



HOKKAIDO UNIVERSITY

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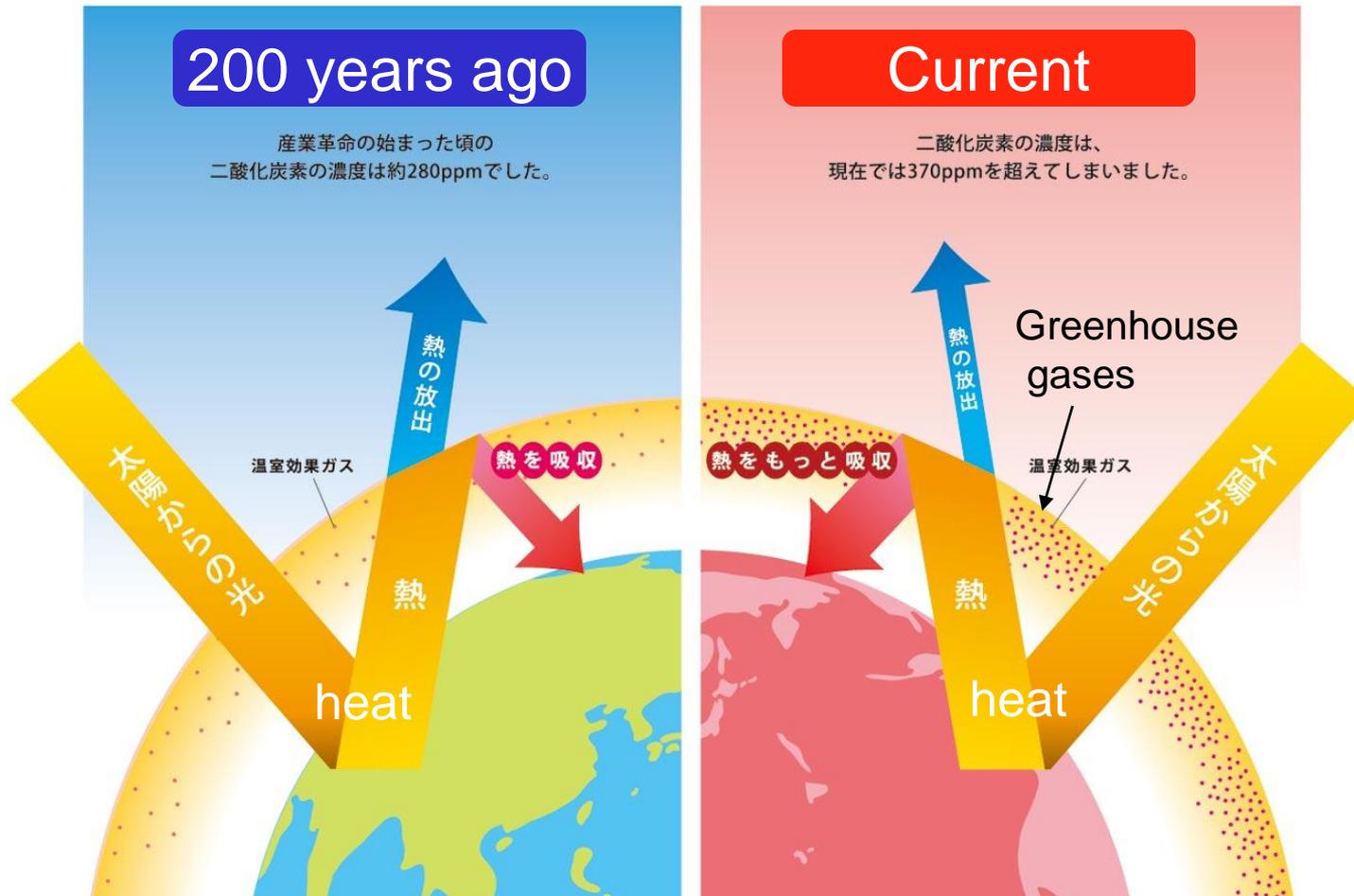
An aerial photograph of a dense green forest. A tall, green metal tower is suspended in the air, with a small green basket hanging from it. The basket is positioned over the forest canopy. The sky is blue with scattered white clouds. In the background, there are distant mountains and a power line tower.

Simulated warming effects on plant-insect interactions in a cold temperate region

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Mechanism of global warming



Greenhouse gases (atmospheric concentrations of CO₂, CH₄, and N₂O) have increased dramatically.



