

A photograph of a forest with a ground covered in red leaves. The trees are mostly bare, and the atmosphere is misty. The text is overlaid in the center.

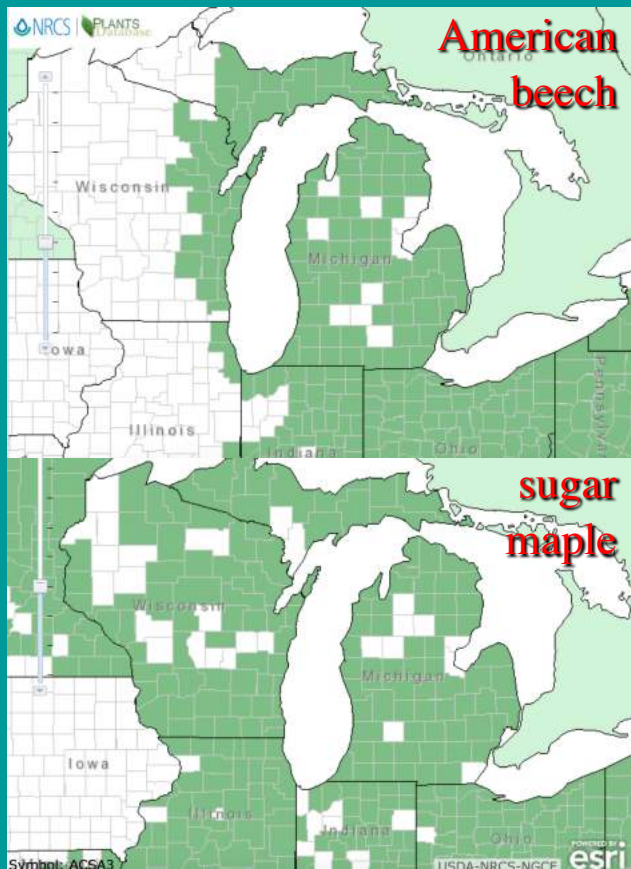
(Dis)Assembly of
the Great Lakes
Forests

The Questions

- **Pleistocene** placement of the forests - **where** did they hang out
- Holocene migrations - **how** and **when** did they **assemble** into the Great Lakes
- Recent past, present, and future changes – the **dis-assembly**?

Vegetation vs. Flora

- **Vegetation** refers to the physical appearance (physiognomy) of the forest type - **ecology driven**
- **Flora** refers to the species (genus, family) composition of any given forest - **history driven**



Northern hardwood forests in WI and MI have sugar maple, but beech co-dominates mainly in MI

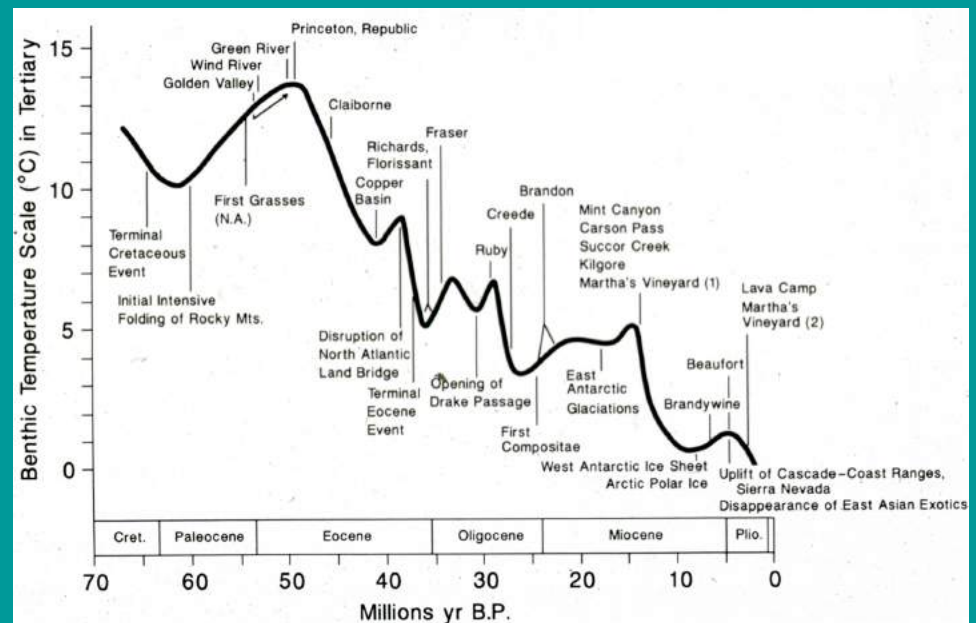


Pleistocene - the Ice Ages



Maximum extent of glaciation in the most recent or Wisconsin stage (Pleistocene epoch).

- The vegetation and flora as we see it now (Holocene) was dramatically affected by Pleistocene events

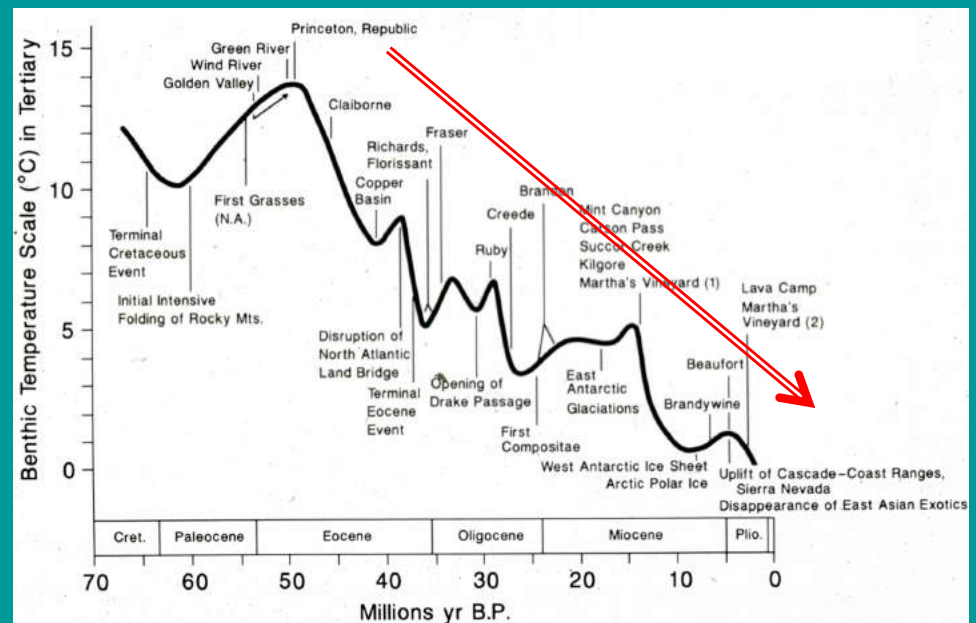


Pleistocene - the Ice Ages



Maximum extent of glaciation in the most recent or Wisconsin stage (Pleistocene epoch).

- In the Tertiary, earth experienced intensification towards climatic cooling
- Culminated with a series of glacial-interglacial cycles in **Pleistocene**
- North American flora and vegetation profoundly influenced by these “ice-age” events



Pleistocene - the Ice Ages

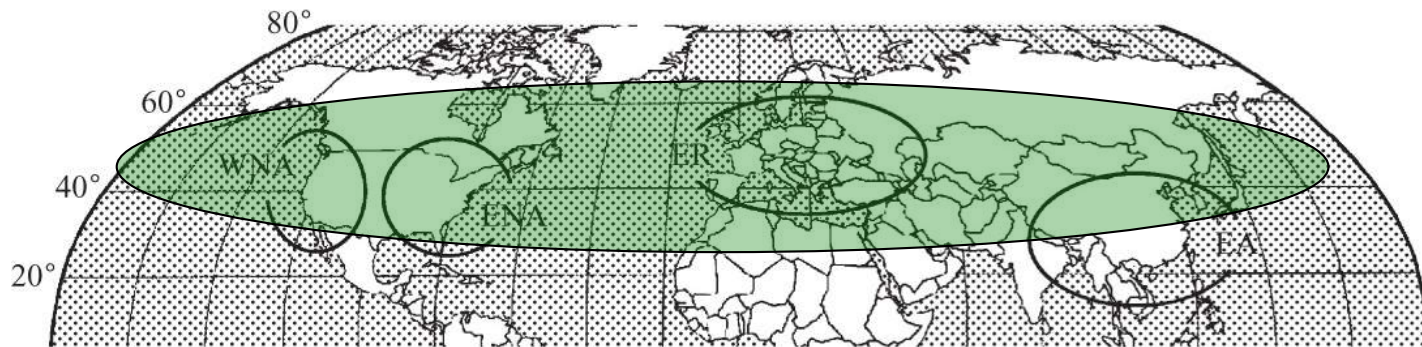


Figure 1. Map of the Northern Hemisphere showing the four major areas of temperate forest endemism that are the focus of the present analysis; EA: eastern Asia; ER: Europe (including southwestern Asia); ENA: eastern North America; WNA: western North America.

Break-up of the great Northern Hemisphere **Arcto-Tertiary** forests

Pleistocene - the Ice Ages



Maximum extent of glaciation
in the most recent or Wisconsin stage
(Pleistocene epoch).

- **Wisconsin glaciation** (last epoch) most important - maximum at 18,000 ya
- Assembly of **flora** and **vegetation** of most Great Lakes was during the late Pleistocene and Holocene - (14,000 ya to present)

Pleistocene - the Ice Ages



Maximum extent of glaciation
in the most recent or Wisconsin stage
(Pleistocene epoch).

Ice-free Areas

- **Southern** North America of glaciers
- **Beringia**, much of Alaska, Siberia
- **Coastal plains**, steep coastlines of Pacific northwest
- **Wisconsin Driftless Area** - never completely surrounded by ice

Pleistocene - the Ice Ages



Ice-free Areas

- North America south of glaciers
- **Beringia**, much of Alaska, Siberia
- **Coastal plains**, steep coastlines of Pacific northwest
- **Wisconsin Driftless Area** - never completely surrounded by ice

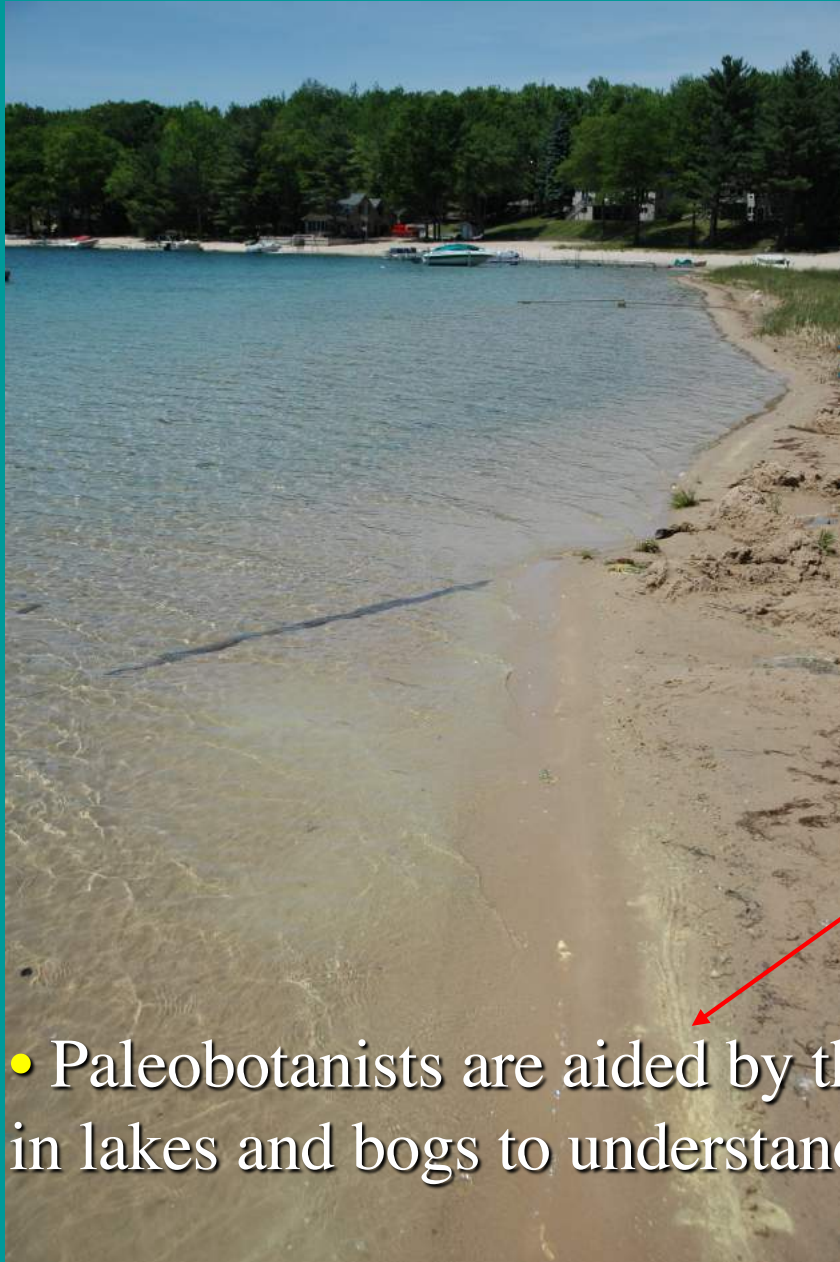
Pleistocene - the Ice Ages

What was happening **south** of the glacial maxima?

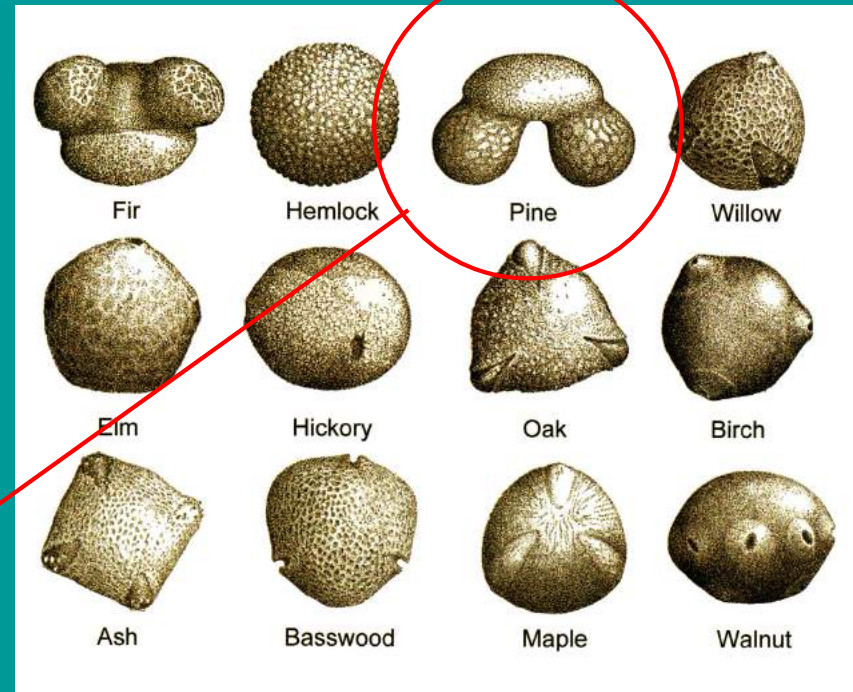


Maximum extent of glaciation in the most recent or Wisconsin stage (Pleistocene epoch).

Pleistocene - the Ice Ages



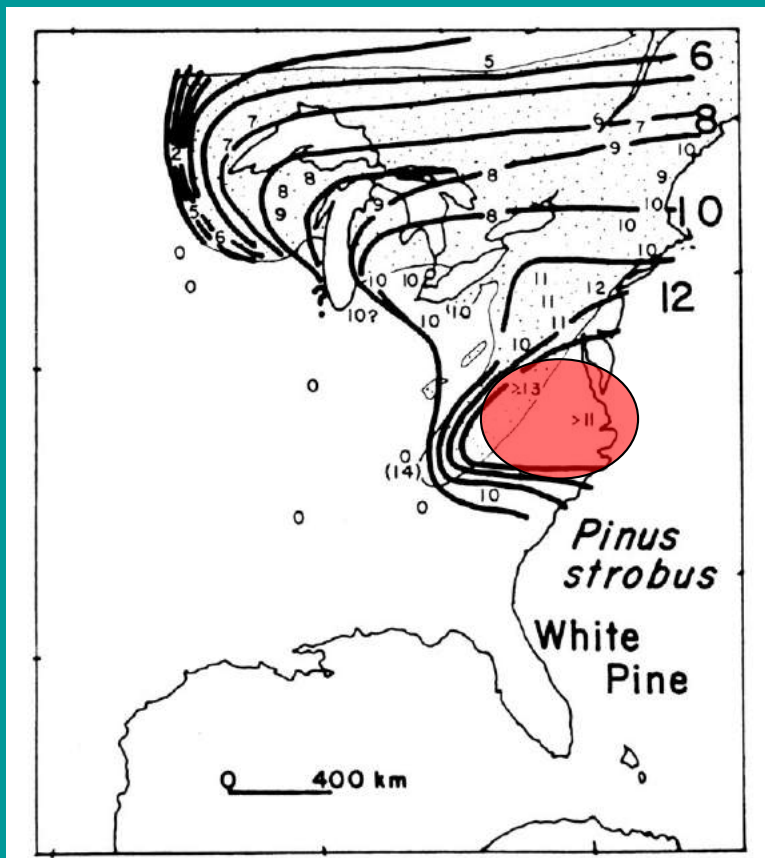
Yearly deposits accumulate in lake bottoms to be covered by silt in layers, or in bog peat strata



