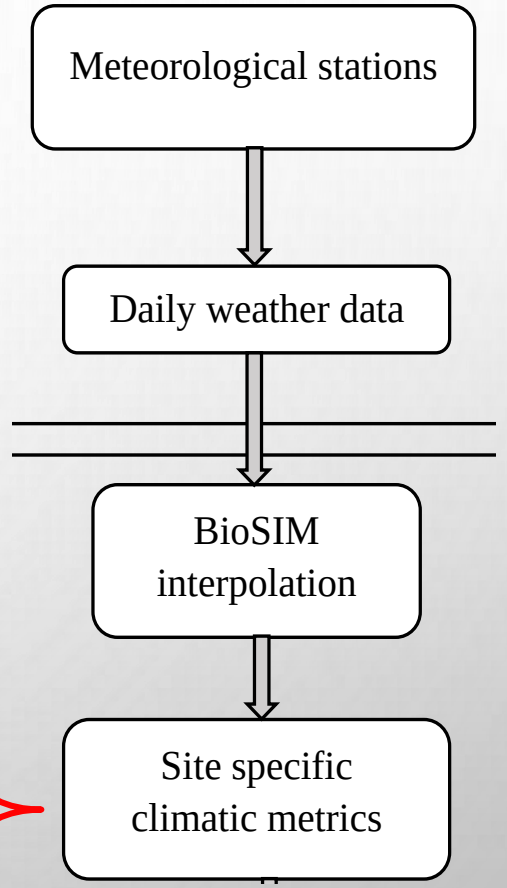
(Gray et al., 2000; MFFP, 2021)

Methodology

Climatic data

Interpolation

- Weather variables on daily basis for each site for each year (1951-2017)



Variable selection

- Summarized based on important stages in biology of SBW:

Temperature and Precipitation (1951-2017)	
Seasonal:	Monthly:
Spring (March-May)	June
Summer (June-August)	July
	August

Climate Moisture Index (CMI) = Precipitation – Potential Evapo-Transpiration (PET)

(Candau & Fleming, 2005, 2011; D'Orangeville et al., 2018b)

Methodology

Statistical analysis

Generalized additive model (GAM)*

- Log(BAI) = log(Basal Area) + spline(age) + Residuals
- Residual contain the effects of interannual climate variation and SBW defoliation

Linear Mixed effect (LME) model*

- Response: residual of the log BAI from GAM model (LogBAI) averaged by site and year
- Predictors: Random effect of sites and year + Fixed effect of cumulative defoliation, scaled climatic variables, and their interaction