26th Sep. 1986

23rd Oct. 2006

The peak of autumn foliage is
behind for one month in
TOEF

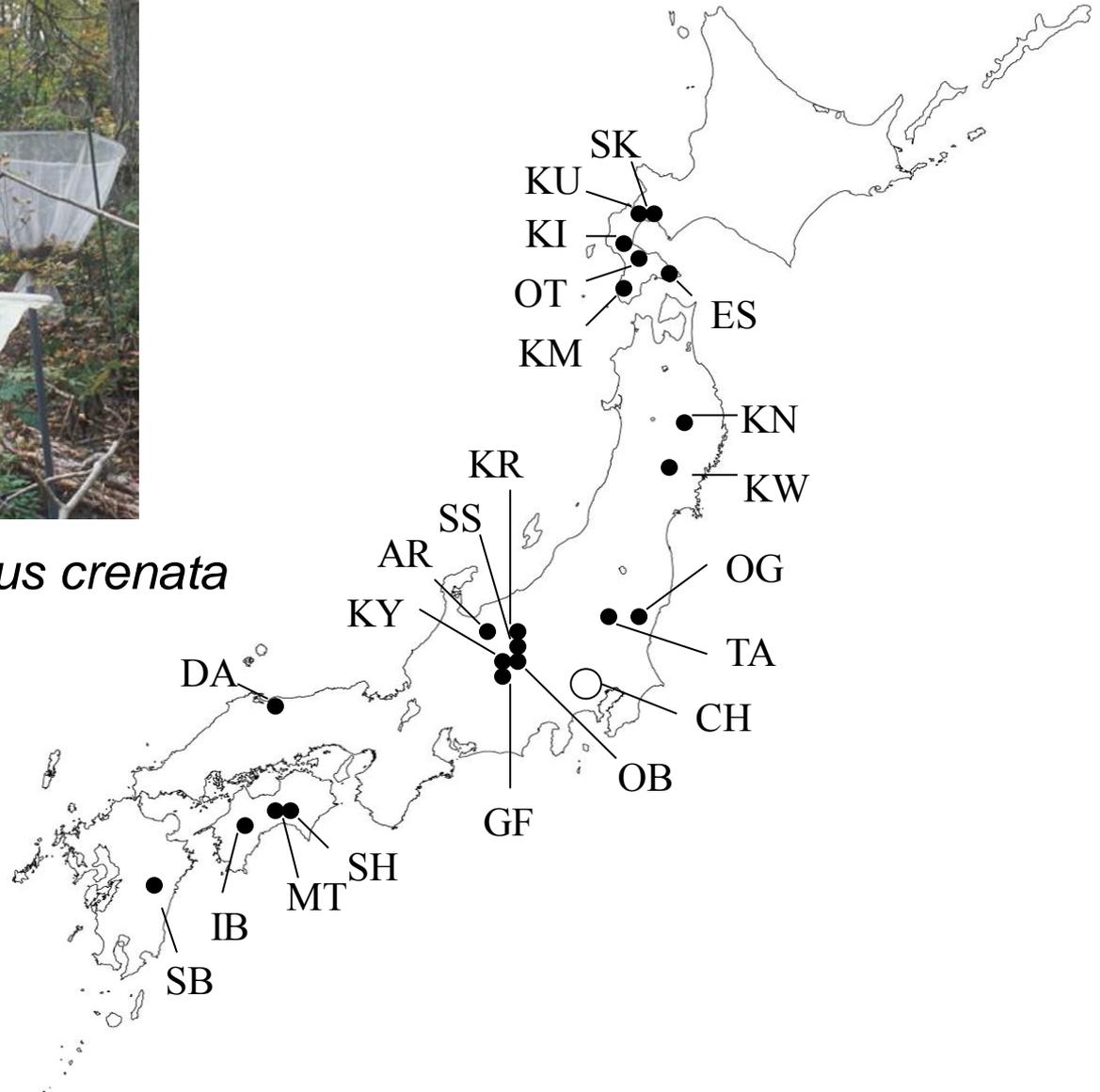


Photo by T. Hiura

Latitudinal gradient study

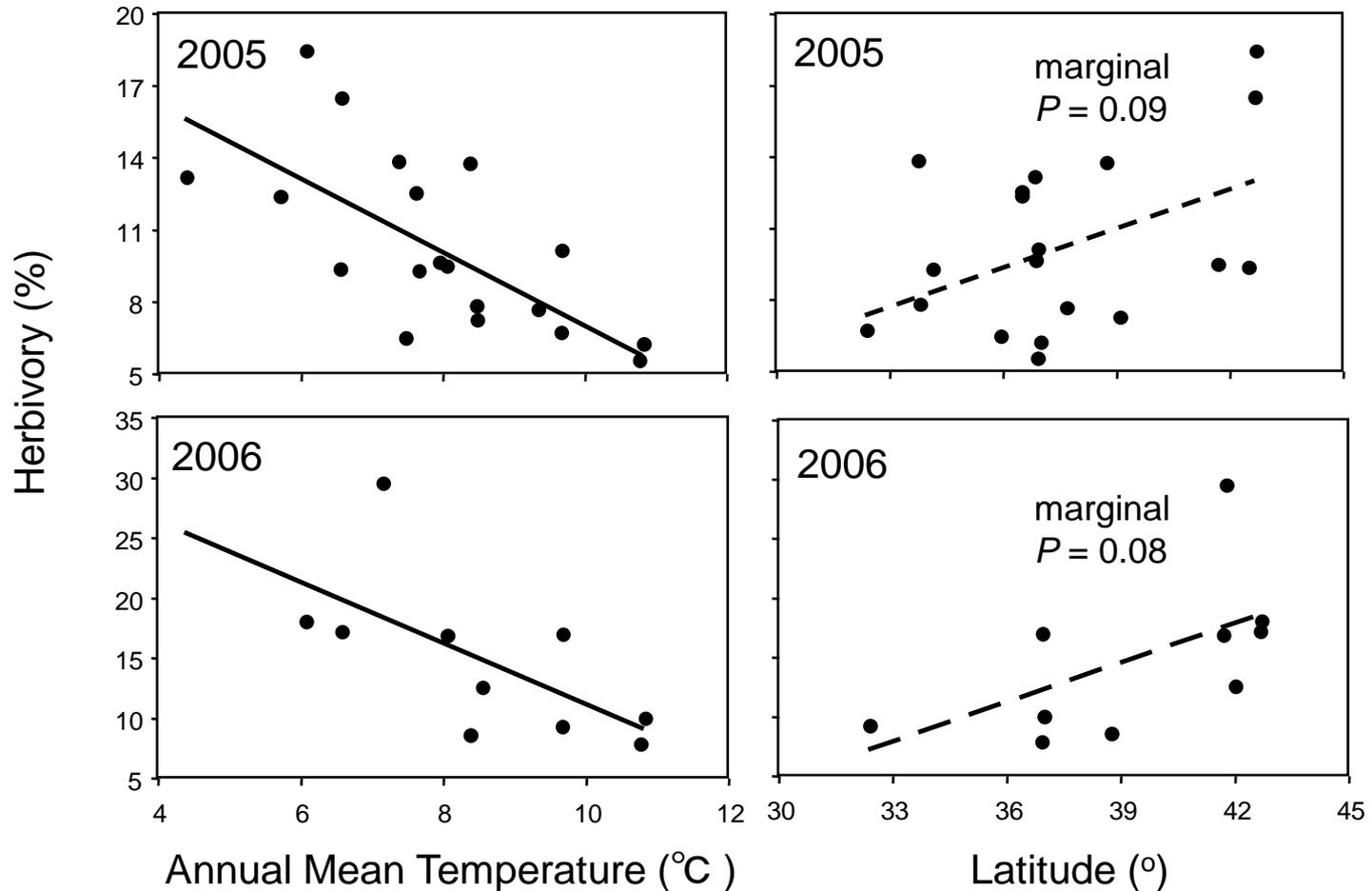


Litter traps of *Fagus crenata*



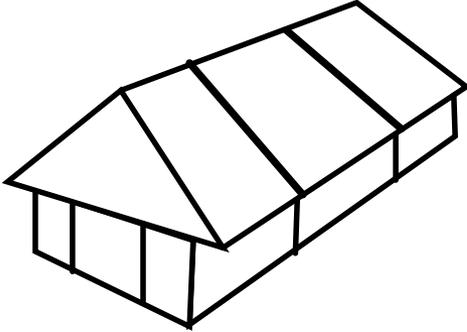
Latitudinal variation in herbivory

Chewing herbivory decreased for southern beech forests

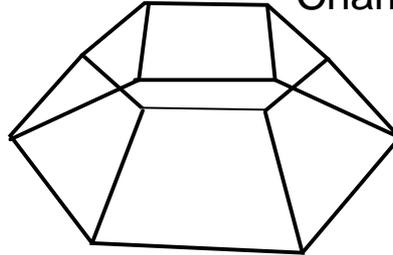


Warming experiments

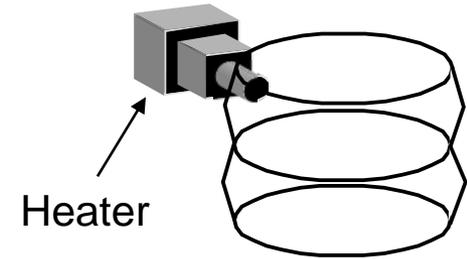
(a) Field Greenhouse



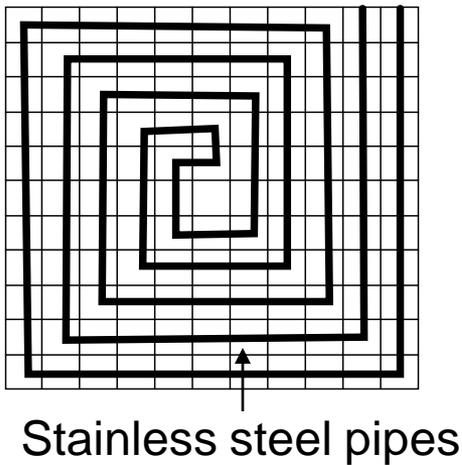
(b) Passive Open-top Chamber



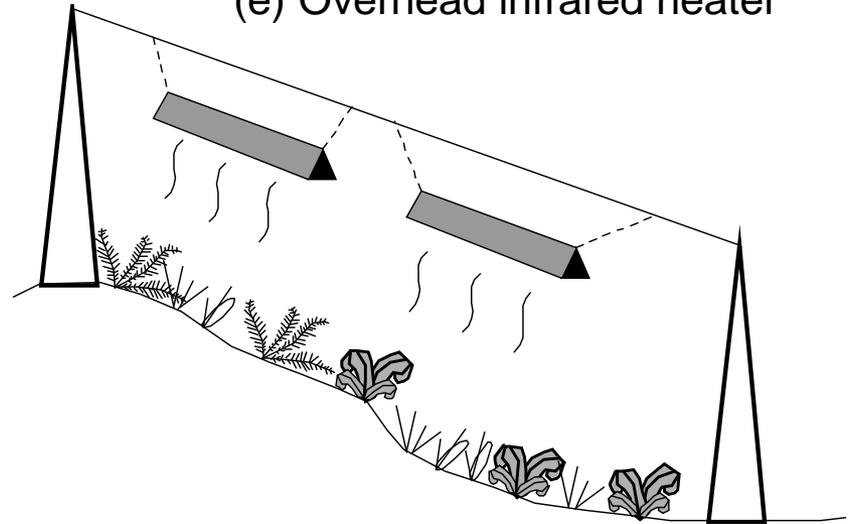
(c) Active Open-top Chamber



(d) Fluid-filled Pipes



(e) Overhead infrared heater



There are no warming experiments using canopy trees.