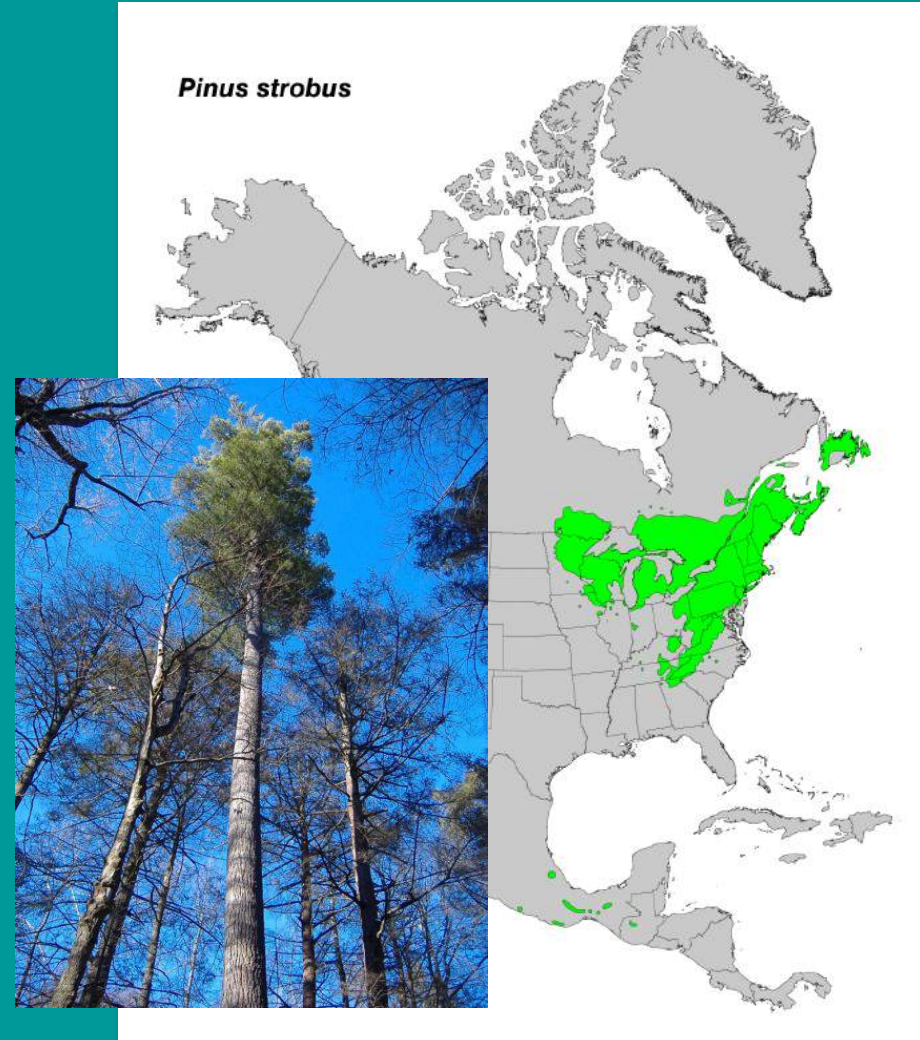
- Paleobotanists are aided by the **pollen record** (especially trees) in lakes and bogs to understand Pleistocene vegetation and flora

Assembly of Flora & Vegetation

Importantly, the different species of trees (and herbs) entering the Great Lakes region after the glaciers retreated entered via different routes - that is, they came from different **refugia** or **survivia**

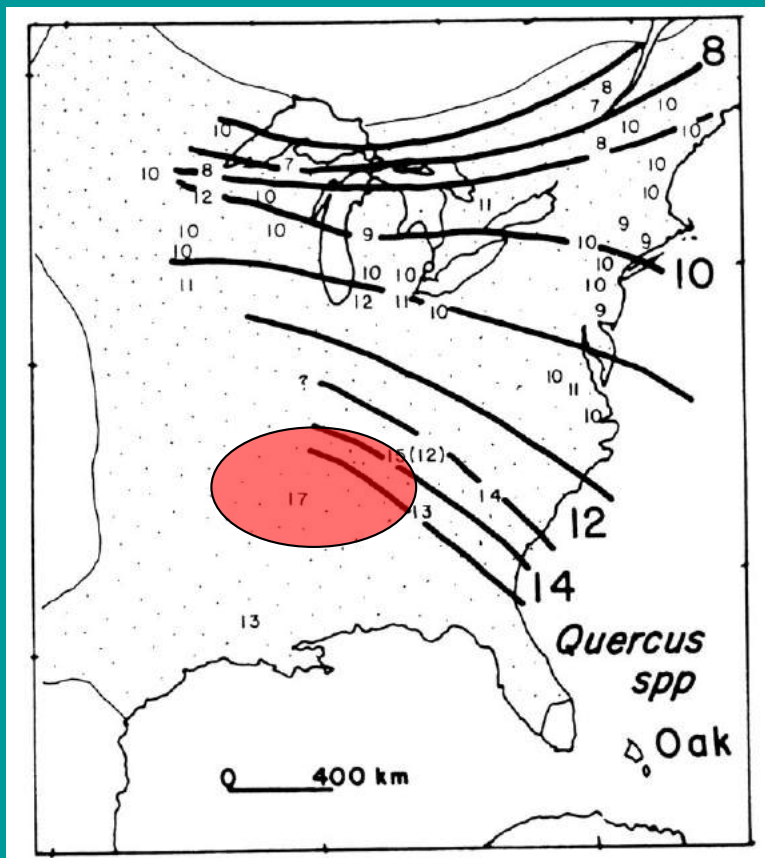


White pine from the **Alleghenian** refugium and present distribution

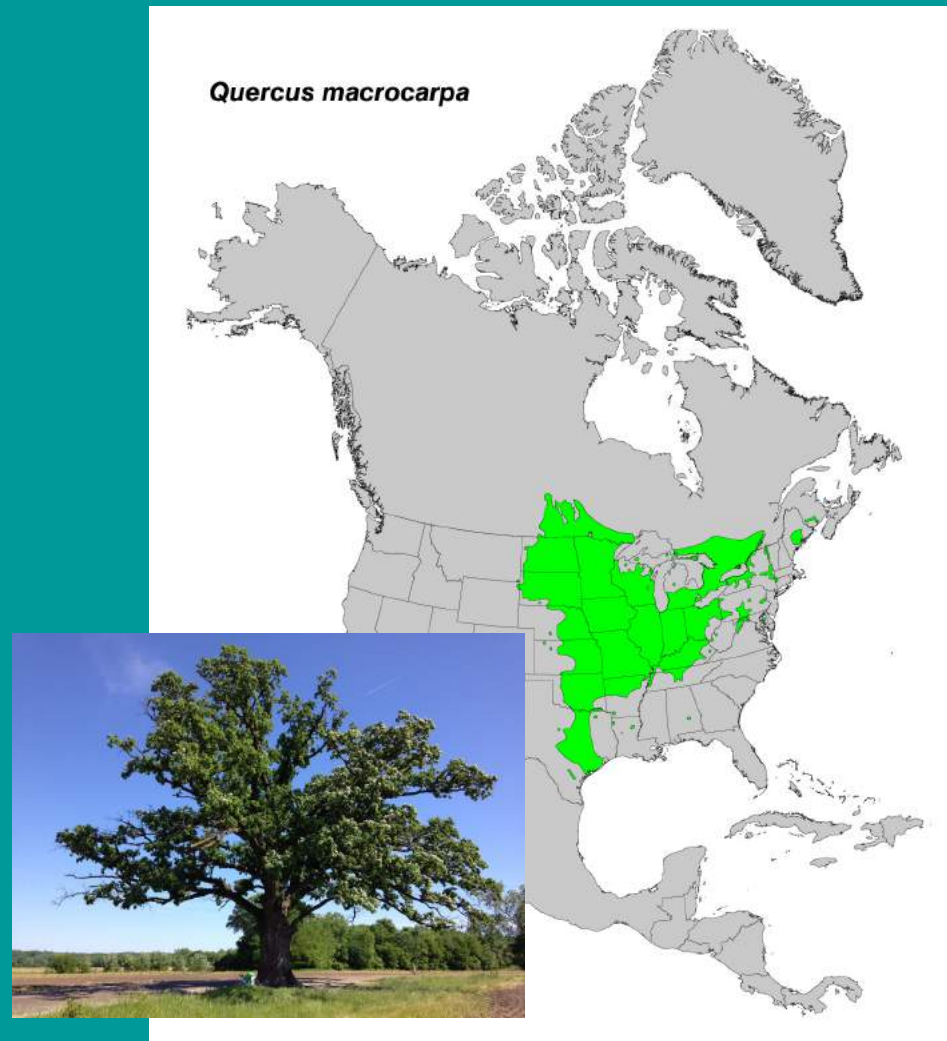


Assembly of Flora & Vegetation

Importantly, the different species of trees (and herbs) entering the Great Lakes region after the glaciers retreated entered via different routes - that is, they came from different **refugia** or **survivia**

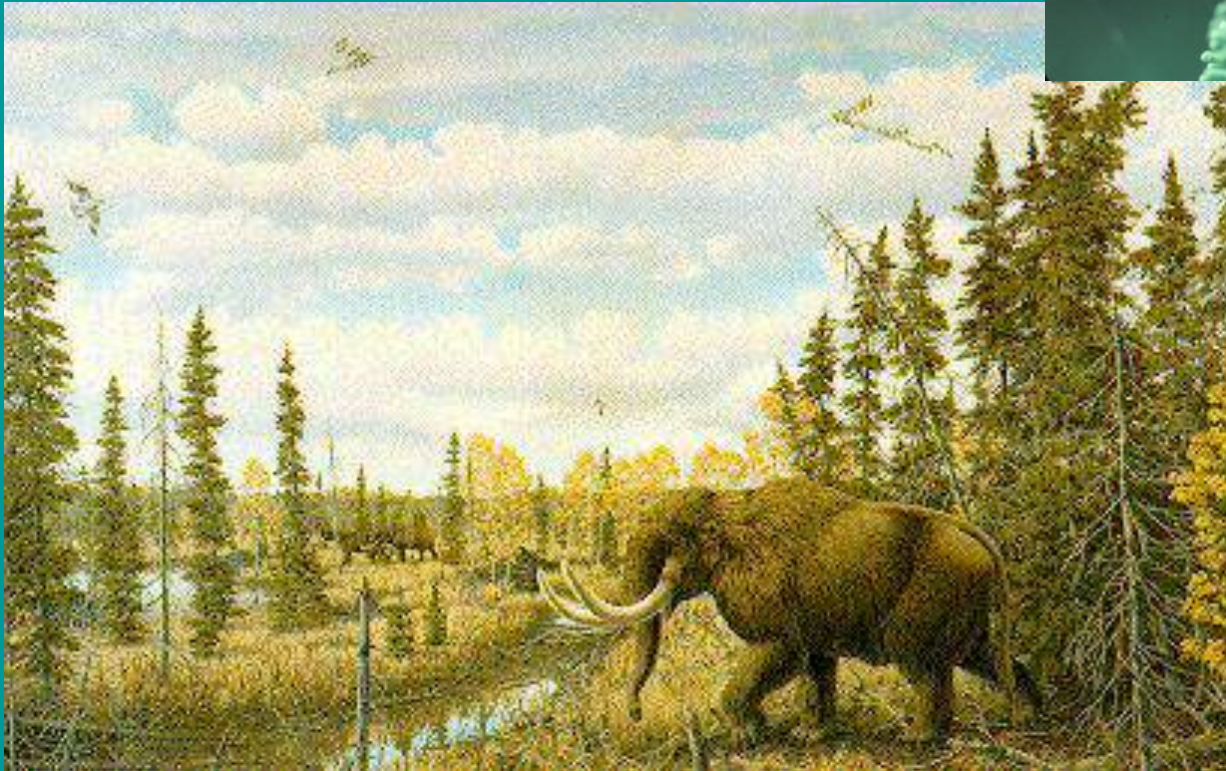


Bur oak from the **Ozarkian** refugium and present distribution



Pleistocene - the Ice Ages

- Much of eastern North America outside these refugia would have looked like this boreal scene



White spruce - *Picea glauca*

Most widespread tree in North America

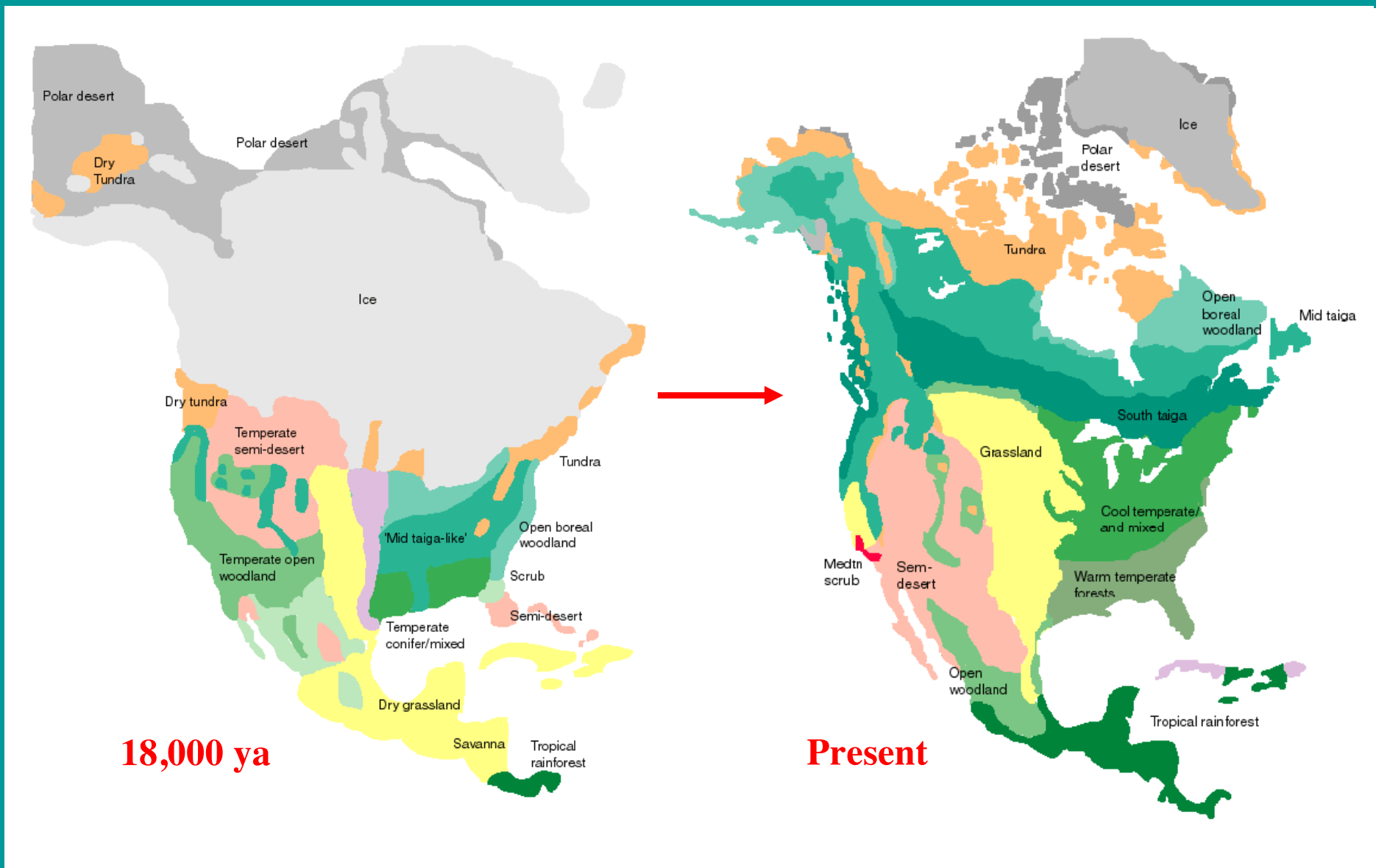
Illinois 16K years ago

The Questions

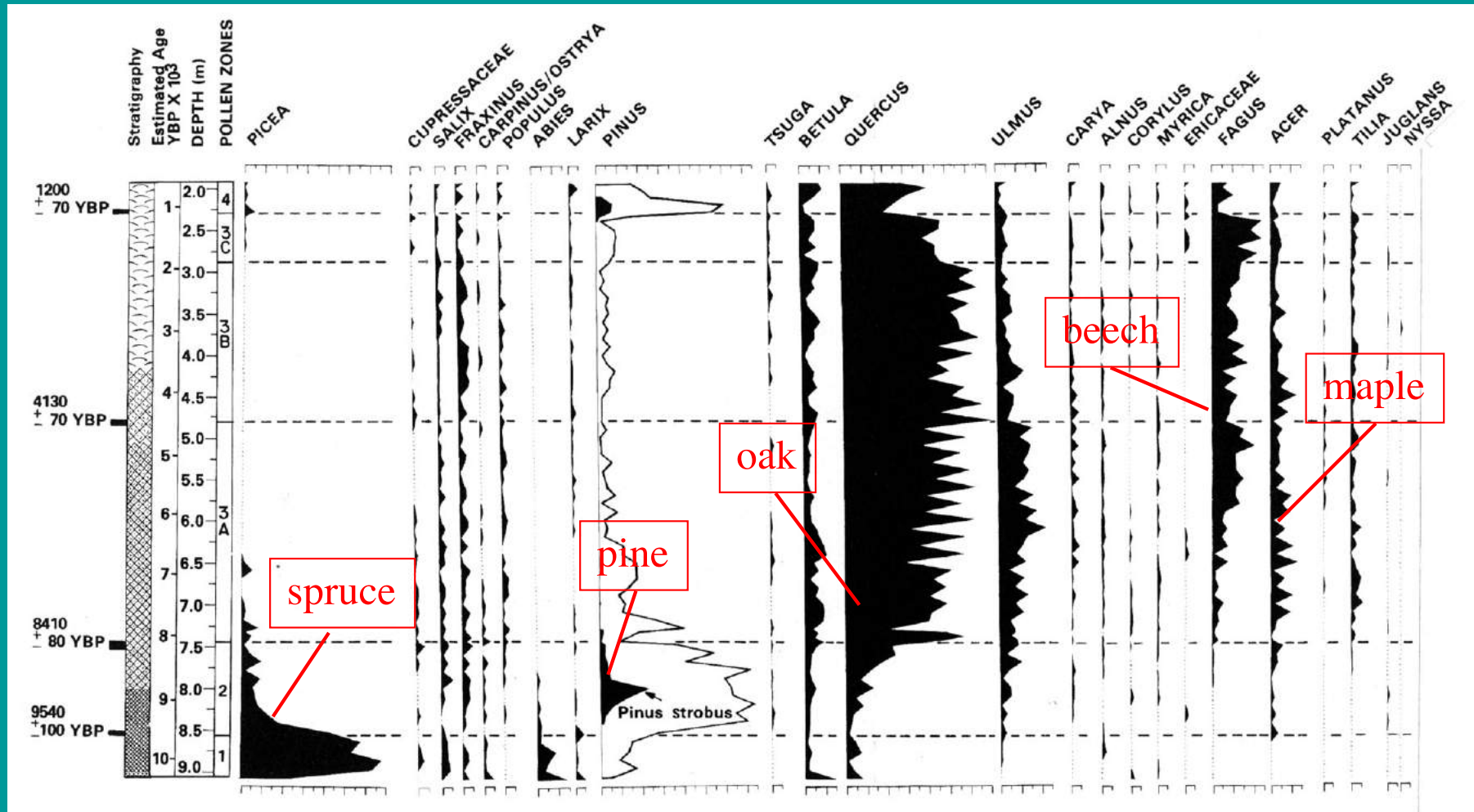
- Pleistocene placement of the forests - where did they hang out
- Holocene migrations - how and when did they assemble into the Great Lakes
- Recent past, present, and future changes – the dis-assembly?

Assembly of Flora & Vegetation

How and when did this assembly in the Great Lakes happen?