Creation of parsimonious model*

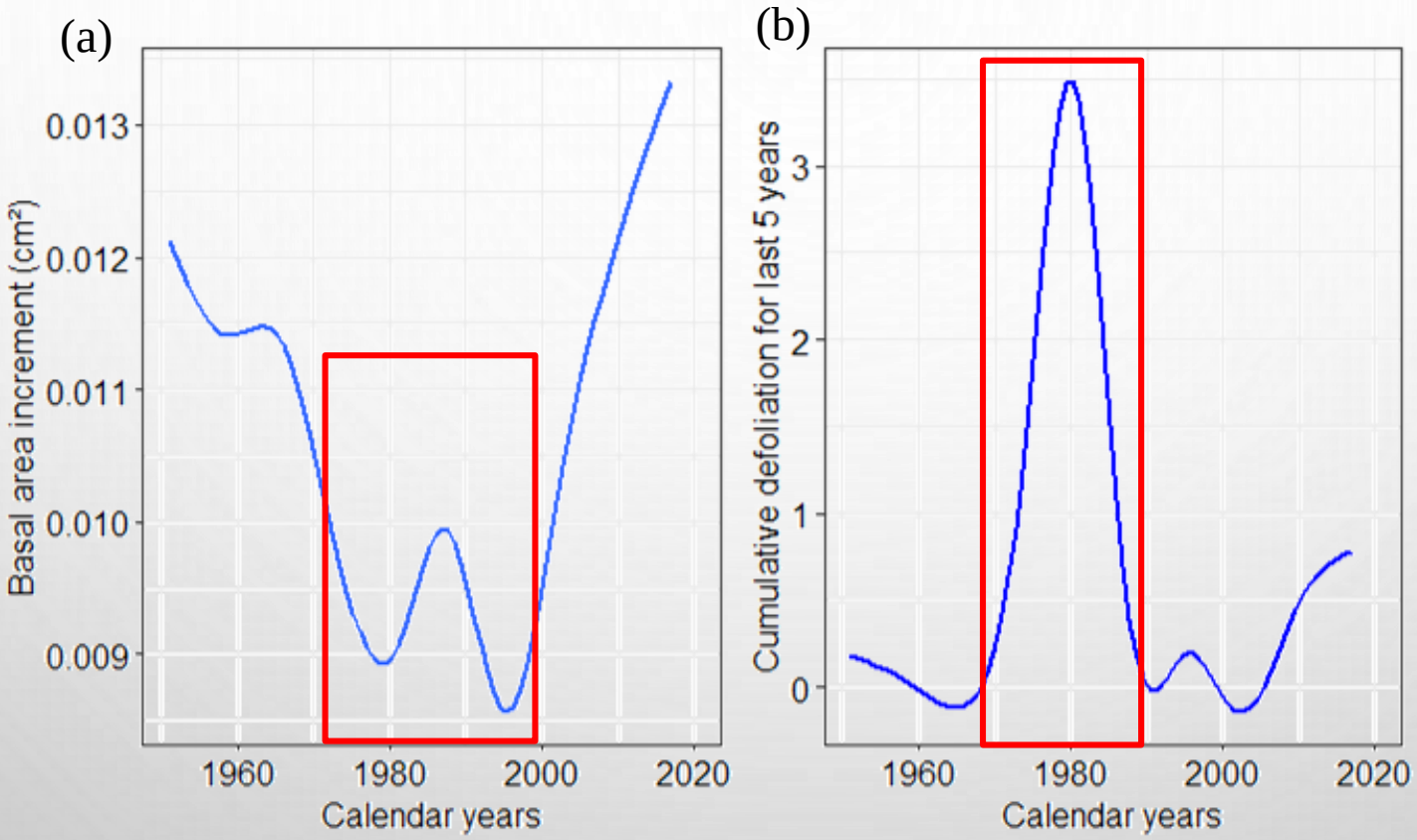
- Backward model selection approach to select parsimonious model based on minimum AIC
- Eliminating interaction between climatic variables and defoliation

**All the statistical assumption were sufficiently met.*

(Akaike, 1974;Pinheiro et al., 2021)

Results

Growth and cumulative defoliation:

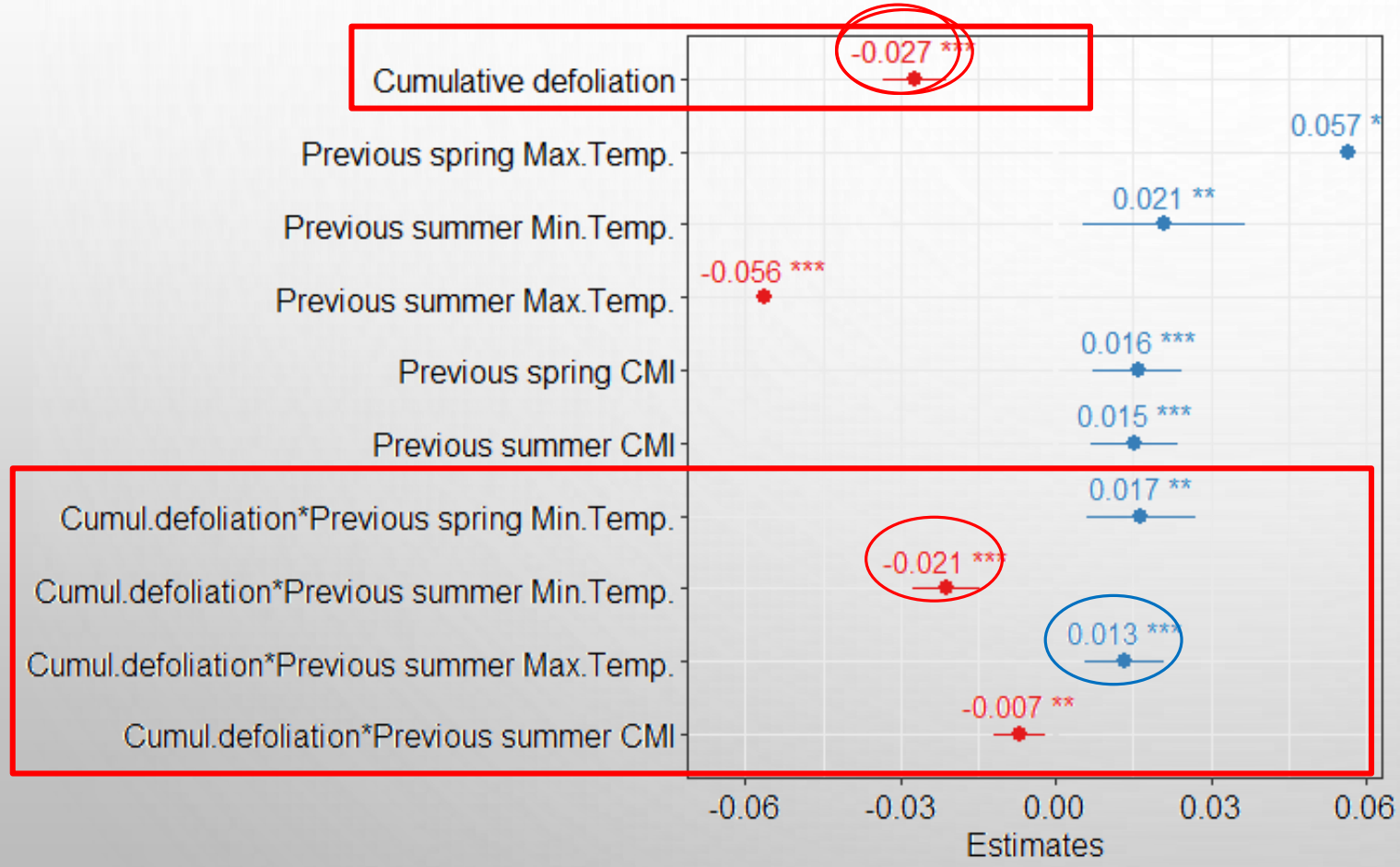


The growth of black spruce (a) and the cumulative defoliation (b) recorded each year

- Growth reduction approximately within the same period (1970-1990) when the cumulative defoliation reached its peak

Results

Seasonal scale:

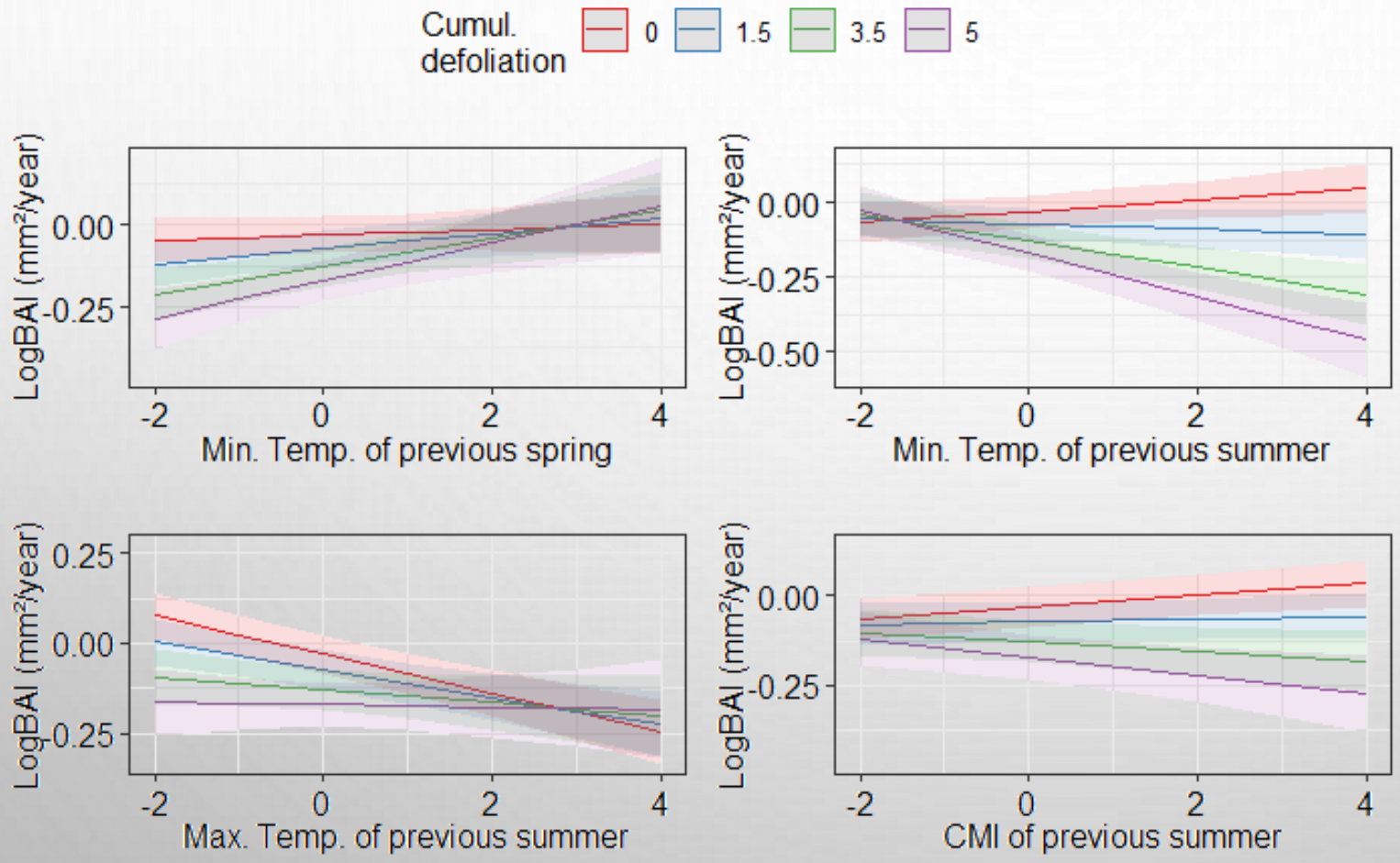


The effect of the interaction between climate and defoliation on the growth of the black spruce

- Severe defoliation (71-100%) for a year reduces the growth by 2.7%
- Increase in one standard deviation above average in previous summer Min. Temp. caused further reduction in growth by 2.1%
- However, reduction of the defoliation effect by 1.3% with increase in previous summer Max. Temp.

Results

Seasonal scale:

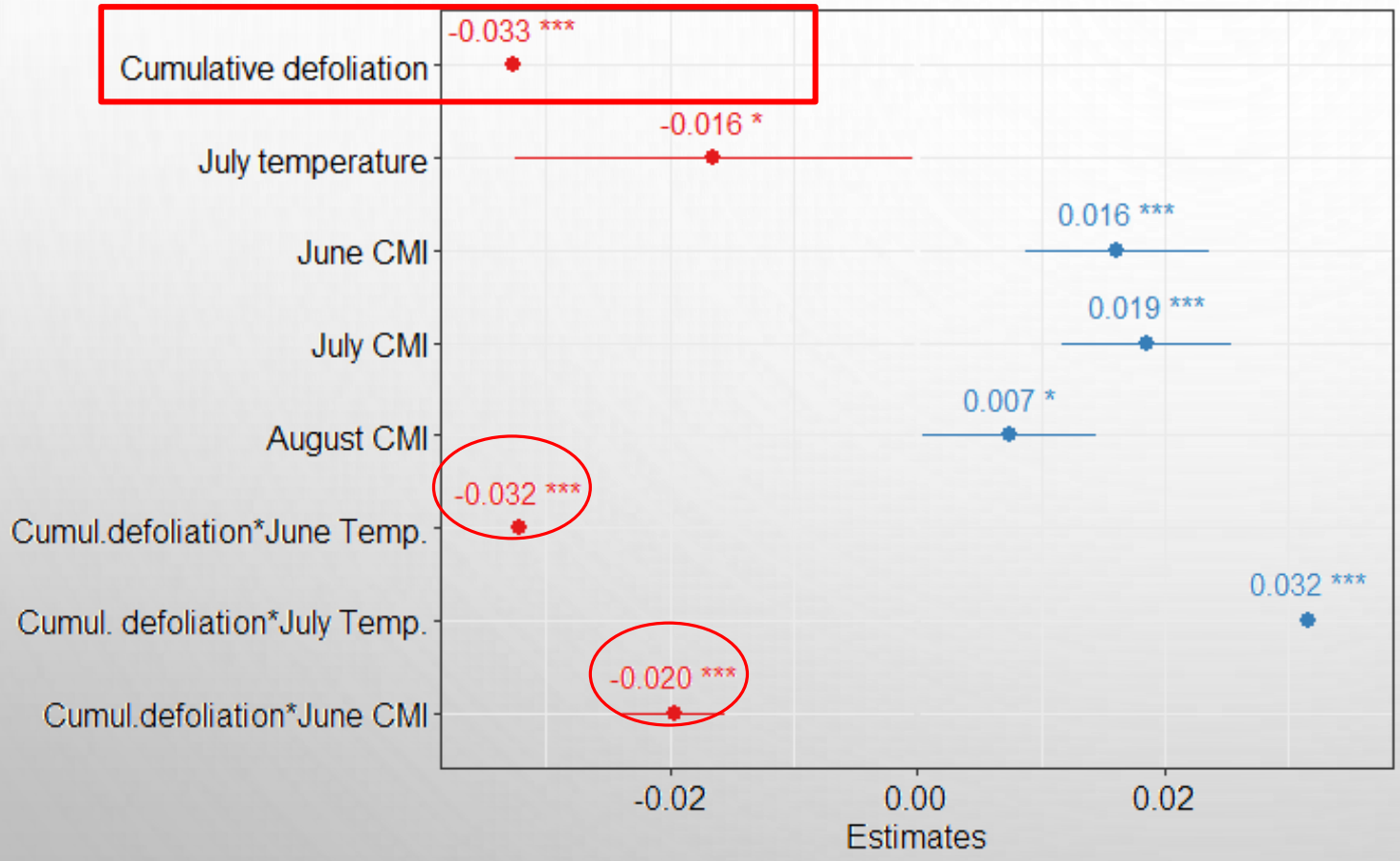


The effect of defoliation and climatic predictors on the growth of black spruce

- At same defoliation level, the growth of black spruce is reduced more with increase in the summer temperature of previous season

Results

Monthly scale:



- Severe defoliation (71-100%) for a year reduces the growth by 3.3%
- Increase in one standard deviation above average in June Temp. caused further growth reduction by 3.2% at the same defoliation level
- Like wisely, growth decrement by 2.0% with increased June CMI

The effect of the interaction between climate and defoliation on the growth of the black spruce

Discussion

a. Seasonal variables

- ↑ Summer minimum temperature – ↑ defoliation - ↓ growth
  - Earlier emergence of budworm from hibernation
  - Development of the tree buds providing suitable condition for feeding

- ↑ Summer maximum temperature – ↓ defoliation - ↑ growth
  - Too hot summer detrimental for budworm – survival failure - limited defoliation
  - Growth release on black spruce

- ↑ Climate moisture index – ↑ defoliation - ↓ growth
  - Increasing the early instar larva survival
  - Suitable precipitation facilitates spread of budworm– higher success

(Weed et al., 2013; Dickison et al.,1986; Larroque et al., 2022; Navarro et al., 2018, Pureswaran et al., 2018; D'Orangeville et al., 2018)