Canopy facilities in TOEF

More than 10 scaffolding systems
(height = 12-18m)



One canopy crane
(height = 25m,
length of jib = 41m)



Question



How do **soil and branch warming** affect forest ecosystem of canopy oak trees?



Measurements

- ▶ Leaf phenology
- ▶ Acorn production
- ▶ Leaf traits (LMA, Nitrogen, CN ratio)
- ▶ Herbivory rate

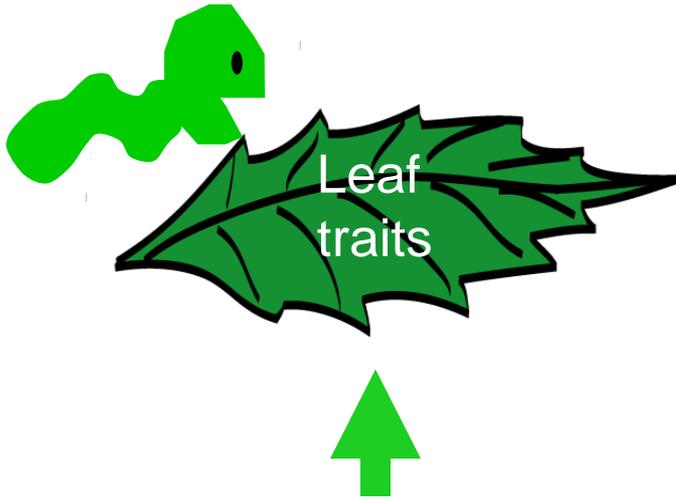
Using canopy crane, we can directly observed canopy foliage.





Leaf traits

- ▶ **Nutrient:** Nitrogen (Schoonhoven et al. 1998)



- ▶ **Physical defense:** LMA (leaf toughness) (Coley 1983)
- ▶ **Chemical defense:** CN ratio (Bryant 1983)

The CNB hypothesis suggest that increase in the CN ratio implies that carbon becomes more available for **carbon-based chemical defense**.