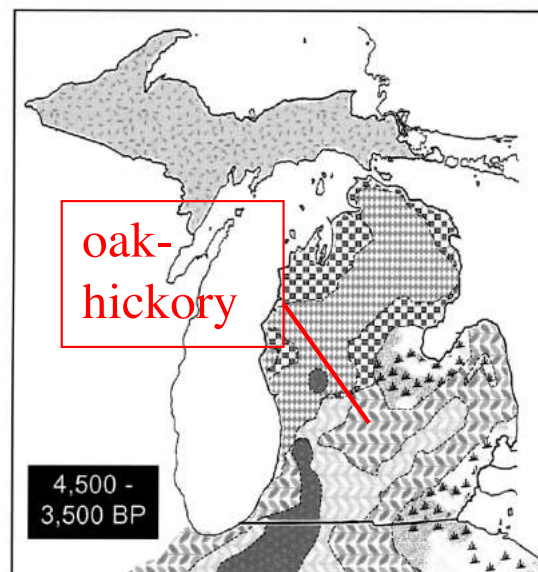
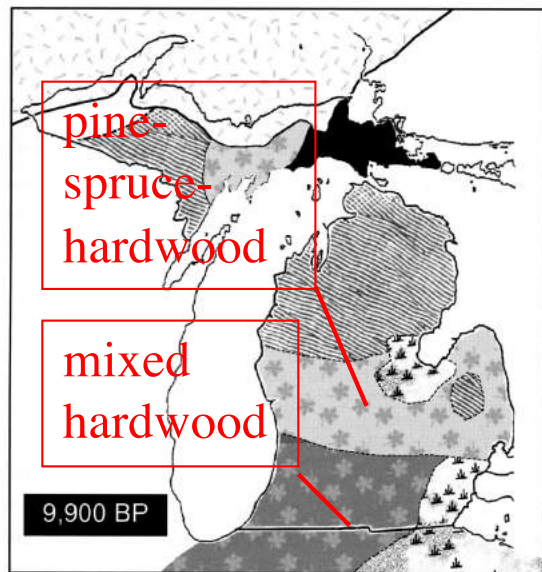
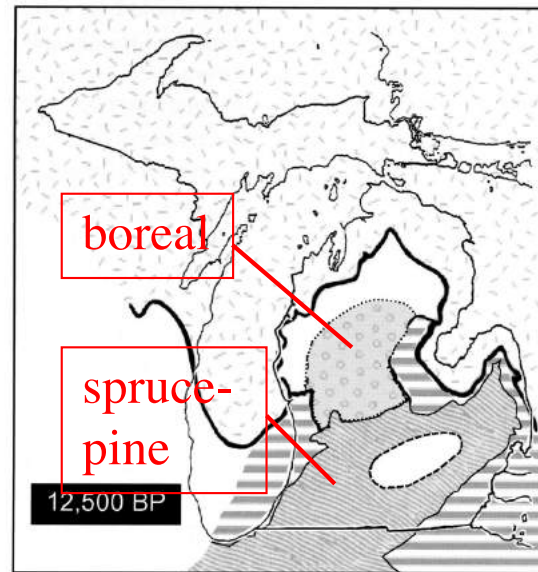
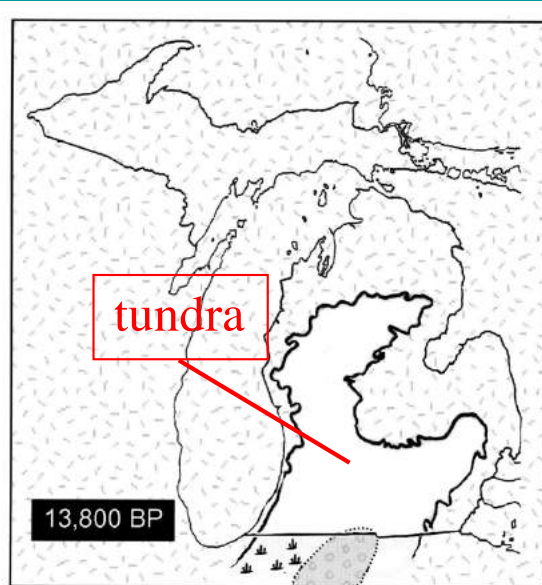


Assembly of Flora & Vegetation



















- Pollen record shows **waves of species** over time
- Boreal elements (spruce) early in the Holocene, followed by pines, and then oaks, maples and lastly beech

Assembly of Flora & Vegetation



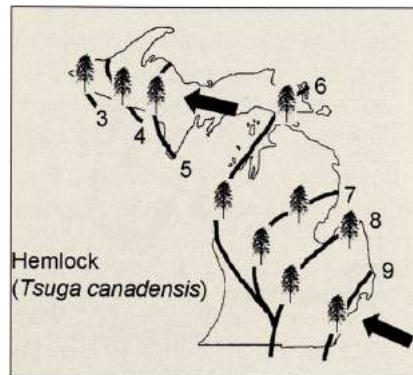
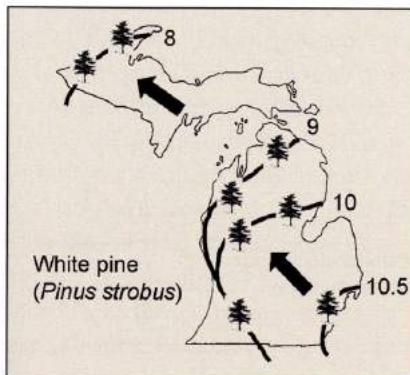
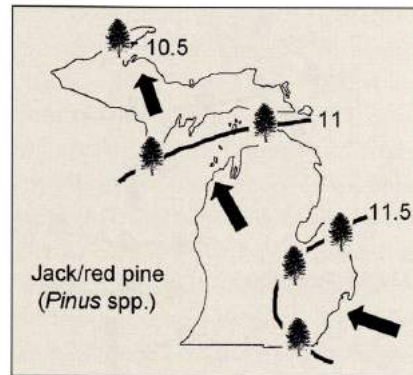
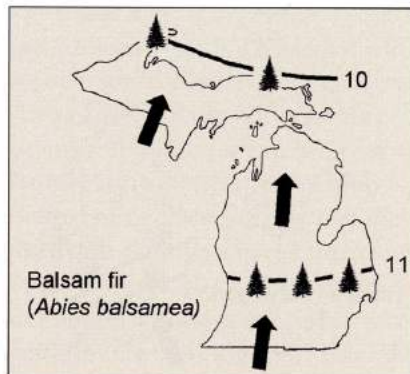
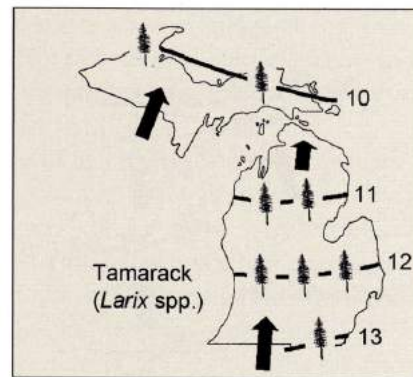
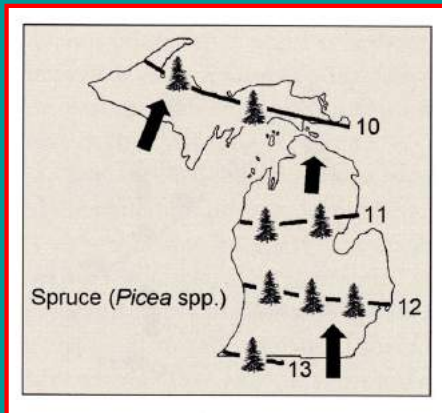
Shifts of vegetation belts starting at about 13,000 ya with tundra, spruce, pine, northern hardwood, pine-oak, and then oak-hickory

-  glacier
-  tundra
-  boreal parkland
-  wetlands
-  proglacial lakes
-  spruce-pine forest
-  spruce forest
-  pine-spruce-hardwood forest
-  mixed conifer and northern hardwood forest
-  swamp hardwood forest, marshes and wetlands
-  northern hardwood forest
-  mixed pine forest
-  pine-oak forest
-  oak-hickory forest
-  beech-maple forest
-  prairie/oak savanna

Assembly of Flora & Vegetation

Coniferous species migrated into the Great Lakes region in waves (flora):

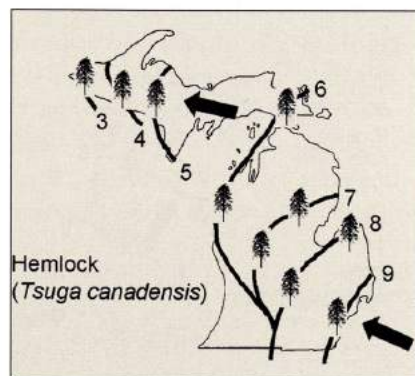
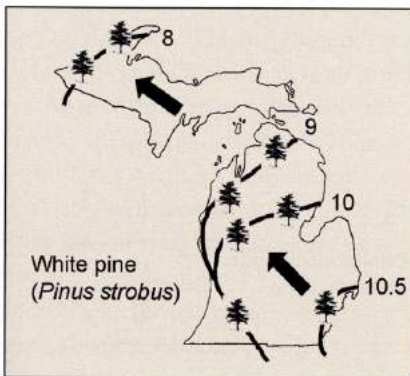
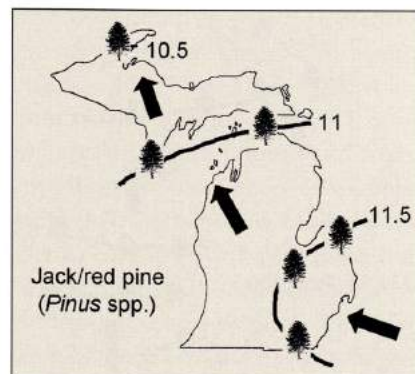
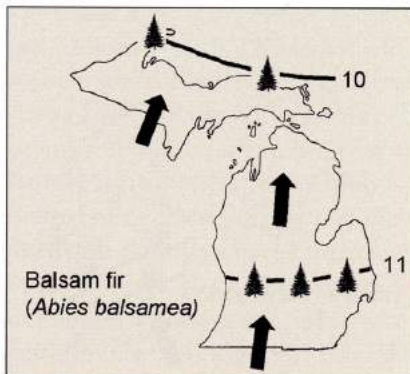
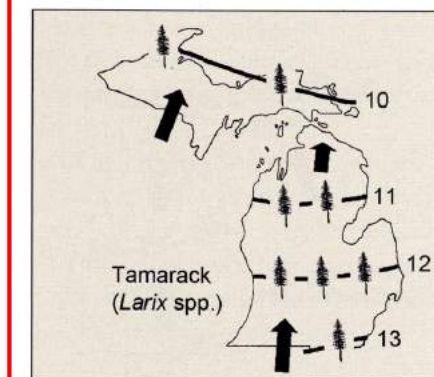
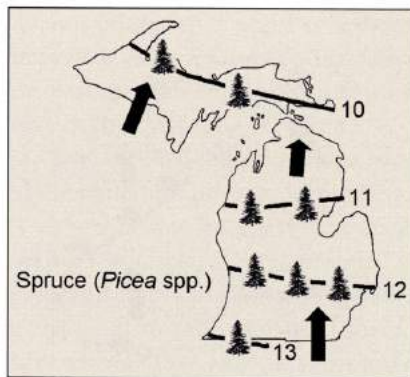
Boreal species like **spruce** & tamarack arrived first



Assembly of Flora & Vegetation

Coniferous species migrated into the Great Lakes region in waves (**flora**):

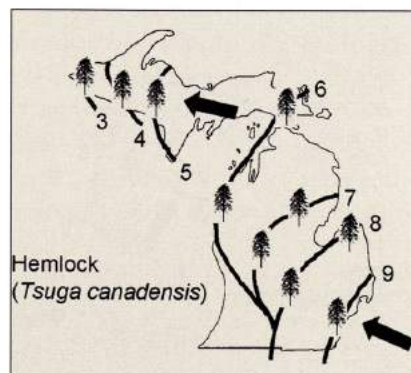
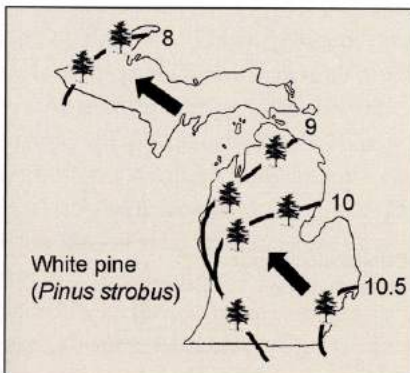
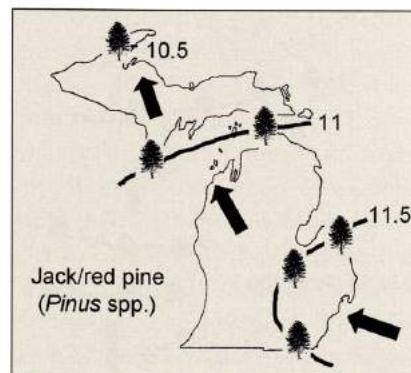
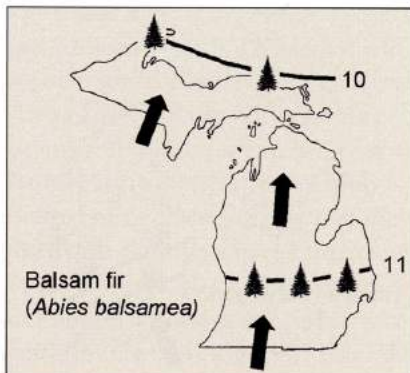
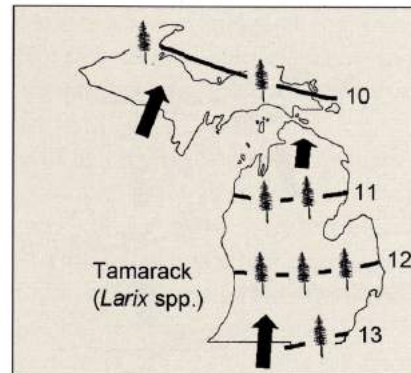
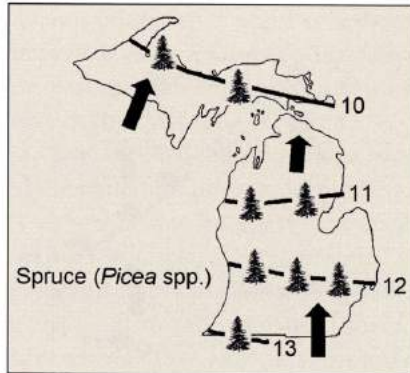
Boreal species like spruce & **tamarack** arrived first



Assembly of Flora & Vegetation

Coniferous species migrated into the Great Lakes region in waves (**flora**):

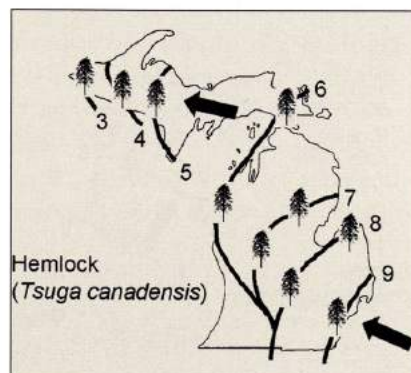
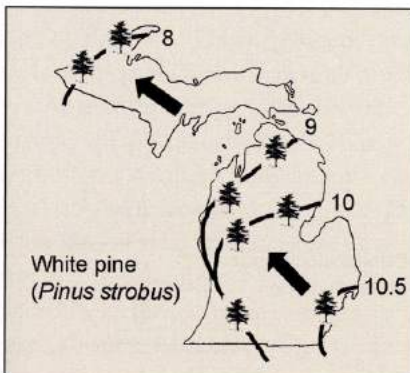
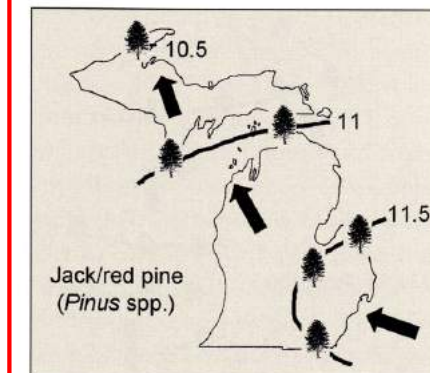
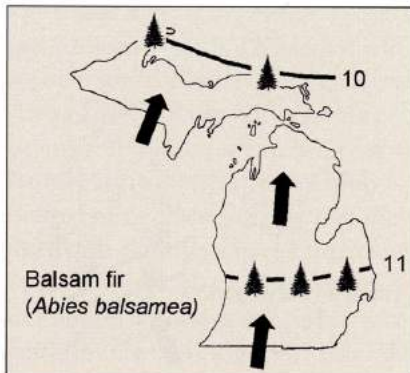
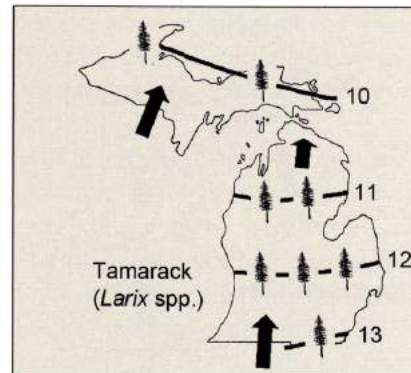
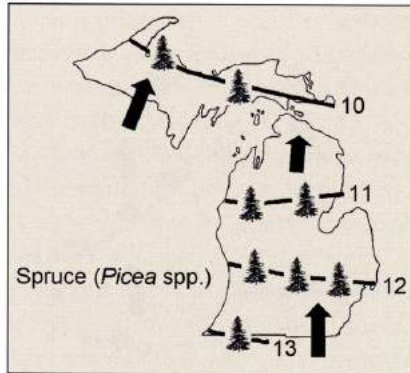
Boreal species like spruce & tamarack arrived first, and later **balsam fir**



Assembly of Flora & Vegetation

Coniferous species migrated into the Great Lakes region in waves (**flora**):