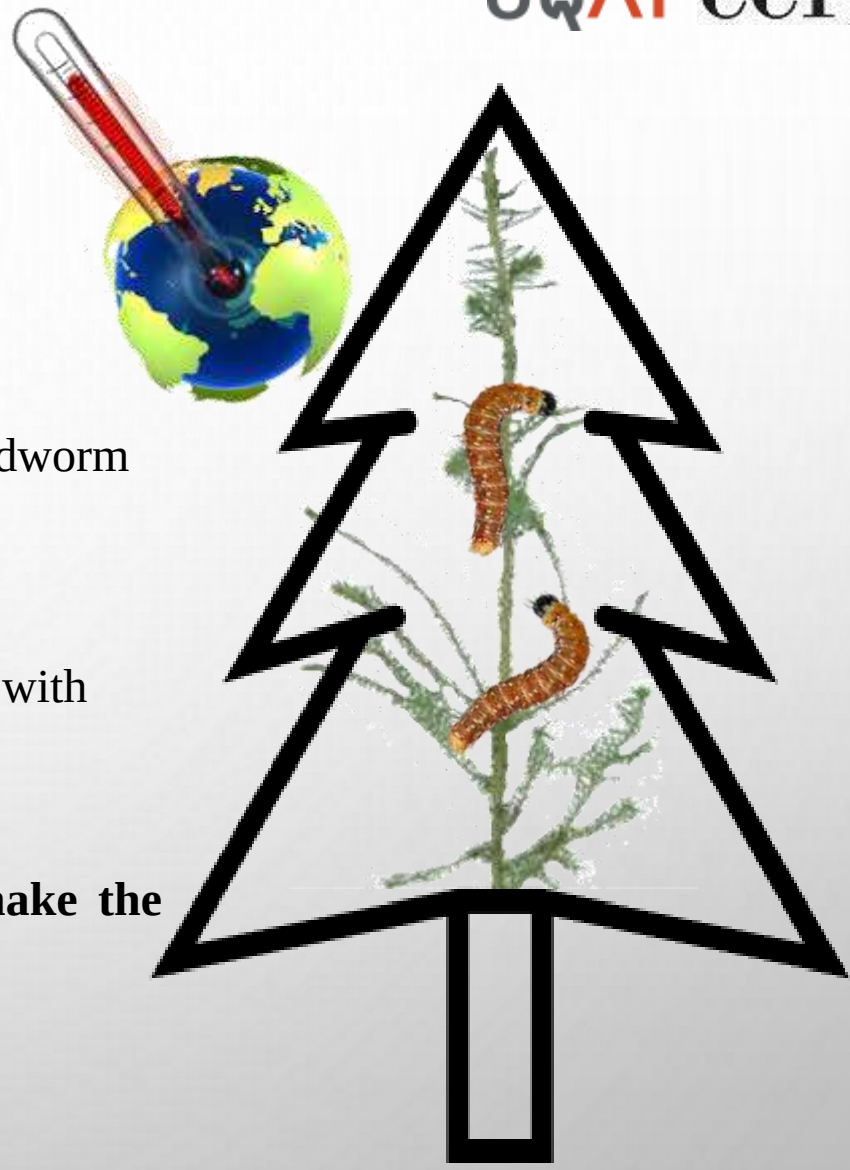
Discussion

b. Monthly variables

- ↑ June temperature and June climate moisture index - ↑ defoliation - ↓ growth
    - Important month on budworm life stages
    - Earlier budburst in black spruce that provided more opportunity for budworm to feed – lost of more foliage
    - Nutritive food reserves for eggs essential for the overwintering success for larva

(Larroque et al., 2022; Pureswaran et al., 2015, 2018; Carisey & Bauce 2002)

Conclusion



- **Growth influenced by temperature and climate moisture**
- **High interference from summer season climate** in growth
- **Increased summer minimum and June temperature** favors the spruce budworm defoliation
- Positive effect of temperature to **growth might be attenuated or reversed** with increase in synchronization
- Continue to develop research to reconstruct the **model in the past to make the projection**

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Thank you !

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