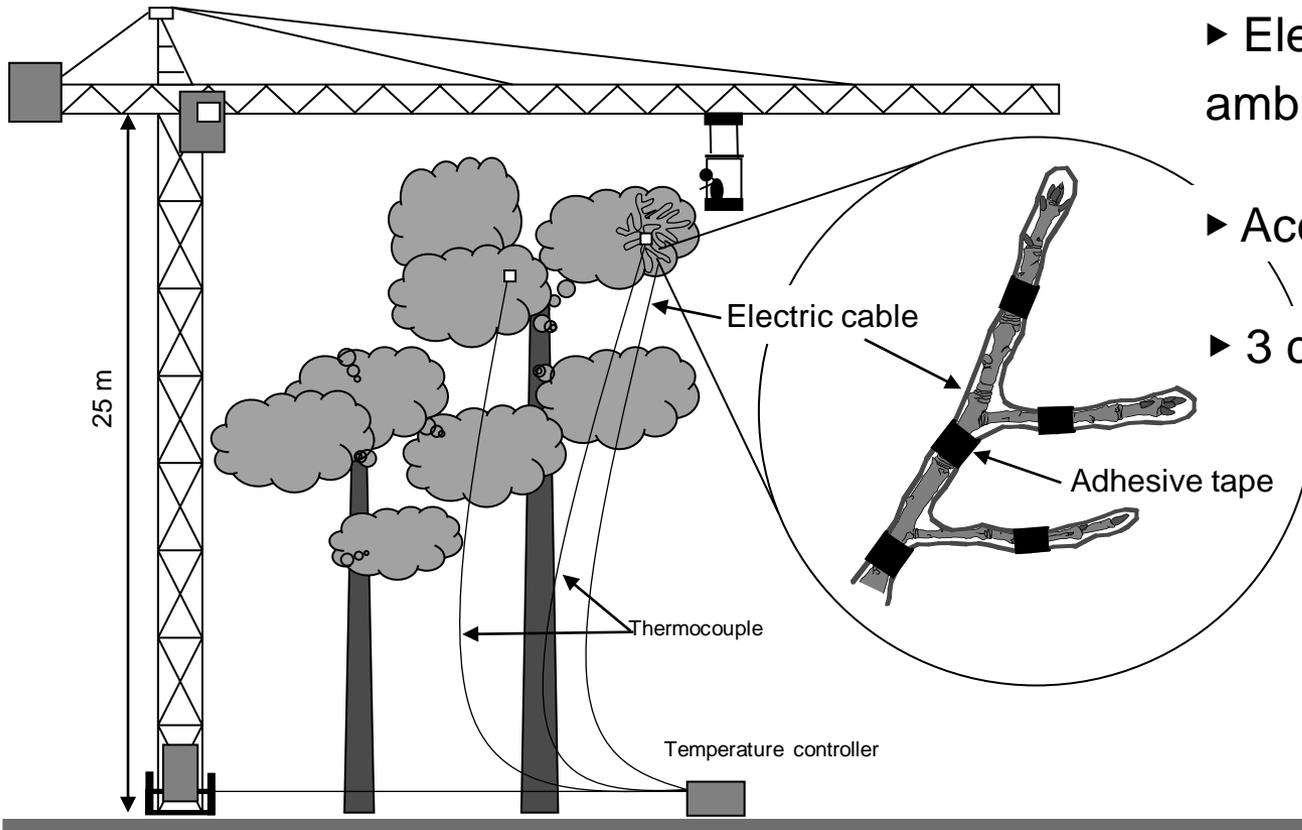
Environments
(e.g. light, soil nutrient)

These leaf traits are often changed by environments
(e.g. Bryant 1983, Nakamura 2008).



Branch warming experiment

- ▶ Attached heating cables to top canopy branches
- ▶ Elevated 5°C above ambient using heating cables
- ▶ Access using canopy crane
- ▶ 3 canopy trees