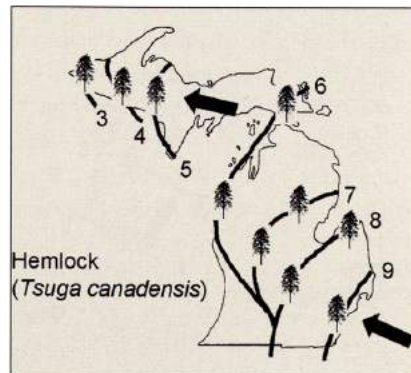
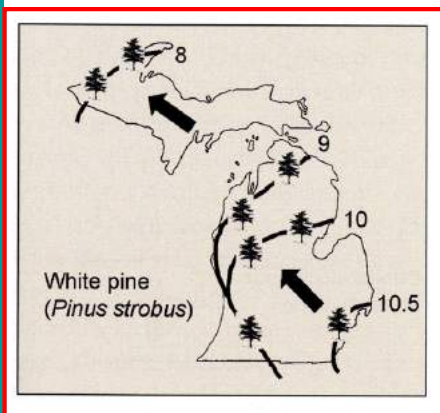
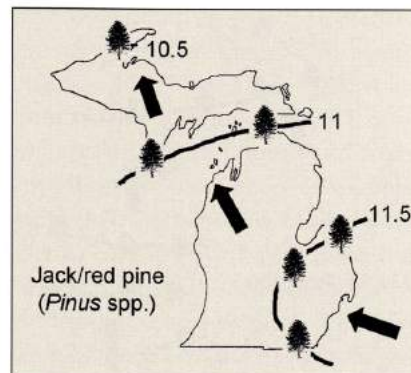
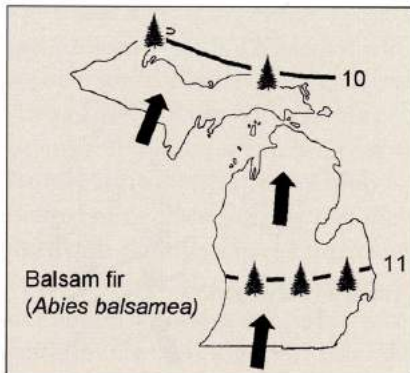
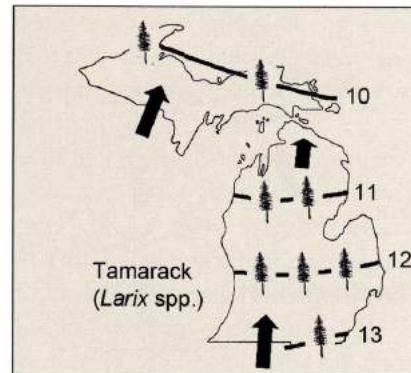
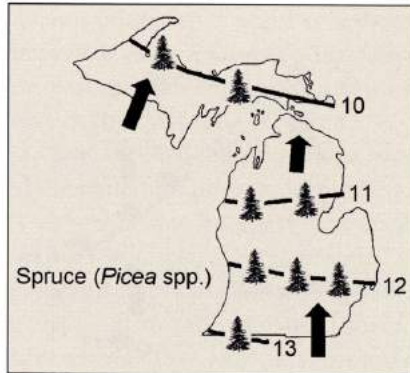
Of pine species, xeric **jack pine** and red pine arrived first



Assembly of Flora & Vegetation

Coniferous species migrated into the Great Lakes region in waves (**flora**):

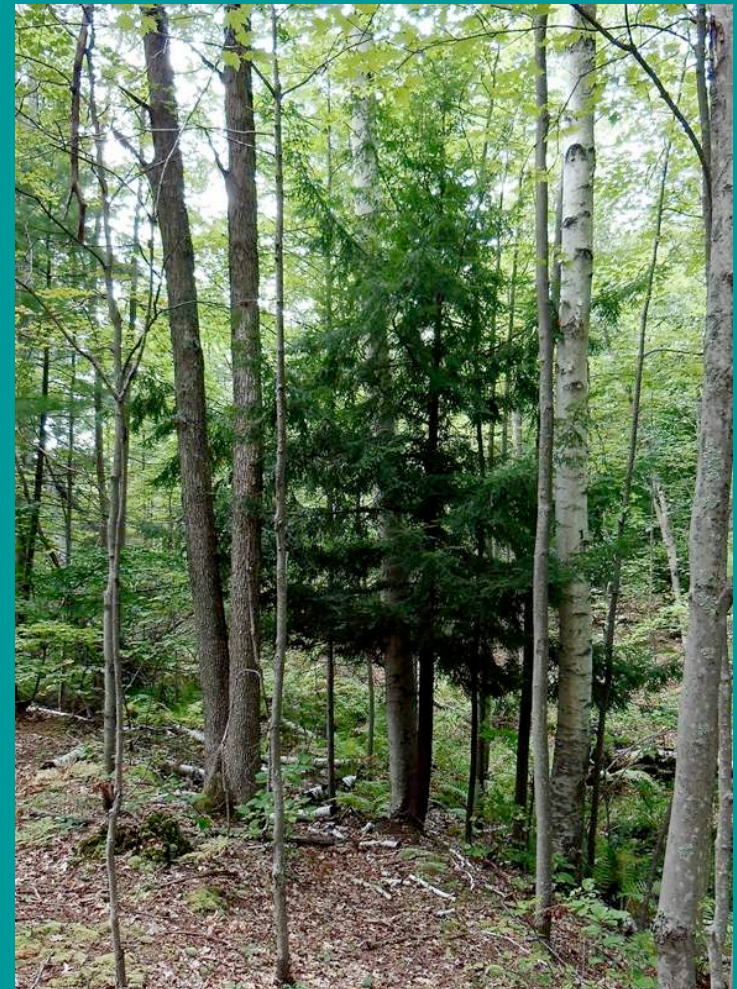
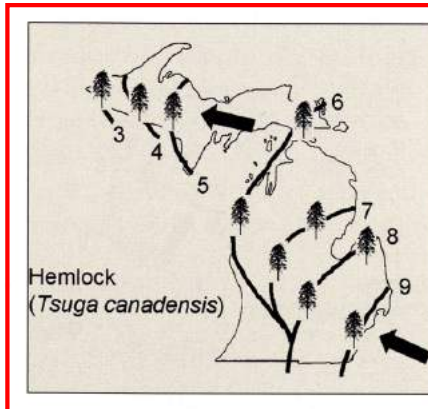
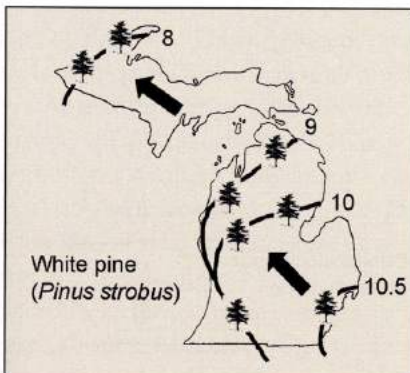
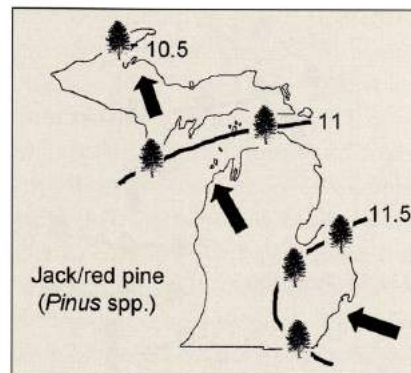
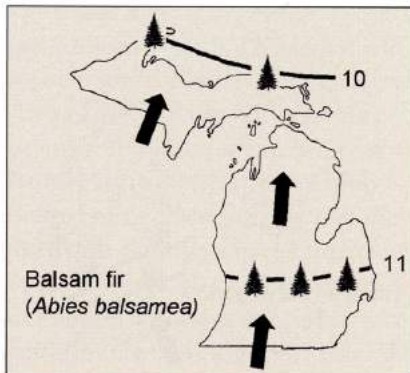
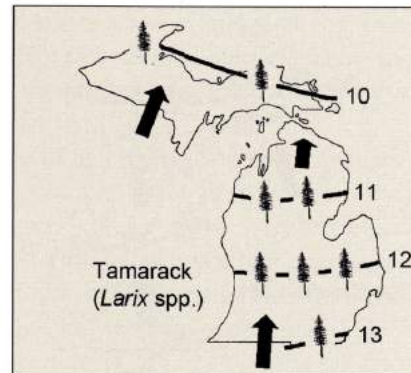
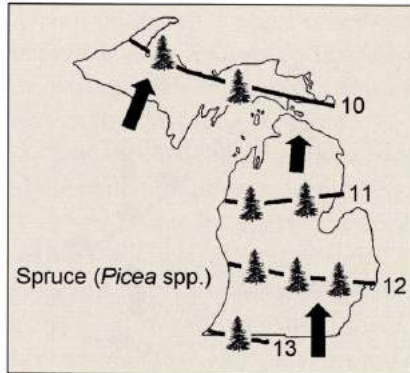
... followed by more mesic loving **white pine**



Assembly of Flora & Vegetation

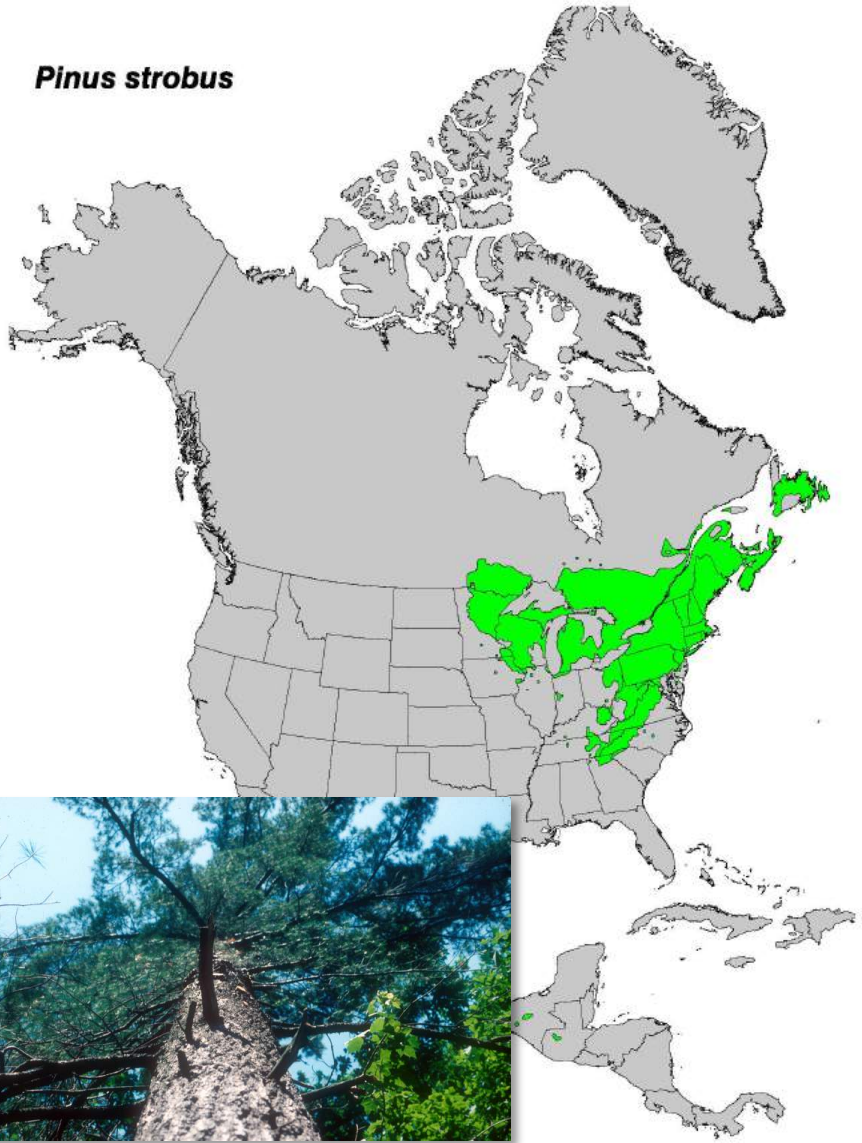
Coniferous species migrated into the Great Lakes region in waves (flora):

Hemlock, characteristic of mesic Northern Hardwood forests, arrived last



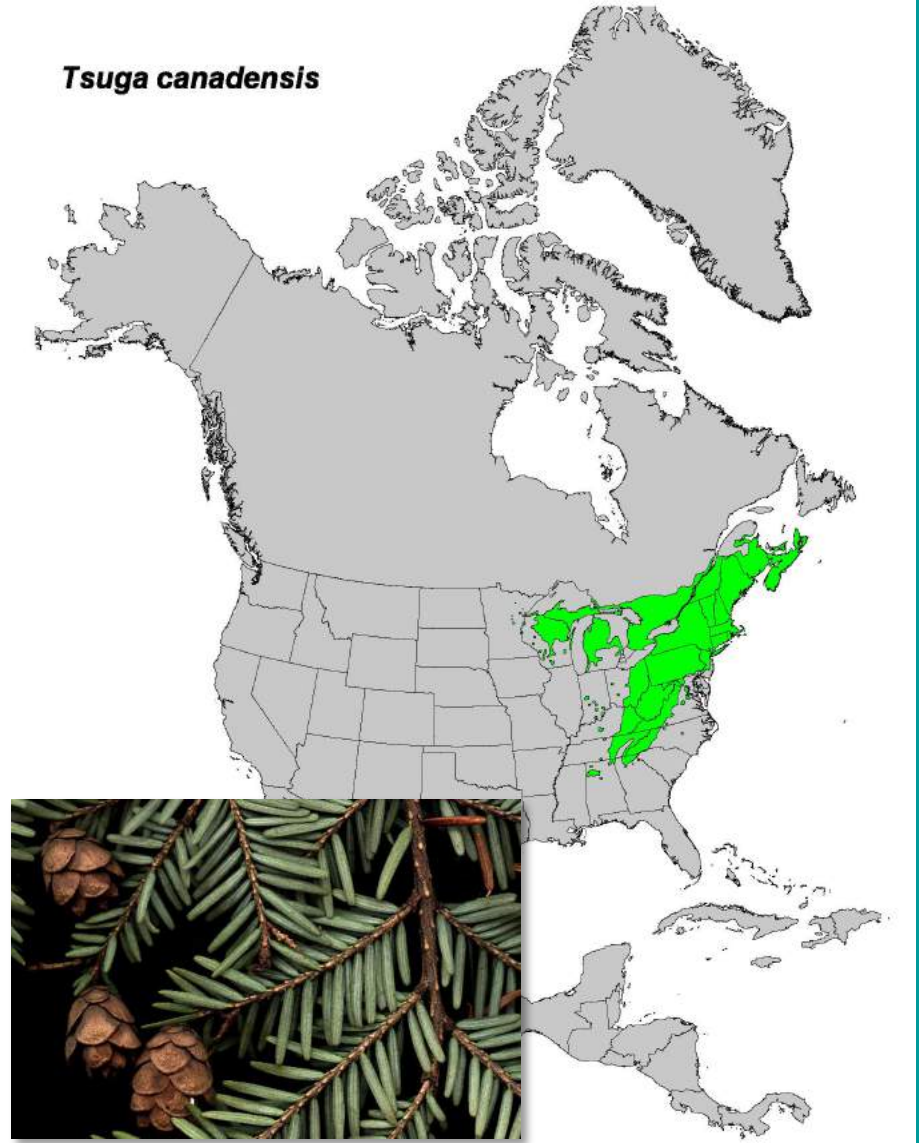
Dis-assembly of the forests?

Pinus strobus



Pinus strobus - white pine

Tsuga canadensis

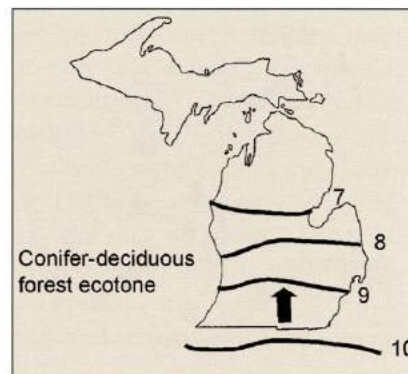
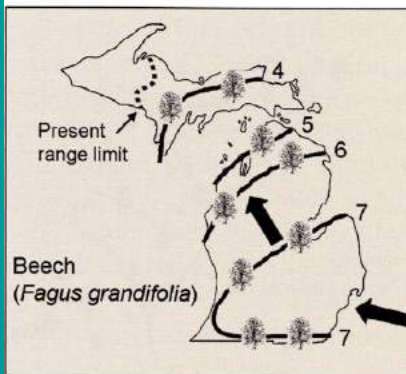
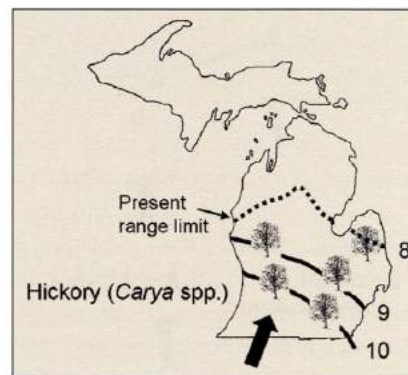
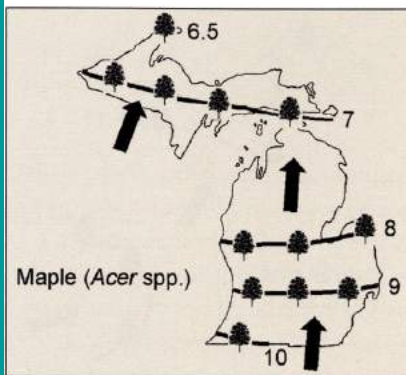
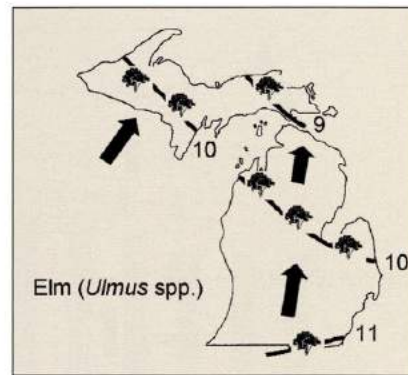
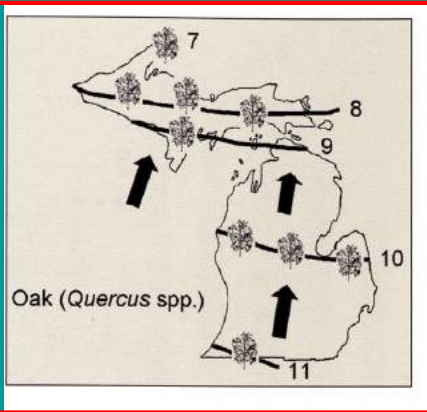


Tsuga canadensis - hemlock

Assembly of Flora & Vegetation

Angiosperm hardwoods migrated into the Great Lakes region in waves towards the end of conifer migration:

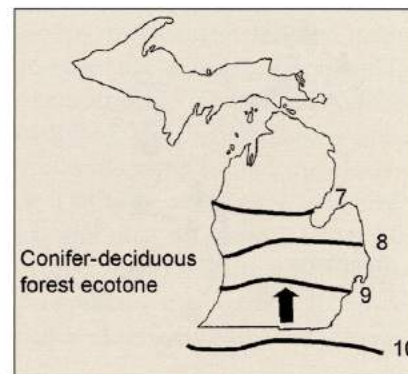
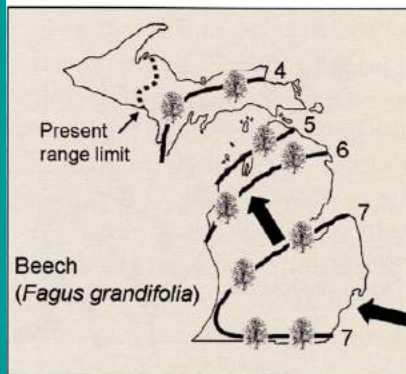
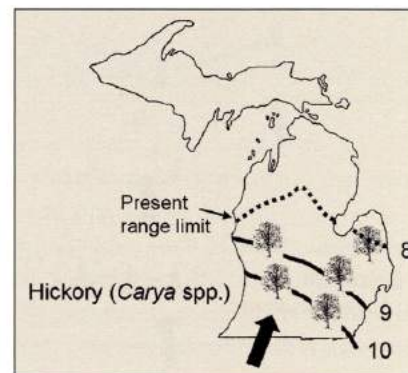
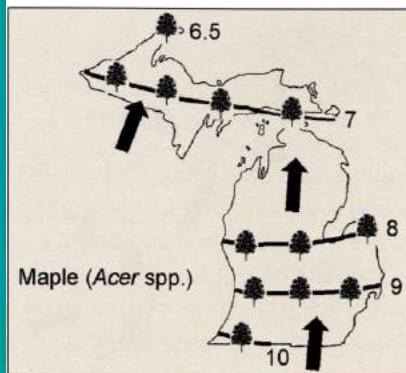
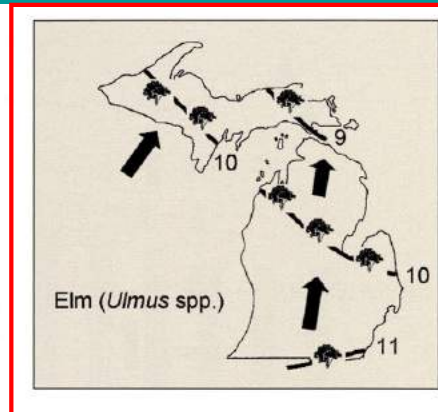
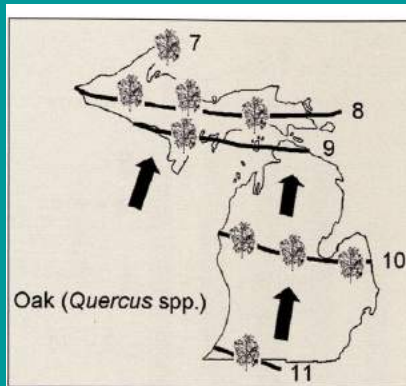
Oaks arrived first from the south - 11,000 ya



Assembly of Flora & Vegetation

Angiosperm hardwoods migrated into the Great Lakes region in waves towards the end of conifer migration:

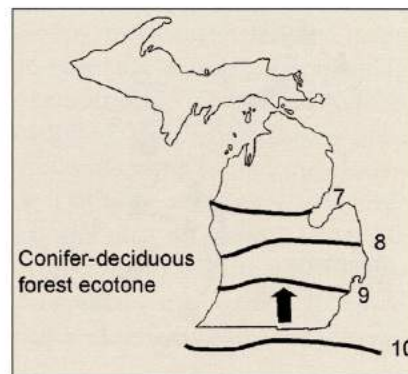
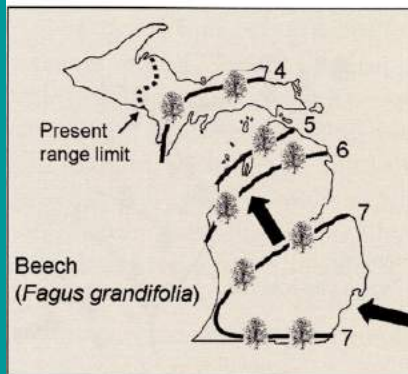
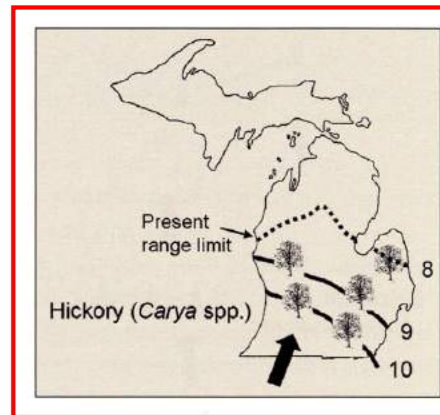
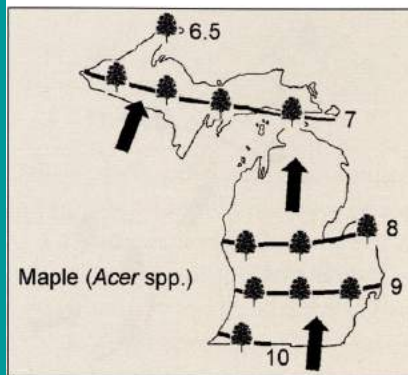
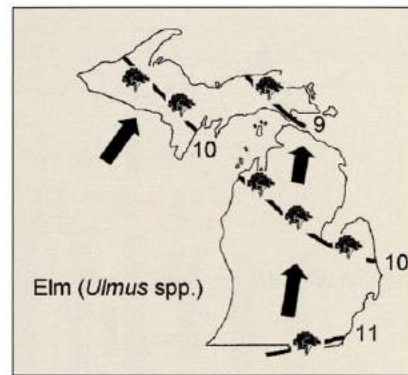
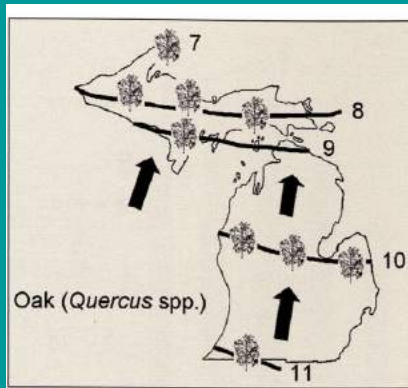
Elms arrived at about the same time from the southeast - 11,000 ya



Assembly of Flora & Vegetation

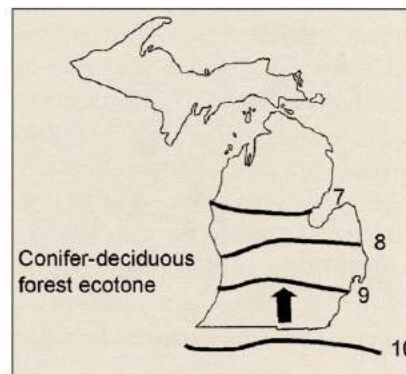
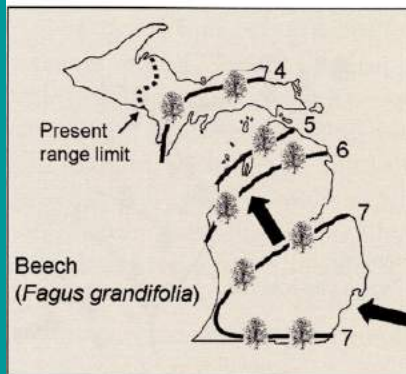
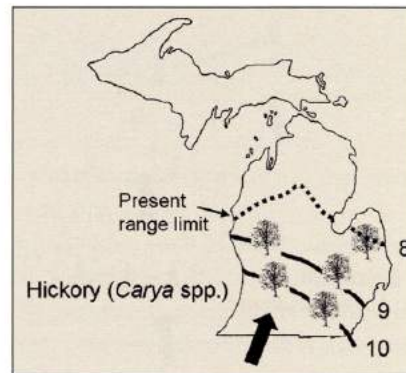
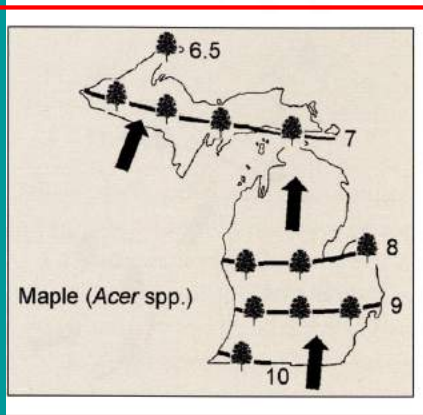
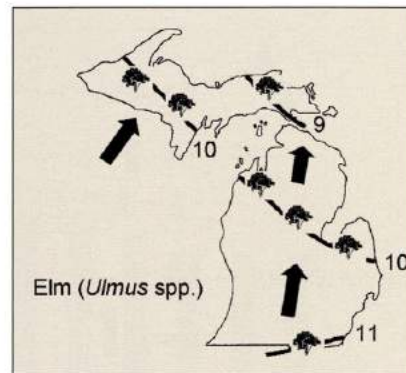
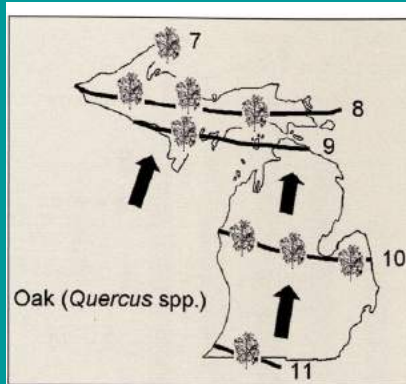
Angiosperm hardwoods migrated into the Great Lakes region in waves towards the end of conifer migration:

Hickories arrived shortly thereafter from the southwest - 10,500 ya



Assembly of Flora & Vegetation

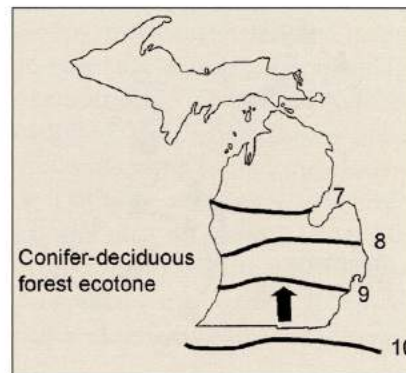
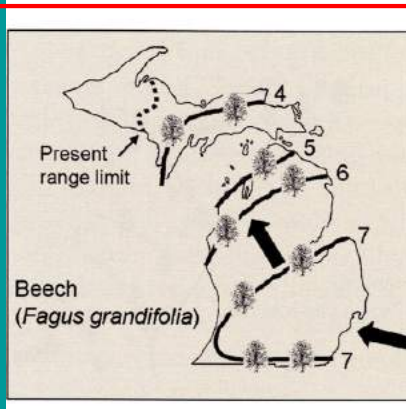
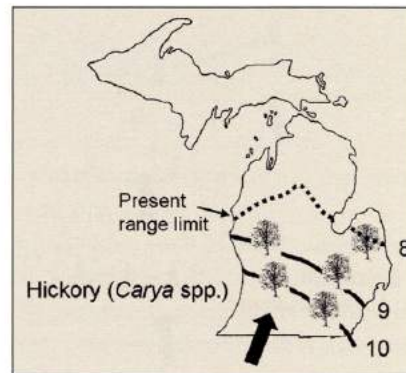
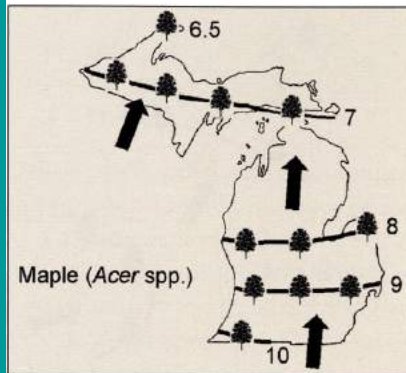
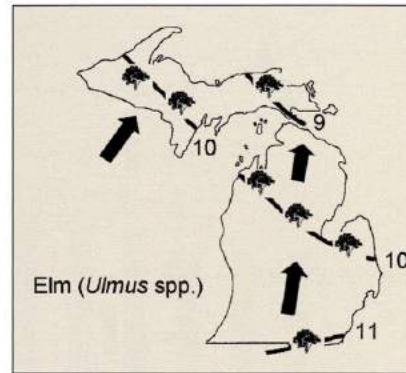
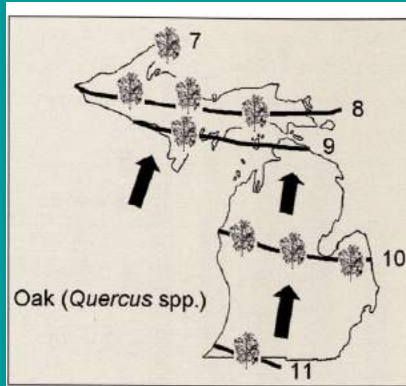
Angiosperm hardwoods migrated into the Great Lakes region in waves towards the end of conifer migration:
Followed by mesic-loving **maples** . . .



Assembly of Flora & Vegetation

Angiosperm hardwoods migrated into the Great Lakes region in waves towards the end of conifer migration:

... and finally **American beech** last



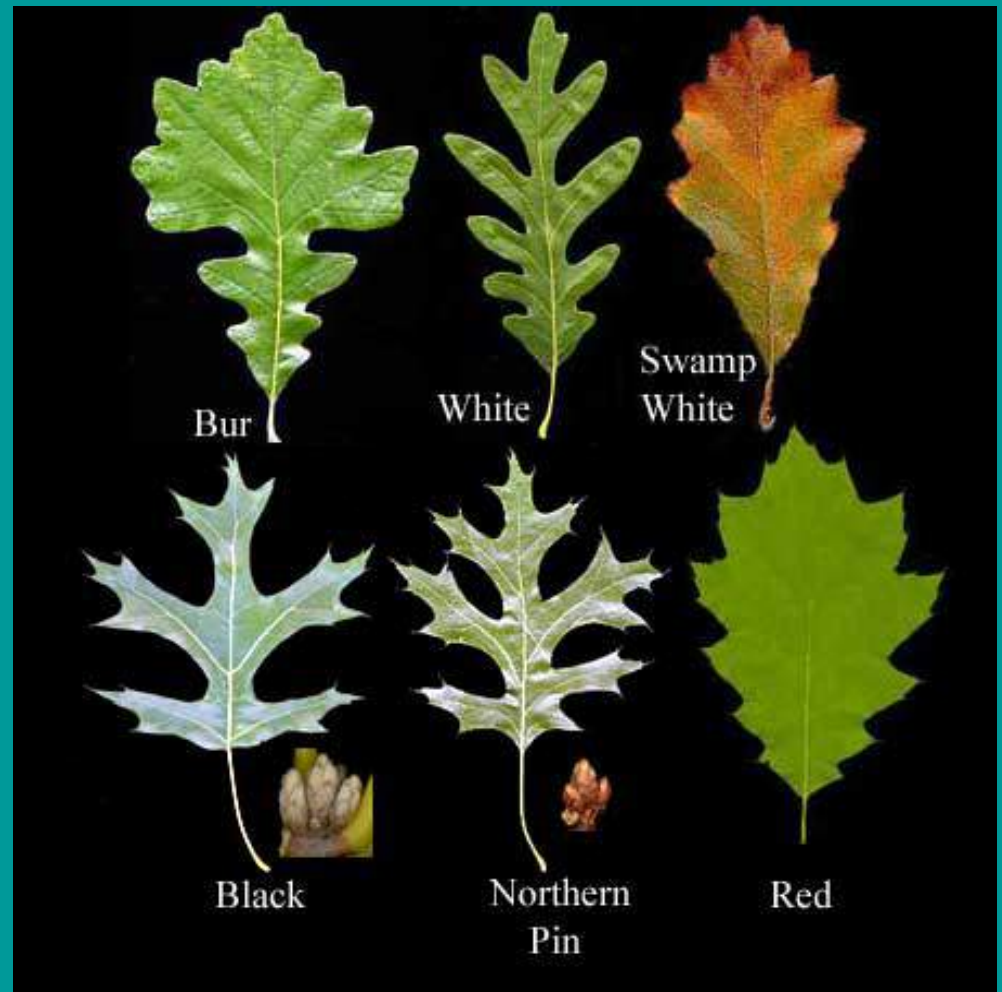
Assembly of Flora & Vegetation

The flora of the Great Lakes can be divided into a number of **elements**, each of which shares a **common geographical origin** (refugia).

Closely related species (such as oaks) can often be part of different floristic elements.

This is due to both different ecological preferences (such as hydric vs. mesic vs. xeric) and to geographical origin.

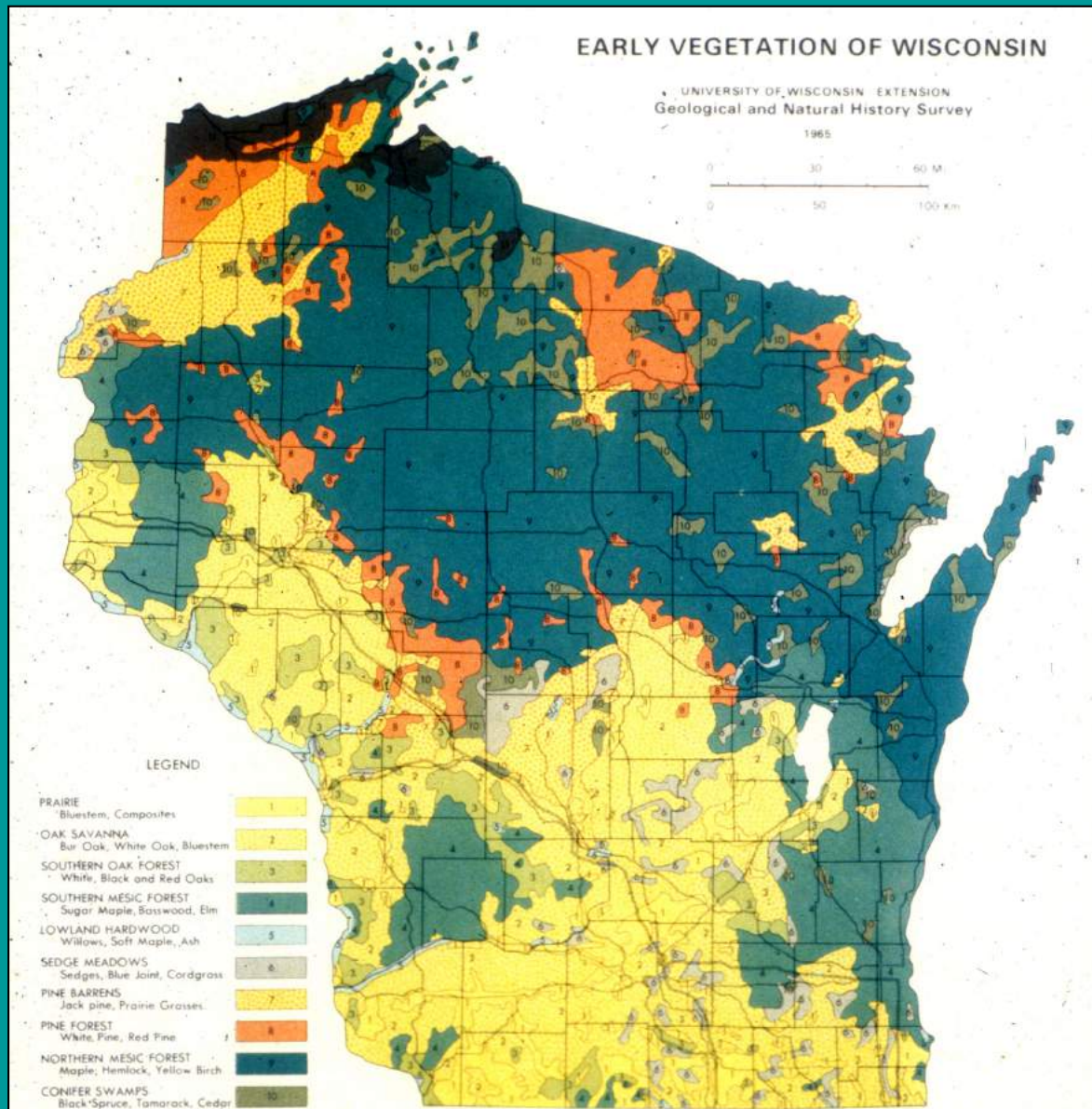
Quercus - the oaks



The Questions

- Pleistocene placement of the forests - where did they hang out
- Holocene migrations - how and when did they assemble into the Great Lakes
- Recent past, present, and future changes – the dis-assembly?