Branch warming experiment

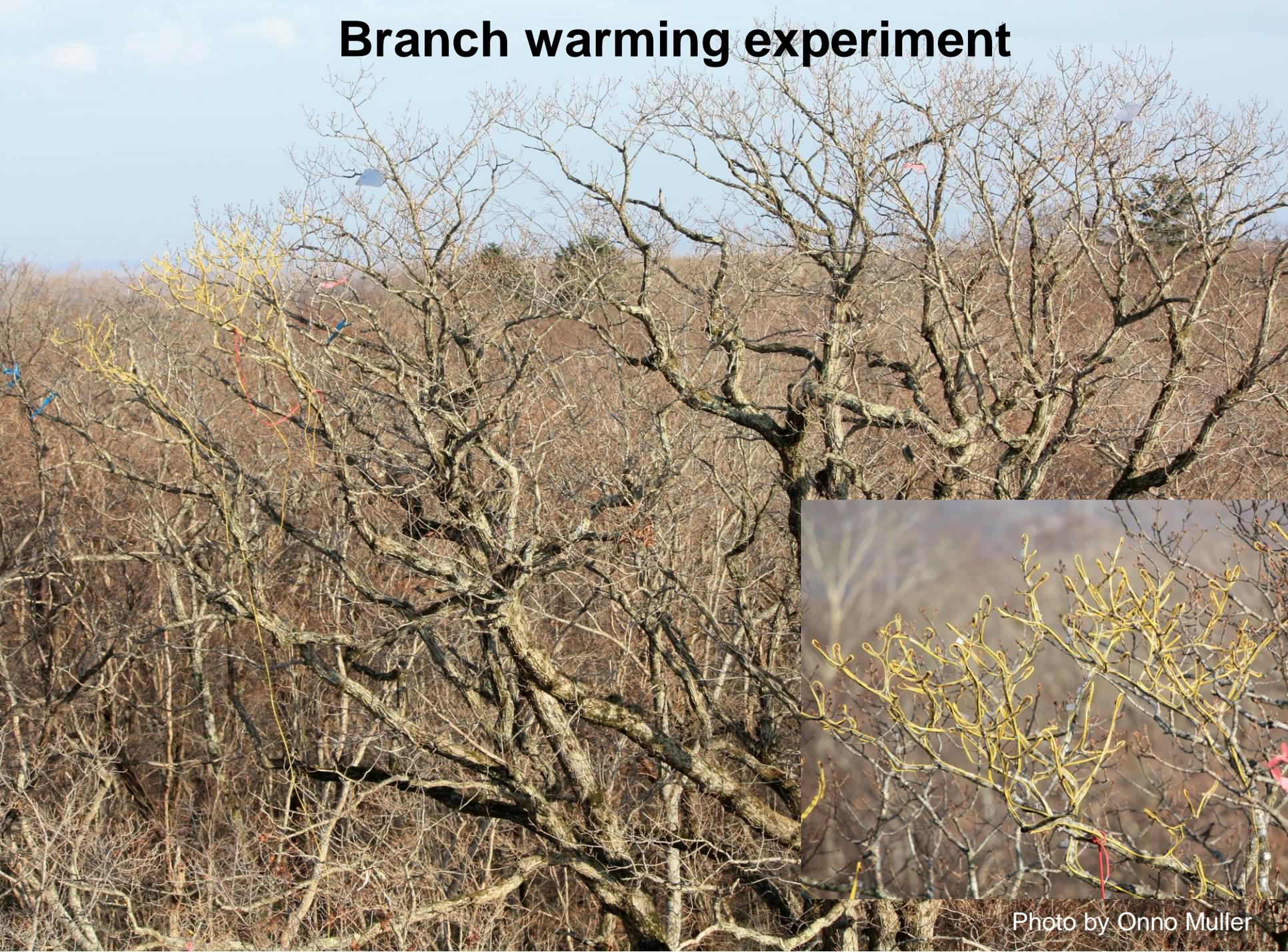
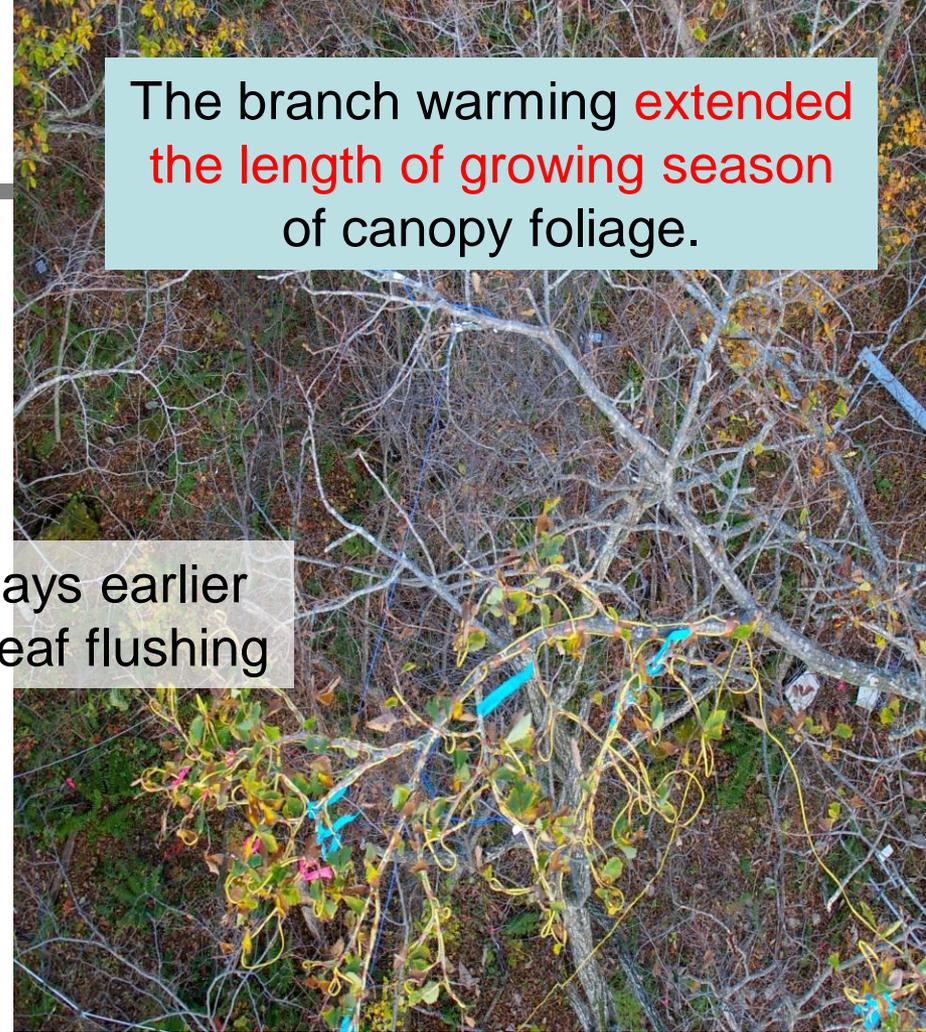
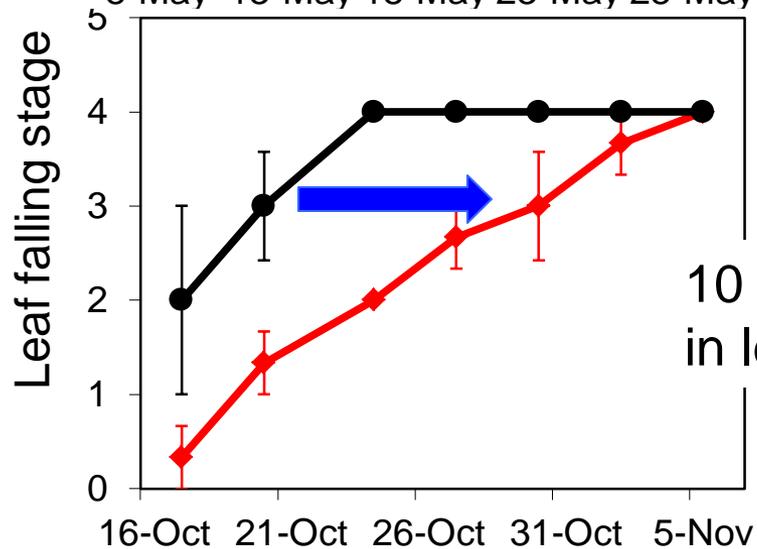
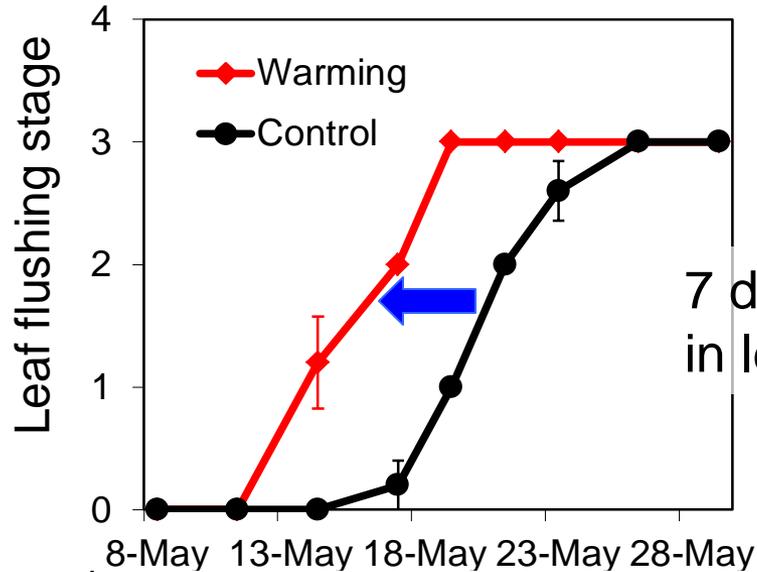