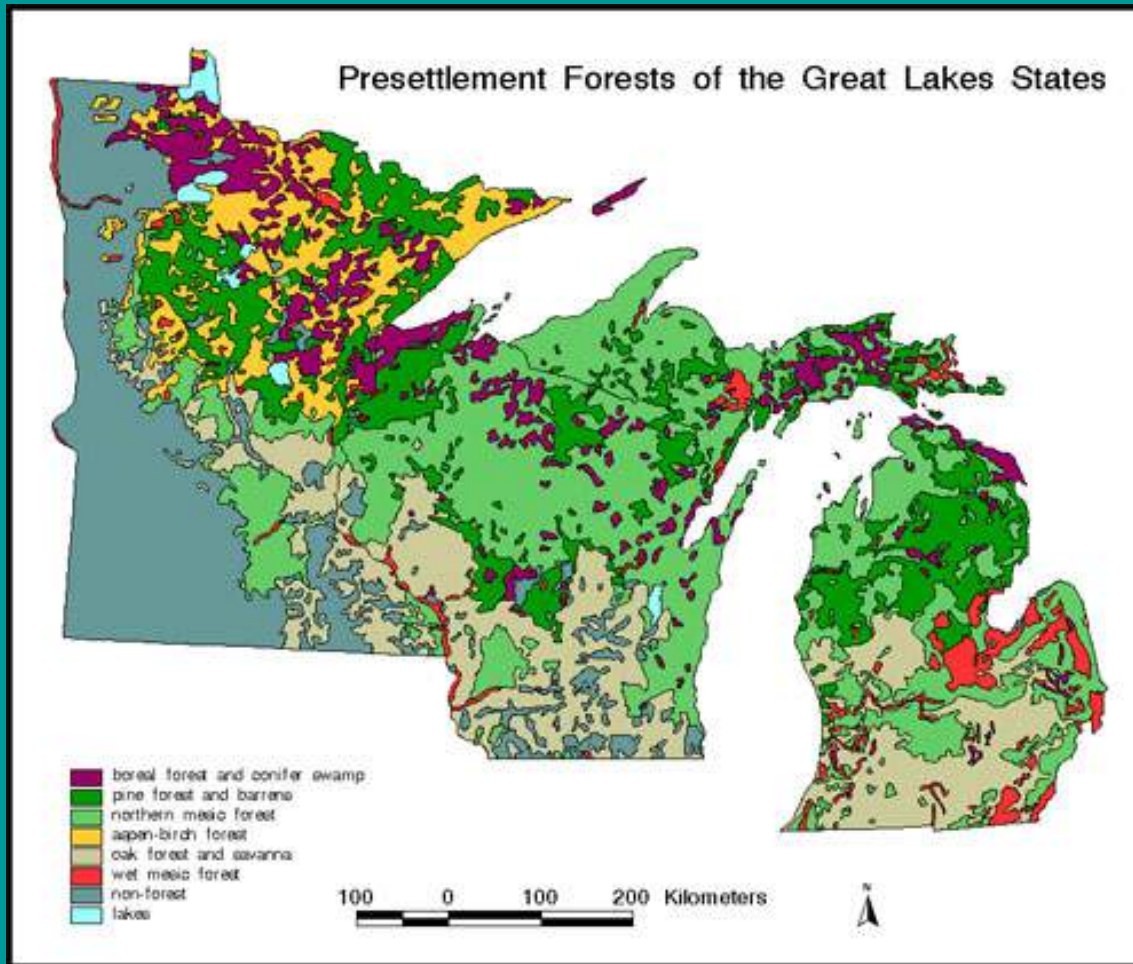
Dis-assembly of the forests?



Substantial changes in forest and prairie communities **since presettlement times** due to urbanization, farming, and forestry

How do we know what **presettlement forests** or community types were actually present mid-1800s?

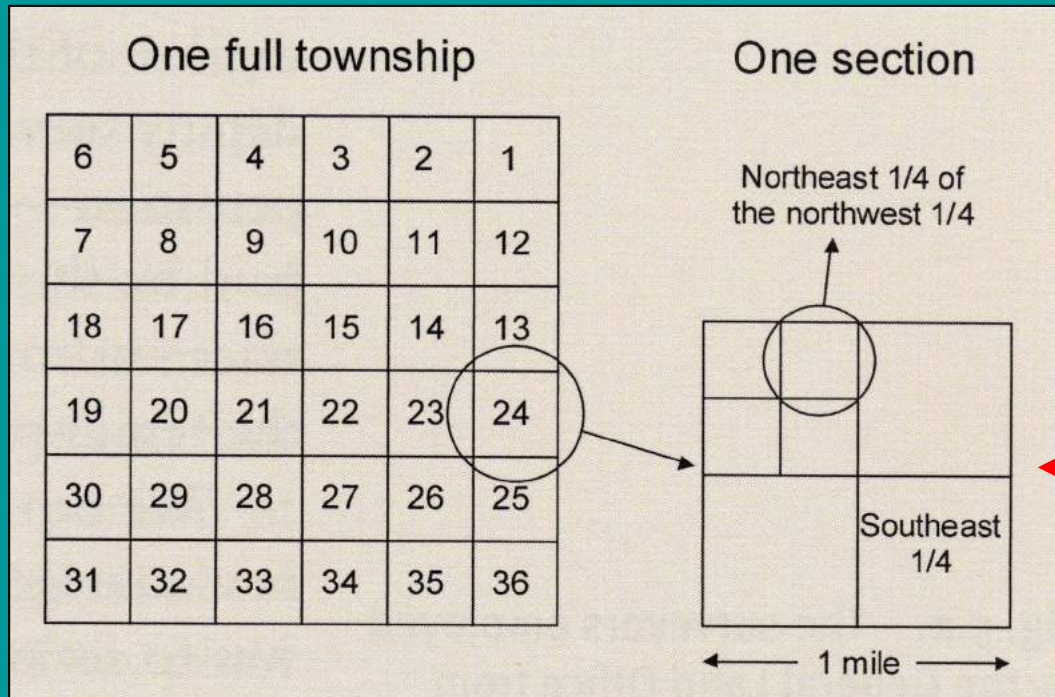
Dis-assembly of the forests?



Substantial changes in forest and prairie communities **since presettlement times** due to urbanization, farming, and forestry

How do we know what **presettlement forests** or community types were actually present mid-1800s?

Dis-assembly of the forests?



How do we know what **presettlement forests** or community types were actually present?

640 acres

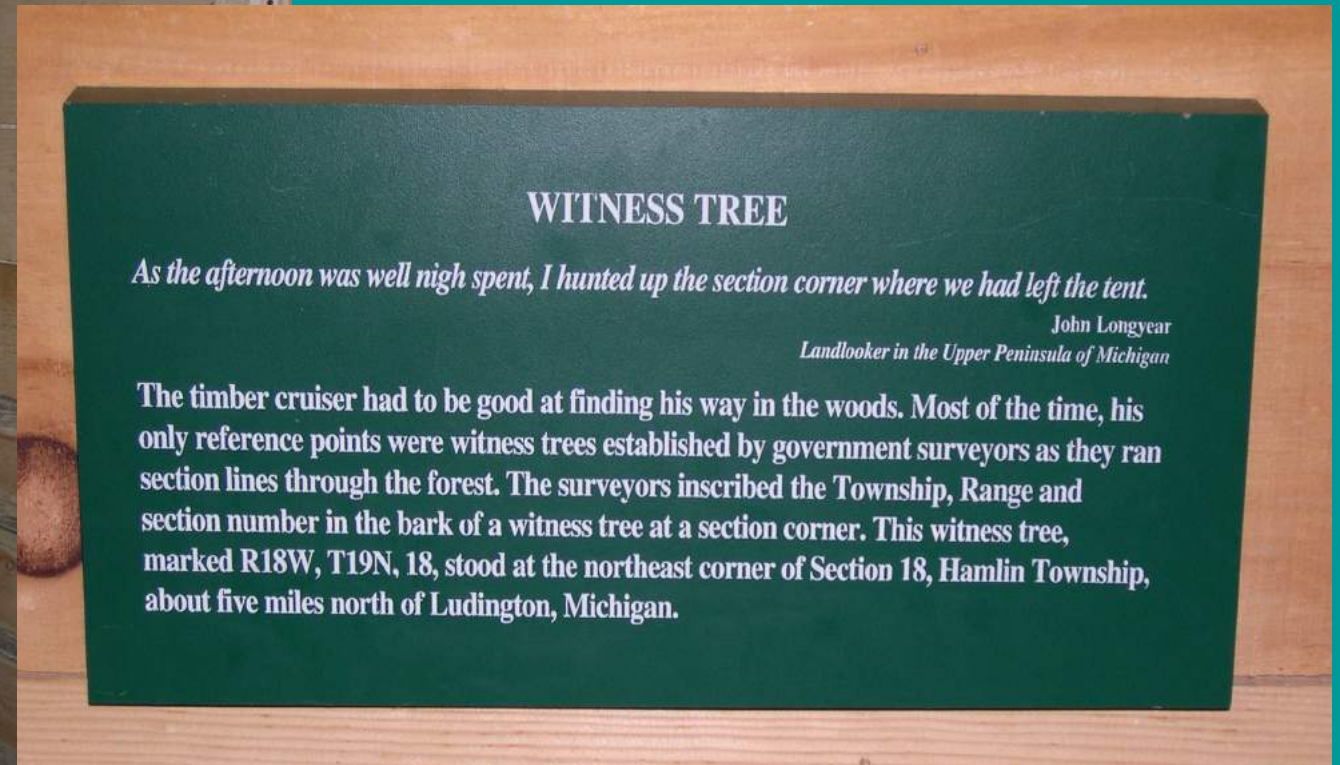
The General Land Office surveys of the 1800s required that a rectangular system of land survey be done. **Trees** nearest each quarter section corner were **bark-slashed, identified, and dbh** recorded.

Fig. 5.1. The basic units of land division in the rectangular system of land survey. A normal township contains 36 sections of one square mile each. Each section contains 640 acres and can be divided into four quarter sections of 160 acres each or 16 quarter-quarter sections of 40 acres each.

Dis-assembly of the forests?



Shown here is such a “**Witness Tree**” from the NE corner of section 18 in Hamlin Township (R18W, T19N) north of Ludington, Michigan.



WITNESS TREE

As the afternoon was well nigh spent, I hunted up the section corner where we had left the tent.

John Longyear

Landlooker in the Upper Peninsula of Michigan

The timber cruiser had to be good at finding his way in the woods. Most of the time, his only reference points were witness trees established by government surveyors as they ran section lines through the forest. The surveyors inscribed the Township, Range and section number in the bark of a witness tree at a section corner. This witness tree, marked R18W, T19N, 18, stood at the northeast corner of Section 18, Hamlin Township, about five miles north of Ludington, Michigan.

Hartwick Pines State Park, MI –
logging museum

Dis-assembly of the forests?



“Witness Tree” from the NE corner of section 18 in Hamlin Township (R18W, T19N) north of Ludington, Michigan.

A close up of the slashed tree shows the original surveyor's marks:

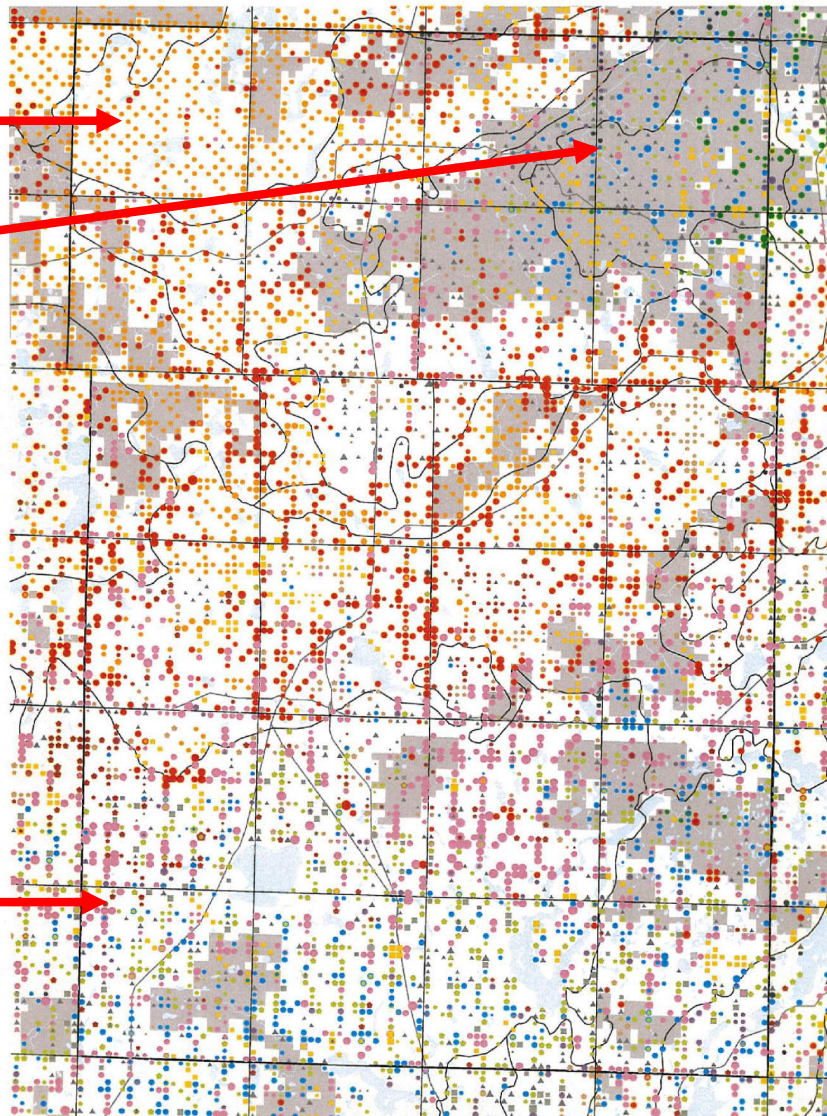
R 18 W

T 19 N 18

Hartwick Pines State Park, MI –
logging museum

Dis-assembly of the forests?

Presettlement Vegetation - Species of All Witness Trees
Washburn County, Wisconsin - DRAFT



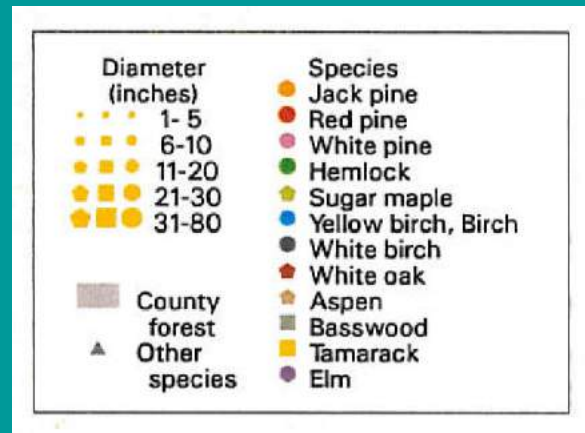
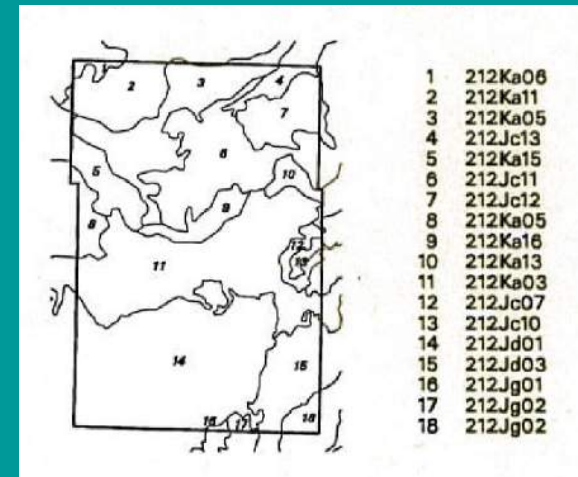
Jack pine forest

Hemlock, yellow birch forest



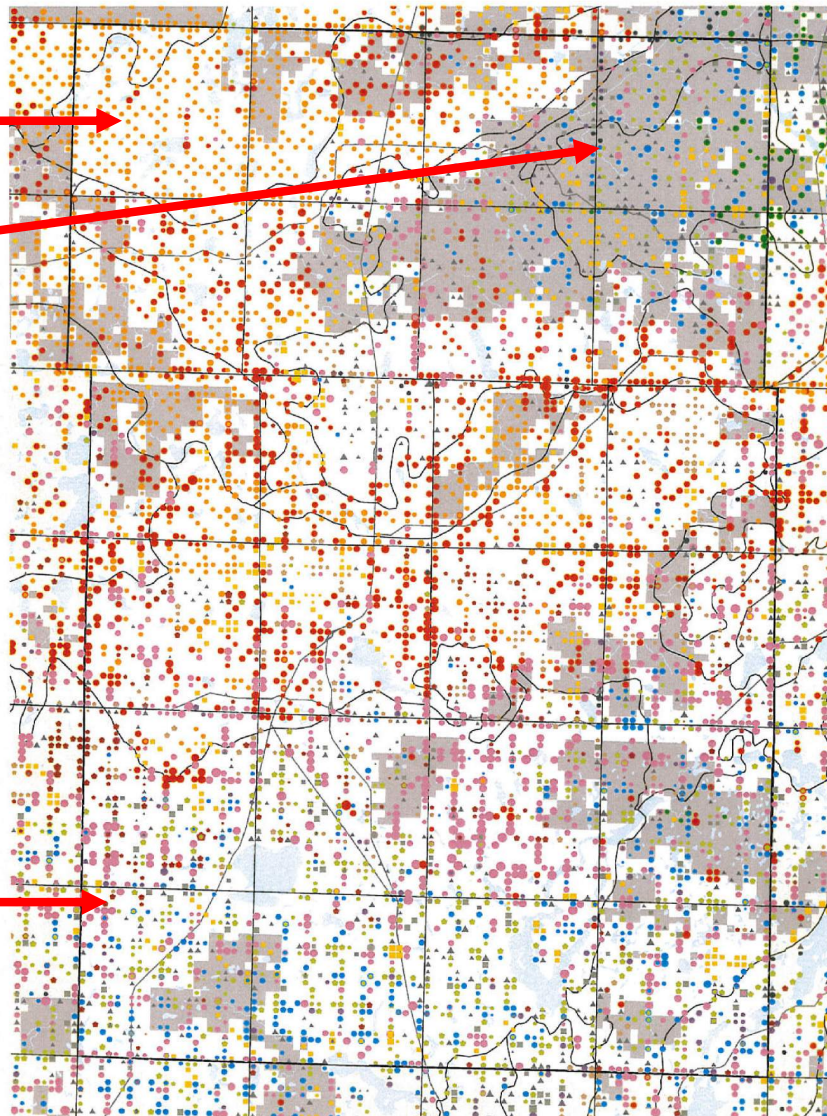
White pine, maple forest

Witness trees used to define forest types



Dis-assembly of the forests?

Presettlement Vegetation - Species of All Witness Trees
Washburn County, Wisconsin - DRAFT



Jack pine forest



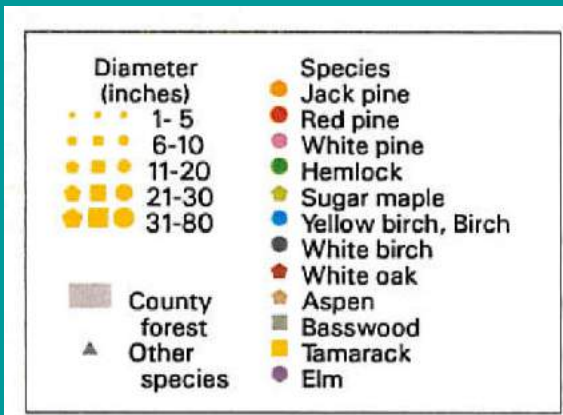
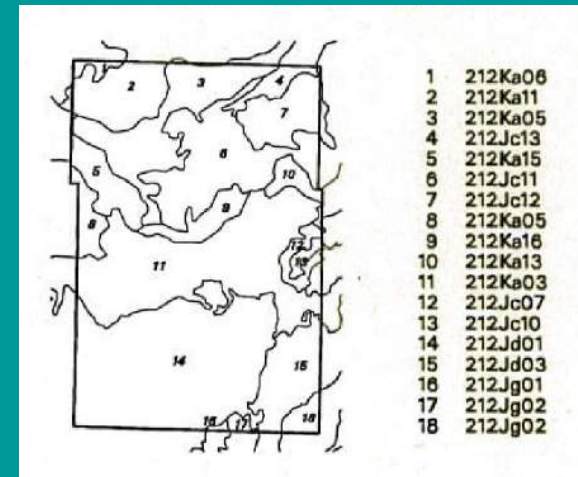
Hemlock, yellow birch forest



White pine, maple forest

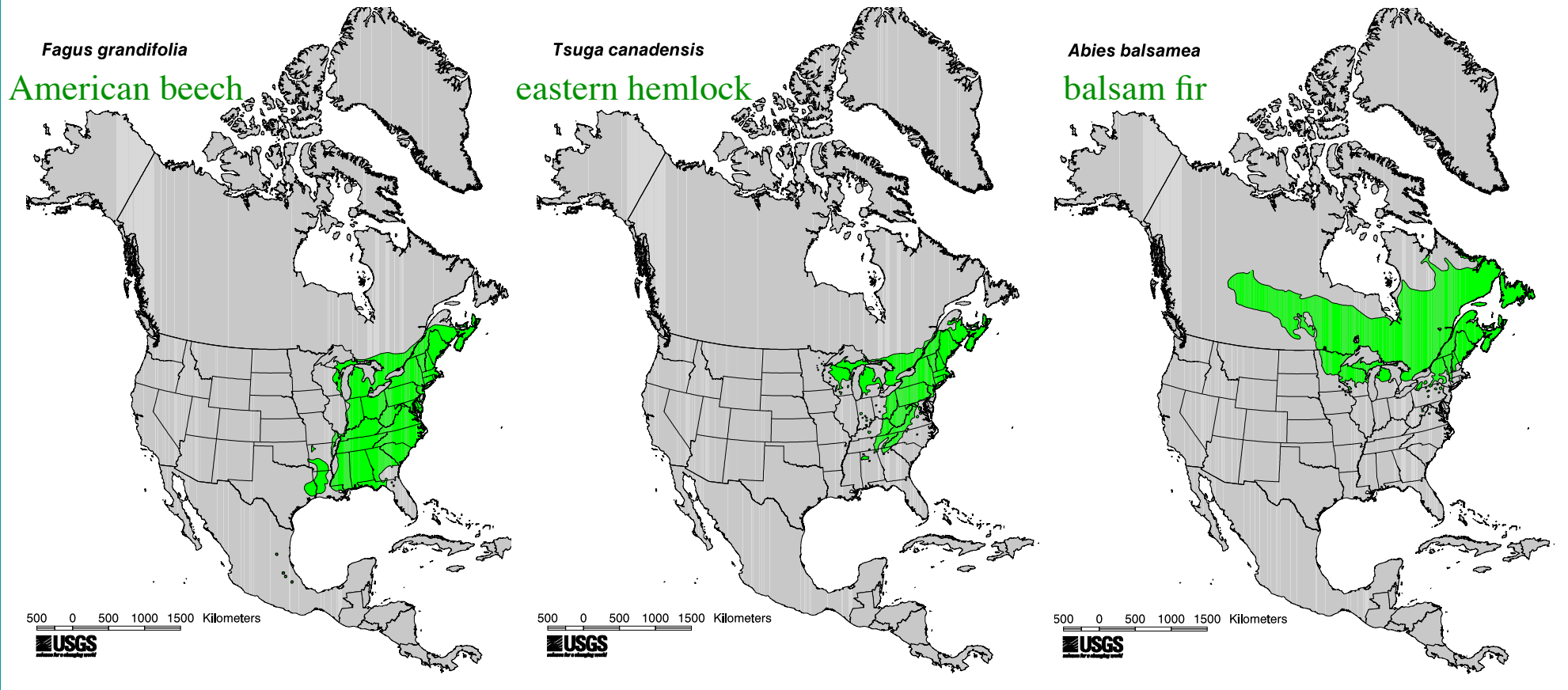


Small forest regions remain & these are different today



Dis-assembly of the forests?

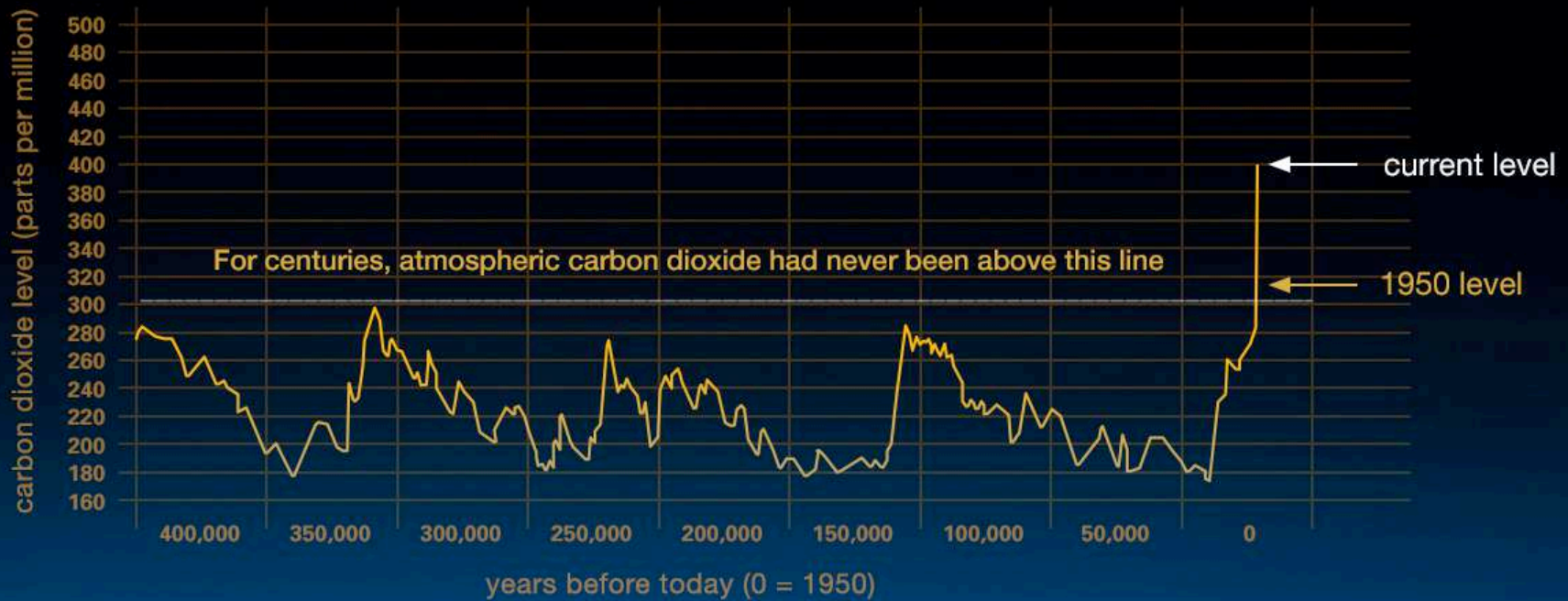
Historical distribution of 3 important tree species –
already impacted by humans



Future distribution of 3 important tree species? –
climate change, disease, invasives

Dis-assembly of the forests?

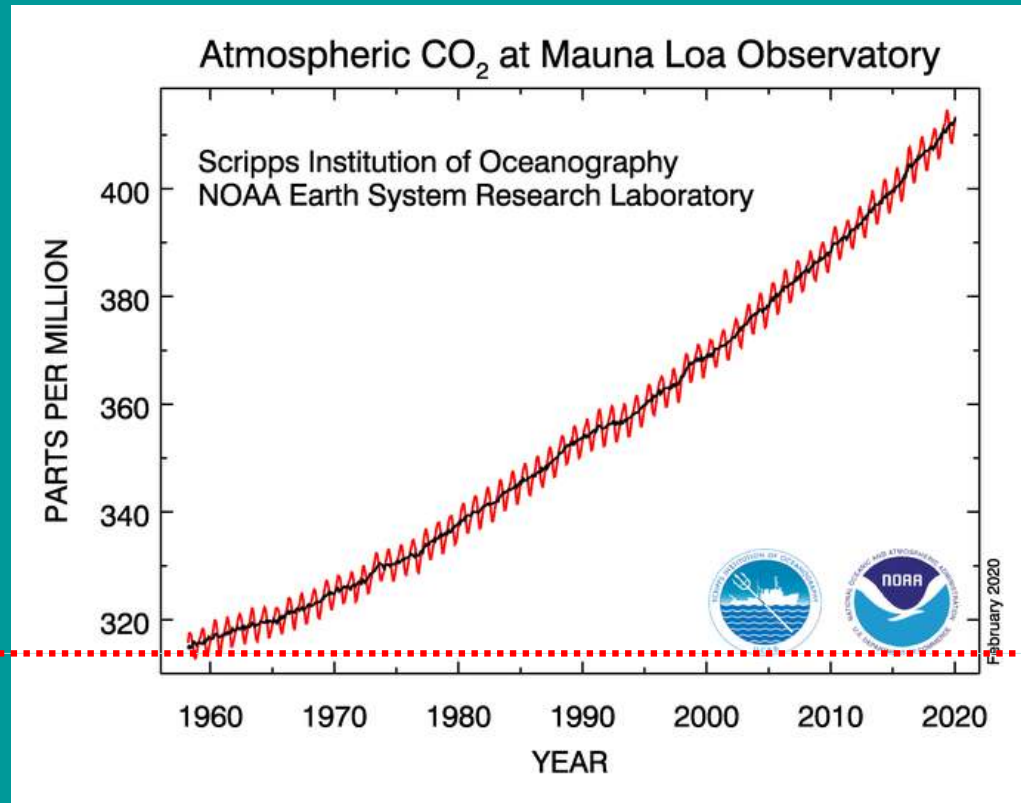
- Climate change



Pleistocene oscillations



Dis-assembly of the forests?



Global temperature increase and climate change

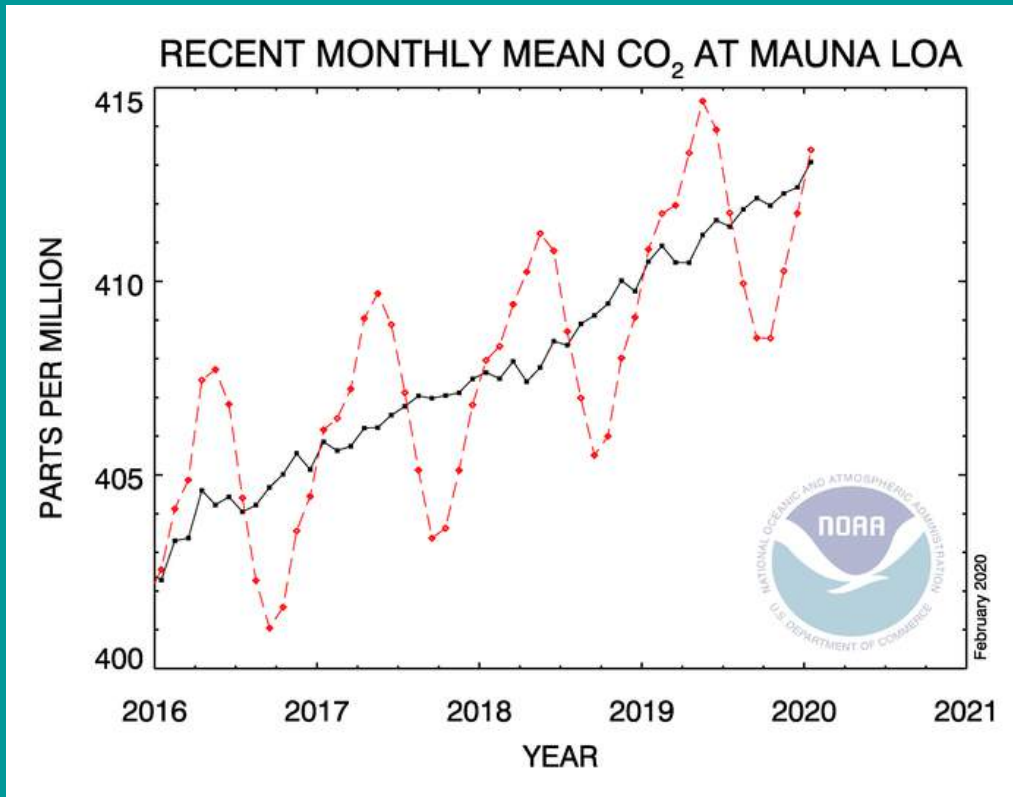
highest record in Pleistocene

CO₂ concentration (showing annual cycle) increasing from 315 ppm to 415 over last 60 years

Measured at top of Mauna Loa, Hawaii



Dis-assembly of the forests?



Global temperature increase and climate change

Last 4 years' CO₂ concentration increasing from 402 ppm to 415 ppm

Measured at top of Mauna Loa

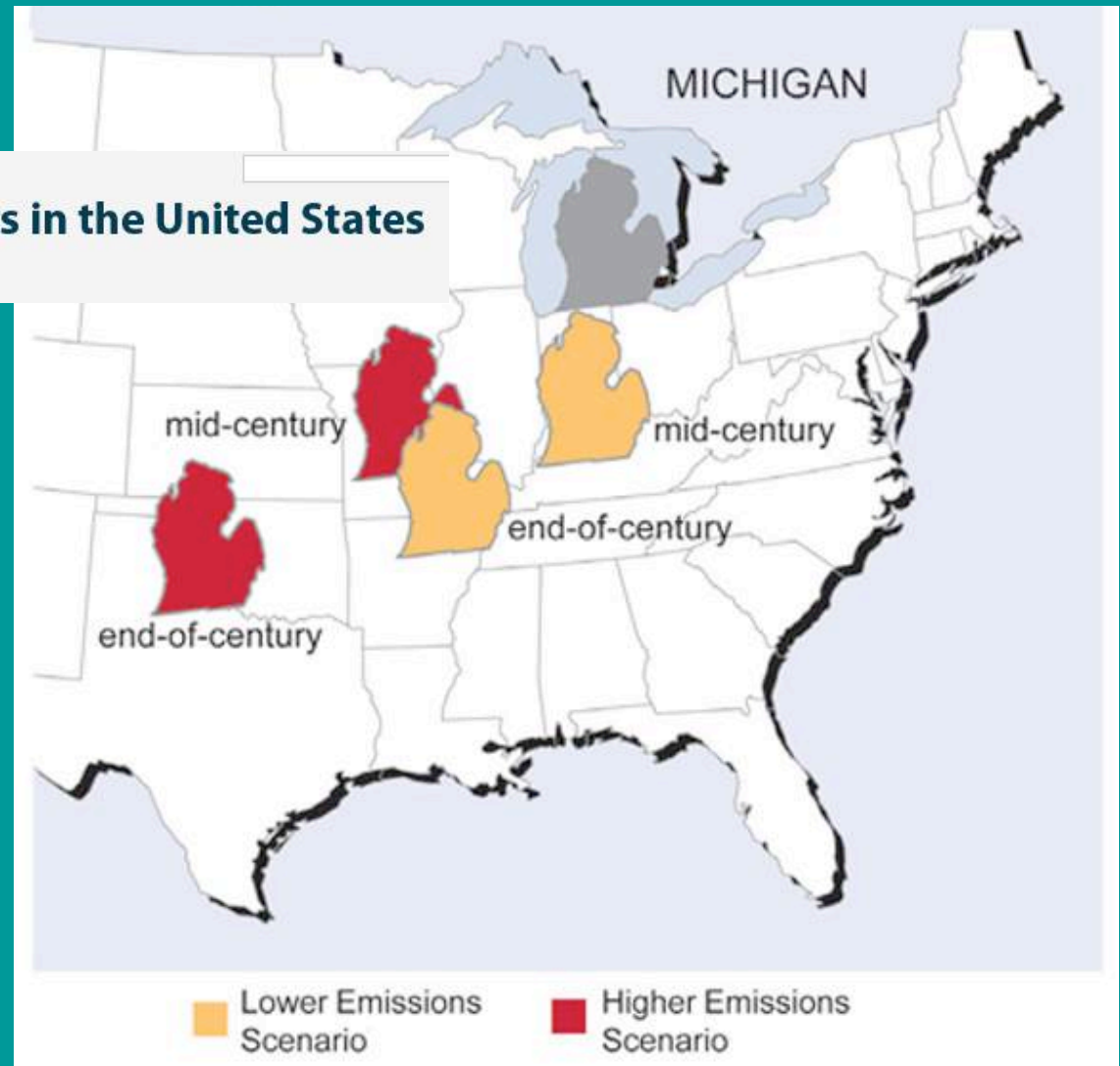


Dis-assembly of the forests?



U.S. Global Change Research Program

Global Climate Change Impacts in the United States
2009 Report



1. Climatic shifts in Great Lakes region

Dis-assembly of the forests?



1. Climatic shifts in Great Lakes region

*No climate analogue was found for these cities in the RCP 4.5 scenario.
NOTE: An RCP is a Representative Concentration Pathway describing future greenhouse gas emissions.

Dis-assembly of the forests?