Photo by Onno Muller



Leaf phenology

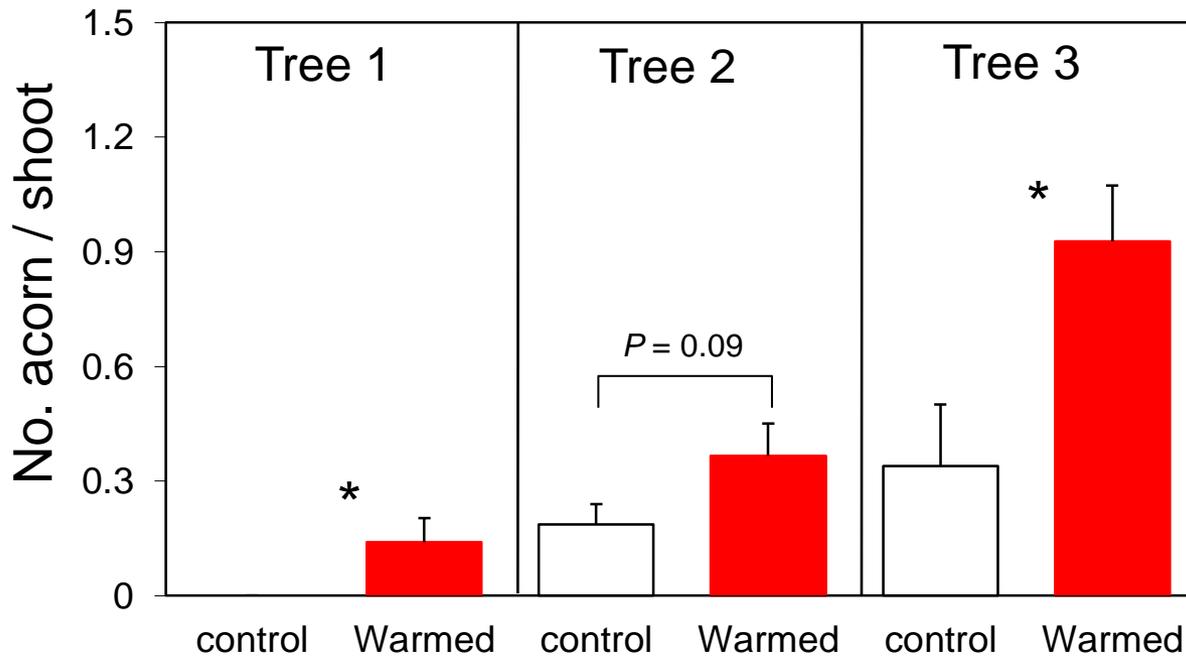
The branch warming **extended** the length of growing season of canopy foliage.



Acorn production



The branch warming **increased acorn production**.

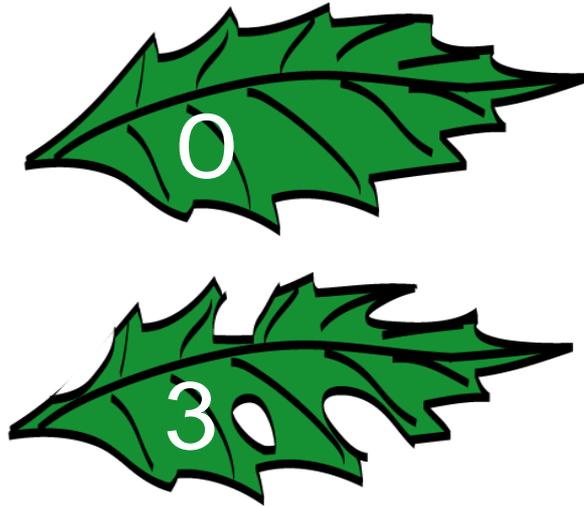


Student's t-test, Significance: * $P < 0.05$

This result may lead to the mechanism elucidation of acorn masting



We visually scored herbivory



Six ranked indices	Percentage of herbivory
--------------------	-------------------------

0:	0%
1:	1-10%
2:	11-25%
3:	25-50%
4:	51-75%
5:	76-100%



Lymantriidae



Geometridae

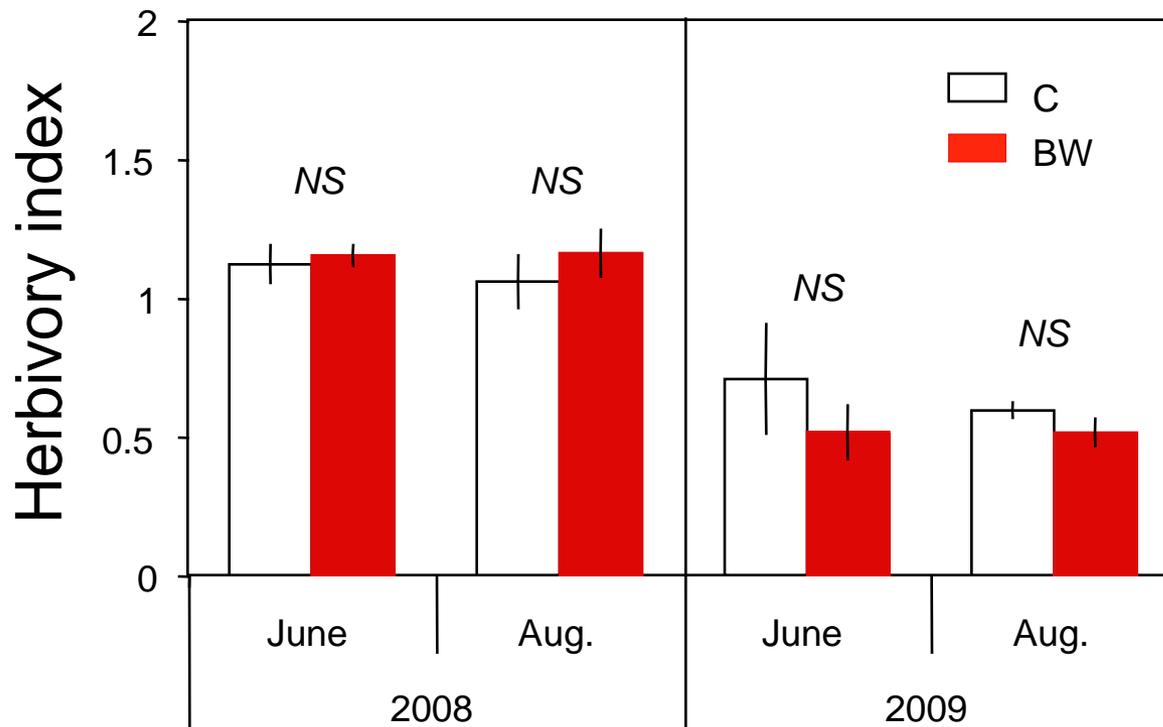


Notodontidae



Herbivory (branch warming: BW)

The branch warming **did not affect herbivory** of canopy foliage.



Student's t-test, Significance: * $P < 0.05$, ** $P < 0.01$



Soil warming



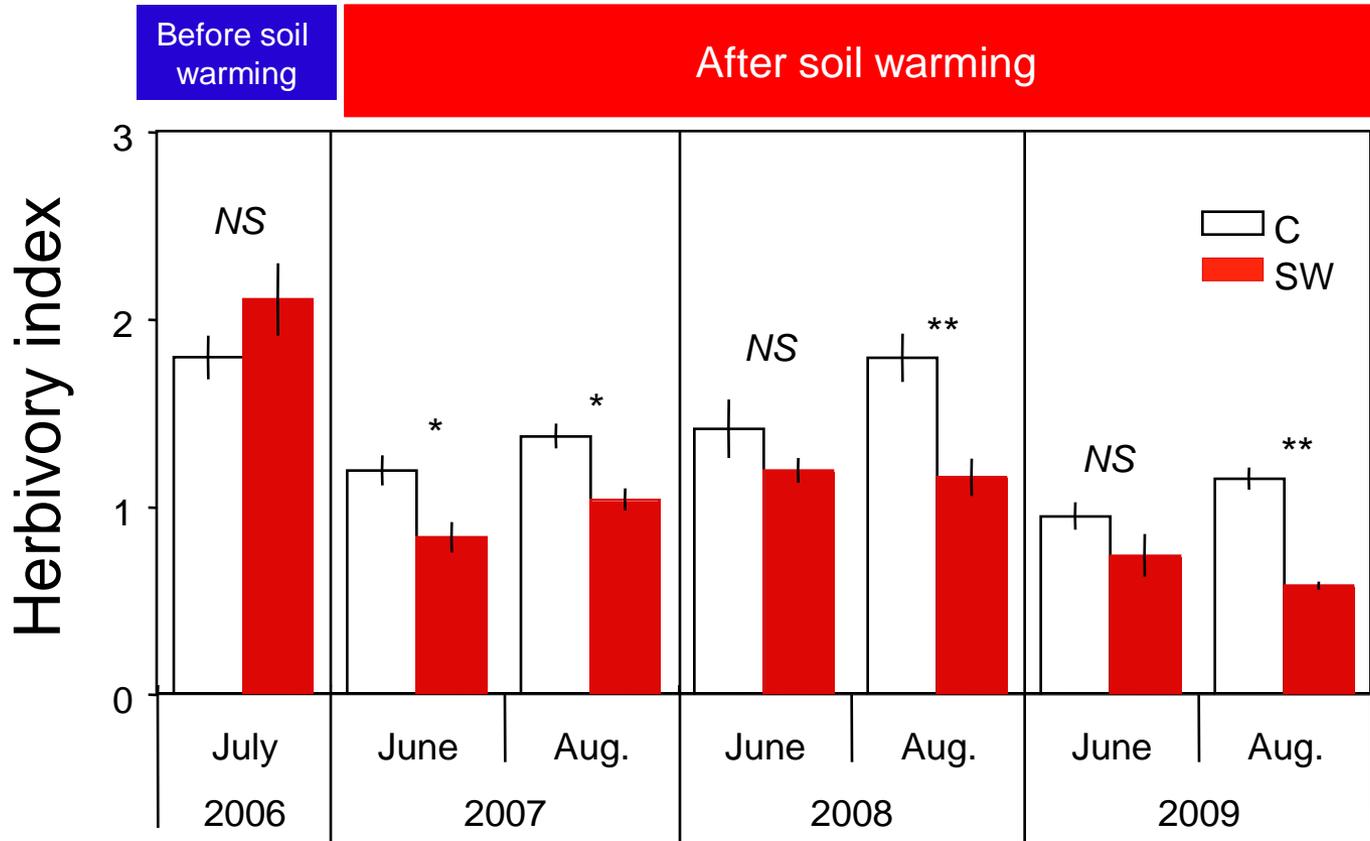
- ▶ 5m x 5m square plots
- ▶ **Buried heating cables** and spaced 20 cm apart
- ▶ Elevated **5°C** above ambient using heating cables



Herbivory (soil warming: SW)



The soil warming **decreased herbivory** of canopy foliage.

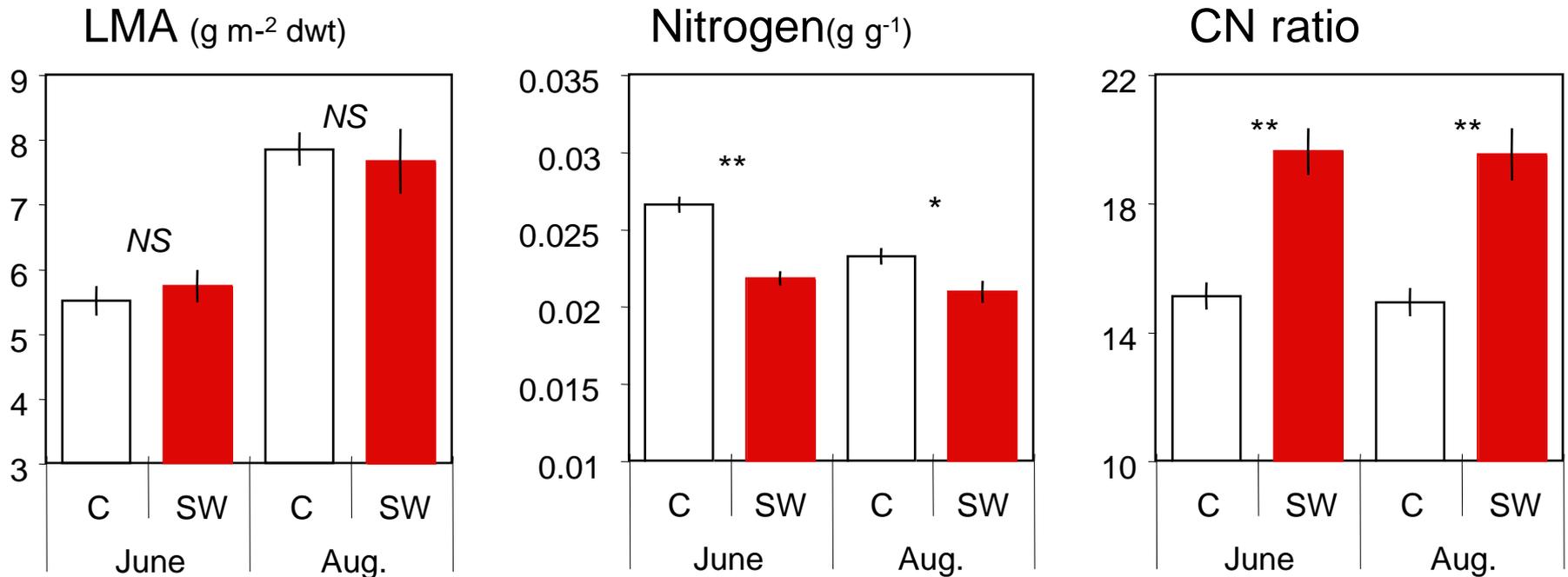


Student's t-test, Significance: * $P < 0.05$, ** $P < 0.01$



Leaf traits (2007)

The soil warming **decreased nitrogen concentration** and **increased CN ratio** in canopy foliage.



Student's t-test, Significance: * $P < 0.05$, ** $P < 0.01$



What leaf traits affect herbivory ?

	LMA (June)	Nitrogen (June)	CN (June)	LMA (Aug.)	Nitrogen (Aug.)	CN (Aug.)	Intercept	P value
Herbivory (June)	-	-	-0.045				0.711	< 0.01
Herbivory (Aug.)	-	-	-0.031	-	58.746	-	-0.623	< 0.01

Generalized linear models (GLMs).

LMA, Nitrogen, and CN ratio in June and August were fixed effects

- ▶ LMA: **Leaf toughness**
- ▶ Nitrogen: **Nutrient**
- ▶ CN ratio: **Carbon-based defense**



Summary

1. The branch warming extended the length of growing season of canopy foliage by earlier leaf flush and later leaf fall.
2. The branch warming increased acorn production.
3. The branch warming did not affect herbivory of canopy foliage.
4. The soil warming decreased herbivory of canopy foliage.
5. The soil warming decreased nitrogen concentrations and increased CN ratios in canopy foliage.
6. The decrease in herbivory by soil warming can be explained by changes in nitrogen and CN ratio of canopy foliage.

These results implies that herbivore insect abundance would decrease on canopy oak trees, if this global warming last.

Future works

To solve the response of northern forest ecosystems to global warming, we added **other tree species** to warming experiments.



Oak Experiment

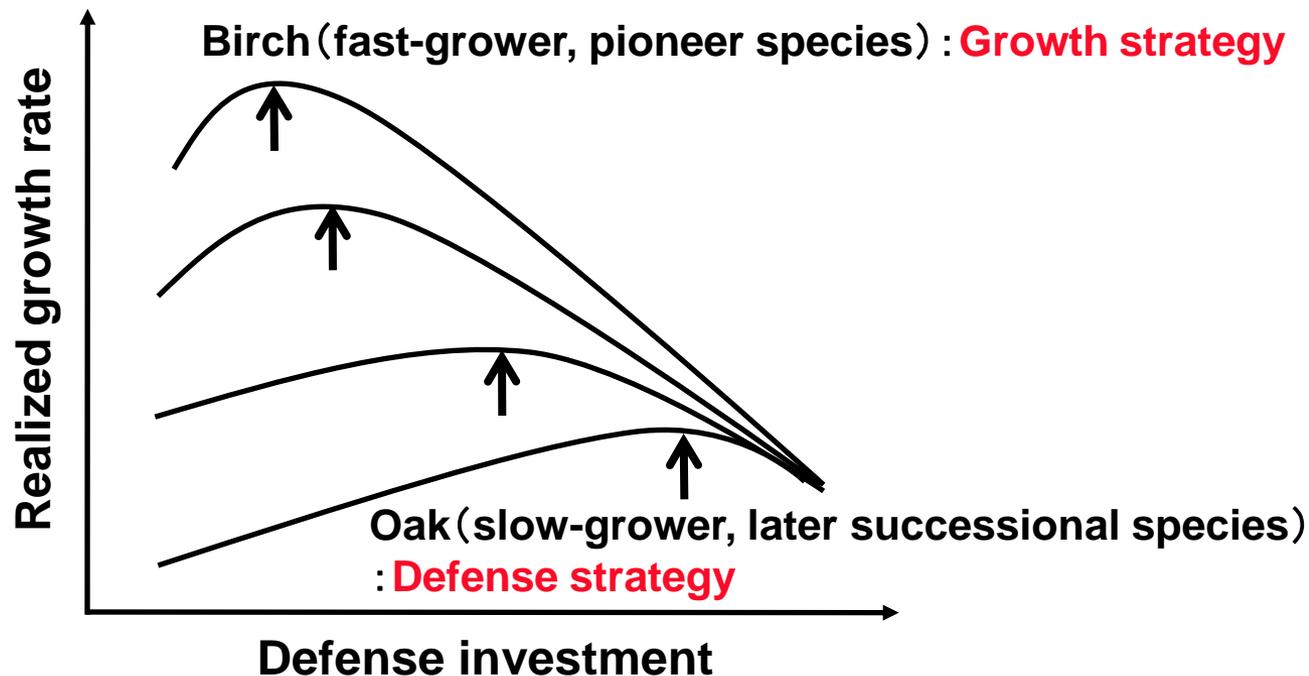


Birch Experiment

Nakagawa

Tomakomai

- ▶ Defense investment affects realized growth.
- ▶ Each curve represents a plant species with different maximum inherent growth rate.
- ▶ Levels of defense that maximize realized growth are indicated by an arrow (Coley *et al.* Science 1985).



Final Goal is to determine that the response to global warming may depend on life history of each tree species

Thank you.
Kiitos.
ありがとうございます。

Collaborators



Ms. Tayanagi



Dr. Muller



Dr. Nakaji



Dr. Oguma



Prof. Hiura