U.S. Global Change Research Program

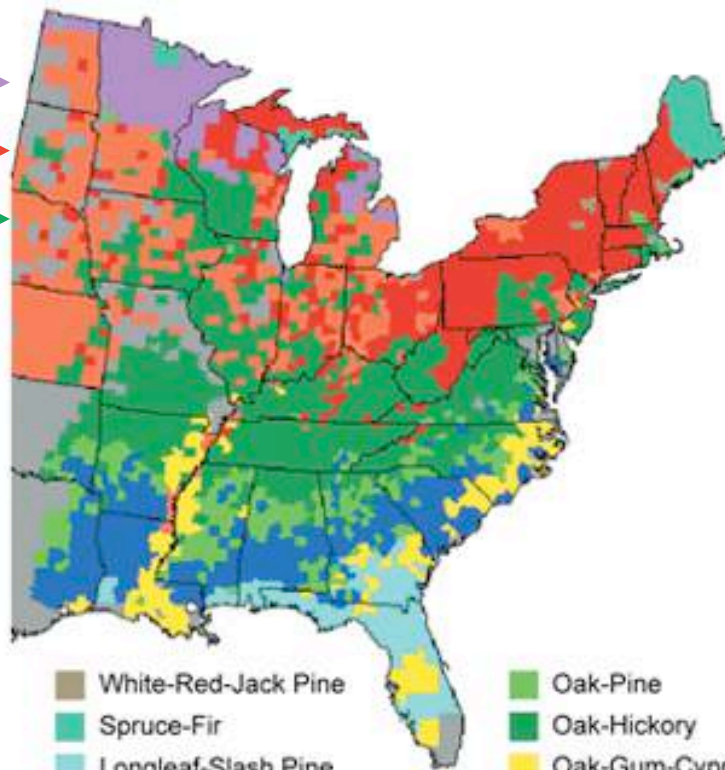
Global Climate Change Impacts in the United States
2009 Report

Aspen-Birch

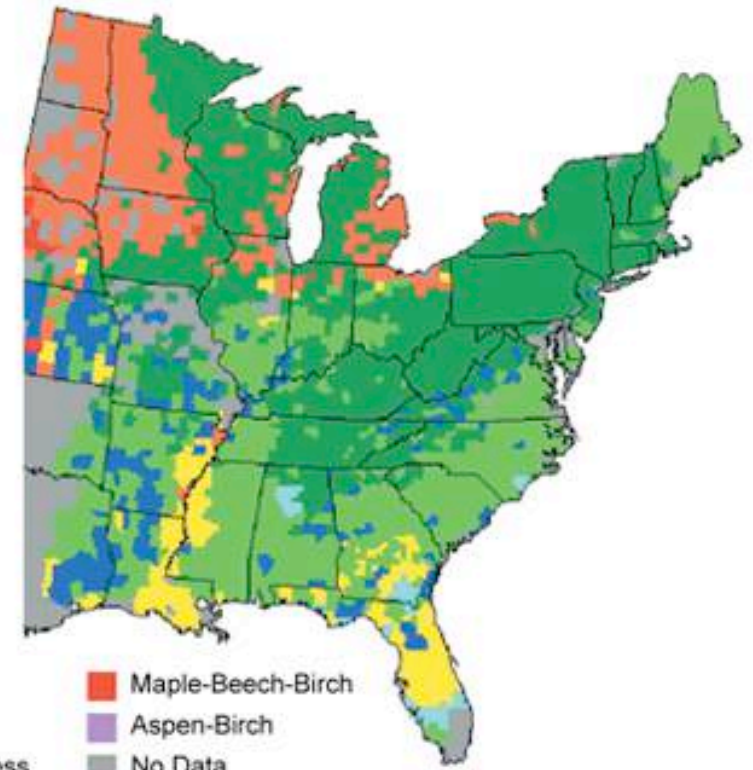
Maple-Beech-Birch

Oak-Hickory

Recent Past
1960-1990



Projected
2070-2100



White-Red-Jack Pine
Spruce-Fir
Longleaf-Slash Pine
Loblolly-Shortleaf Pine

Oak-Pine
Oak-Hickory
Oak-Gum-Cypress
Elm-Ash-Cottonwood

Maple-Beech-Birch
Aspen-Birch
No Data

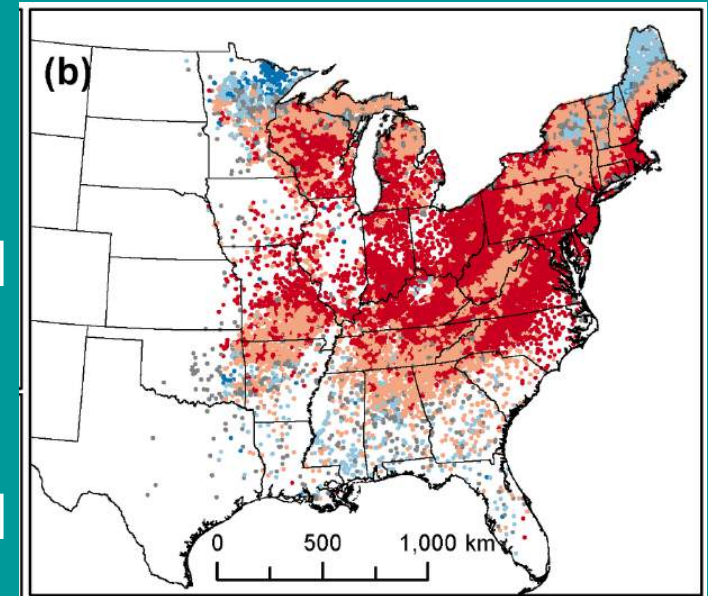
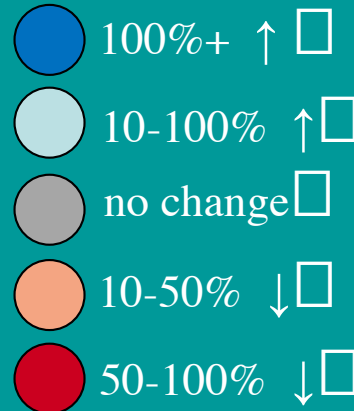
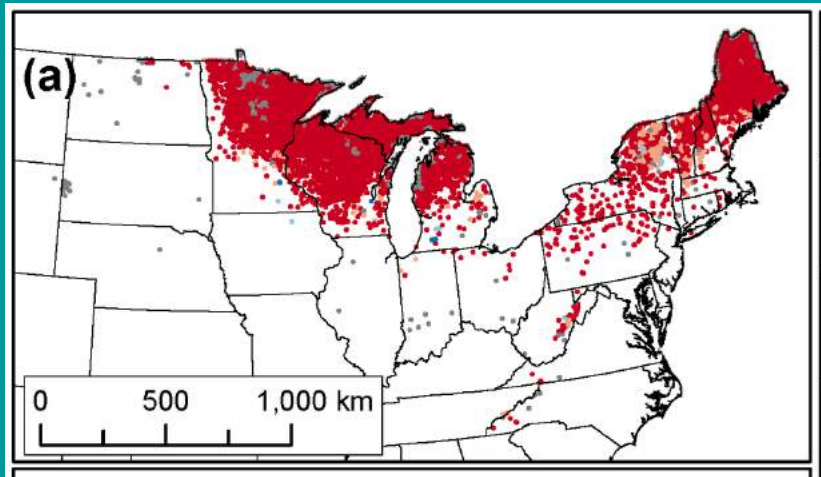
2. Forest biome shifts in Great Lakes region

Dis-assembly of the forests?

An empirical, hierarchical typology of tree species assemblages for assessing forest dynamics under global change scenarios

Jennifer K. Costanza^{1*}, John W. Coulston², David N. Wear³

2017



balsam fir – quaking aspen



sugar maple – red maple

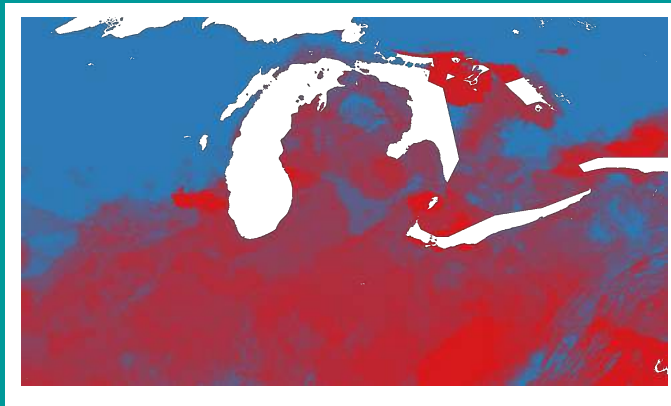
2. Forest biome shifts in Great Lakes region

Dis-assembly of the forests?

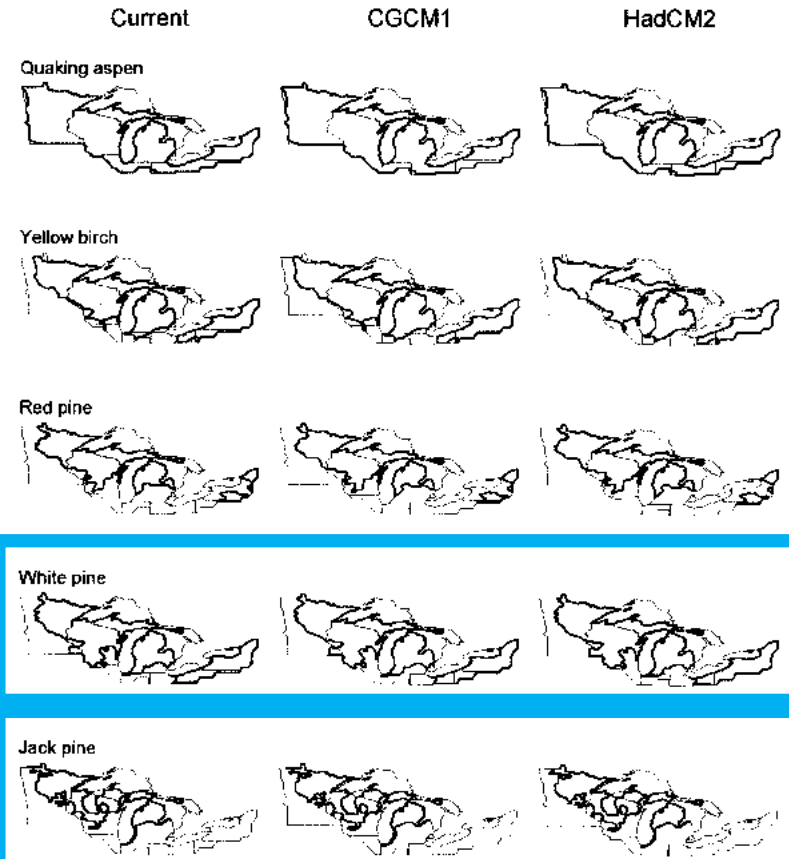
J. Great Lakes Res. 28(4):555-567
Internat. Assoc. Great Lakes Res., 2002

Climate Change and Shifts in Potential Tree Species Range Limits in the Great Lakes Region

Karen V. Walker^{1,*}, Margaret B. Davis², and Shinya Sugita²



Modeled current and future (2090-2099) range limits



500 0 500 Kilometers



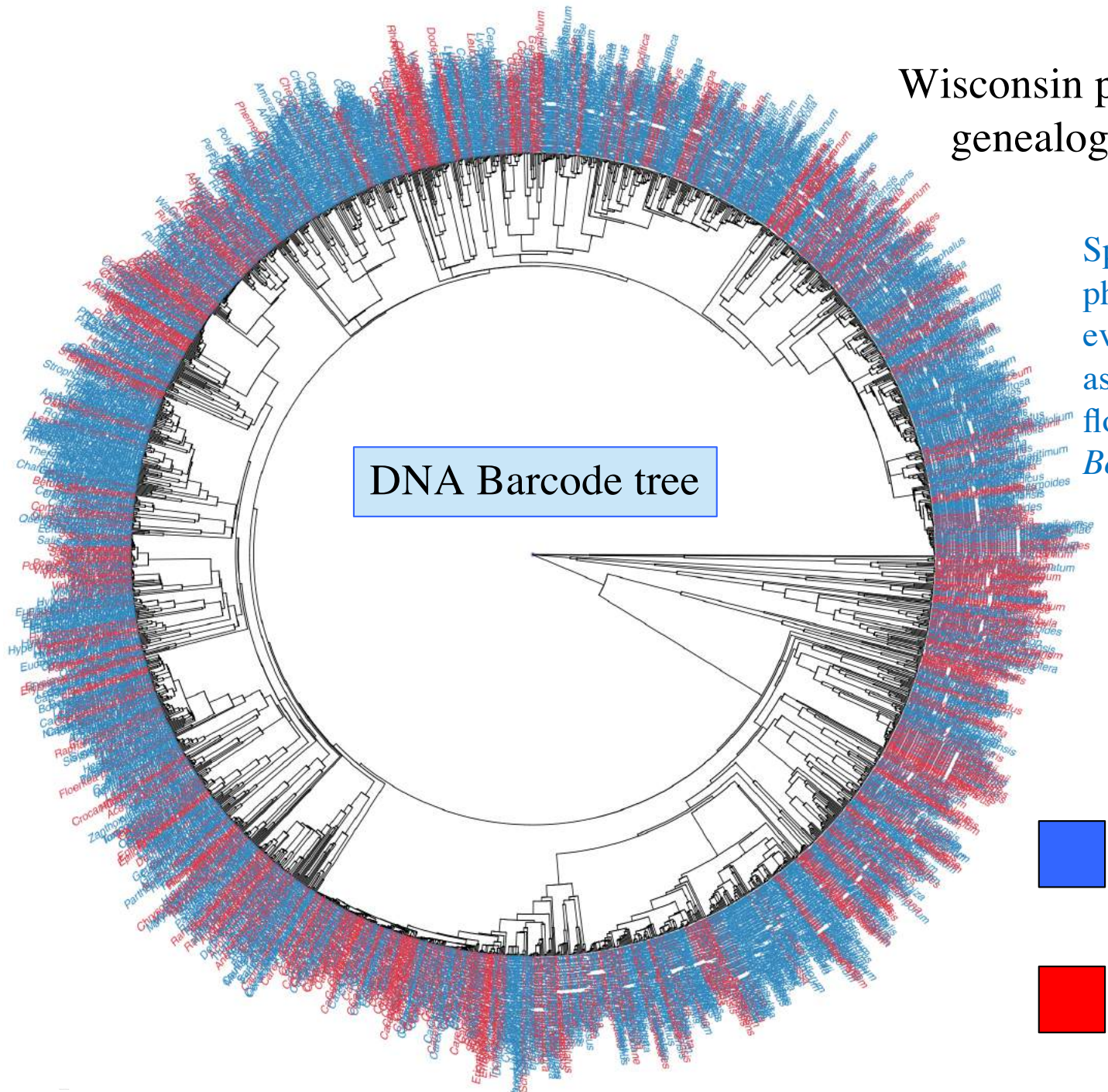
— Actual range limits within region (from Little, 1971)
 [Stippled area] Grid points within predicted range (STASH plus the maximum tolerated temperature of the warmest month)

FIG. 2b. Comparison of actual current ranges (heavy lines), modeled current ranges (stippling, on left), and predicted ranges for 2090 to 2099 (stippling, on right) for quaking aspen, yellow birch, red pine, white pine, and jack pine.

3. Individual species shifts in Great Lakes region

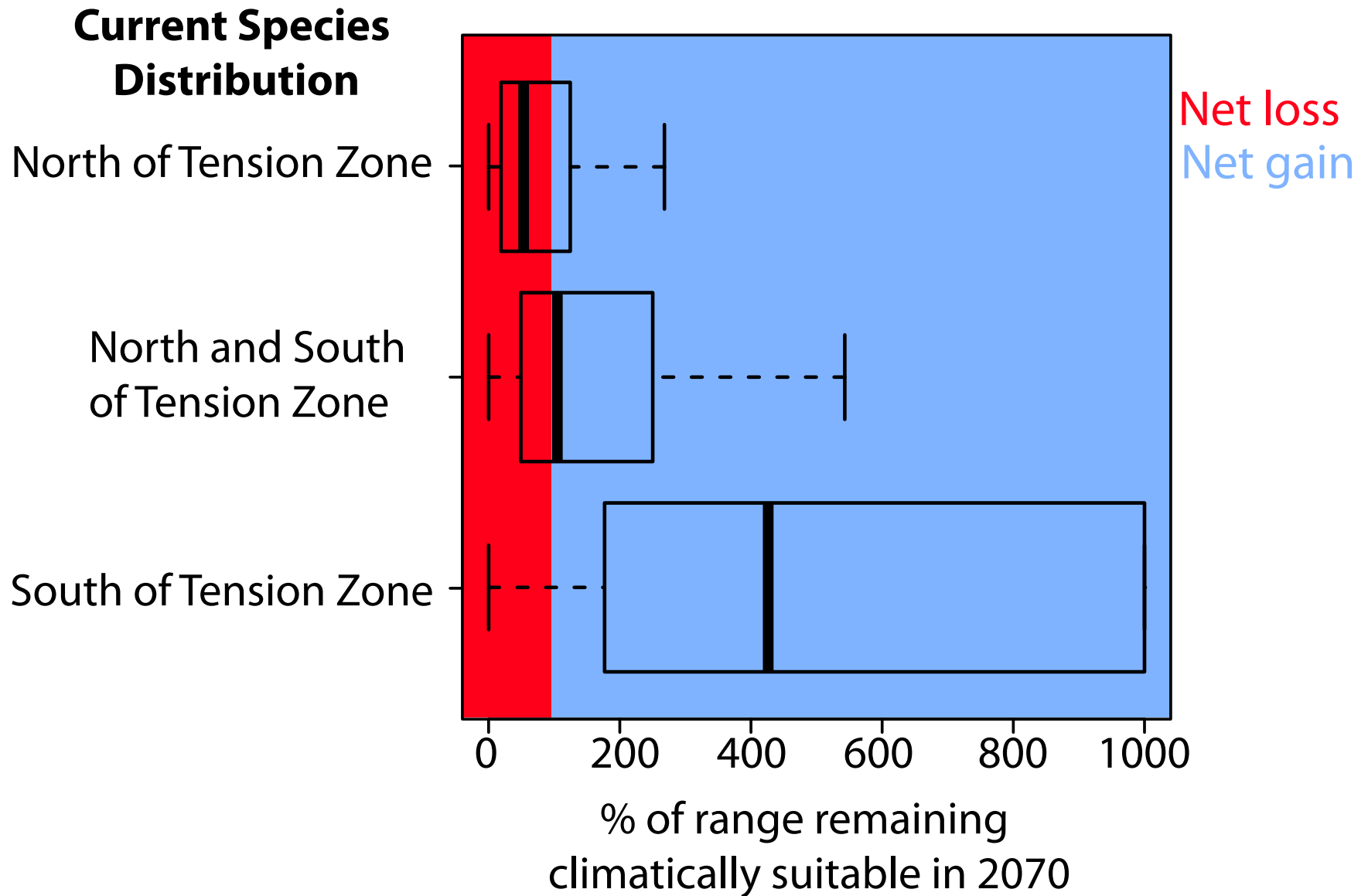
Wisconsin phylogenetic tree - genealogy of all species

Spalink et al. 2018 Spatial phylogenetics reveals evolutionary constraints on the assembly of a large regional flora. *American Journal of Botany* 105: 1938-1950.



3. Individual species shifts in Great Lakes region

Impacts of climate change on suitable habitat

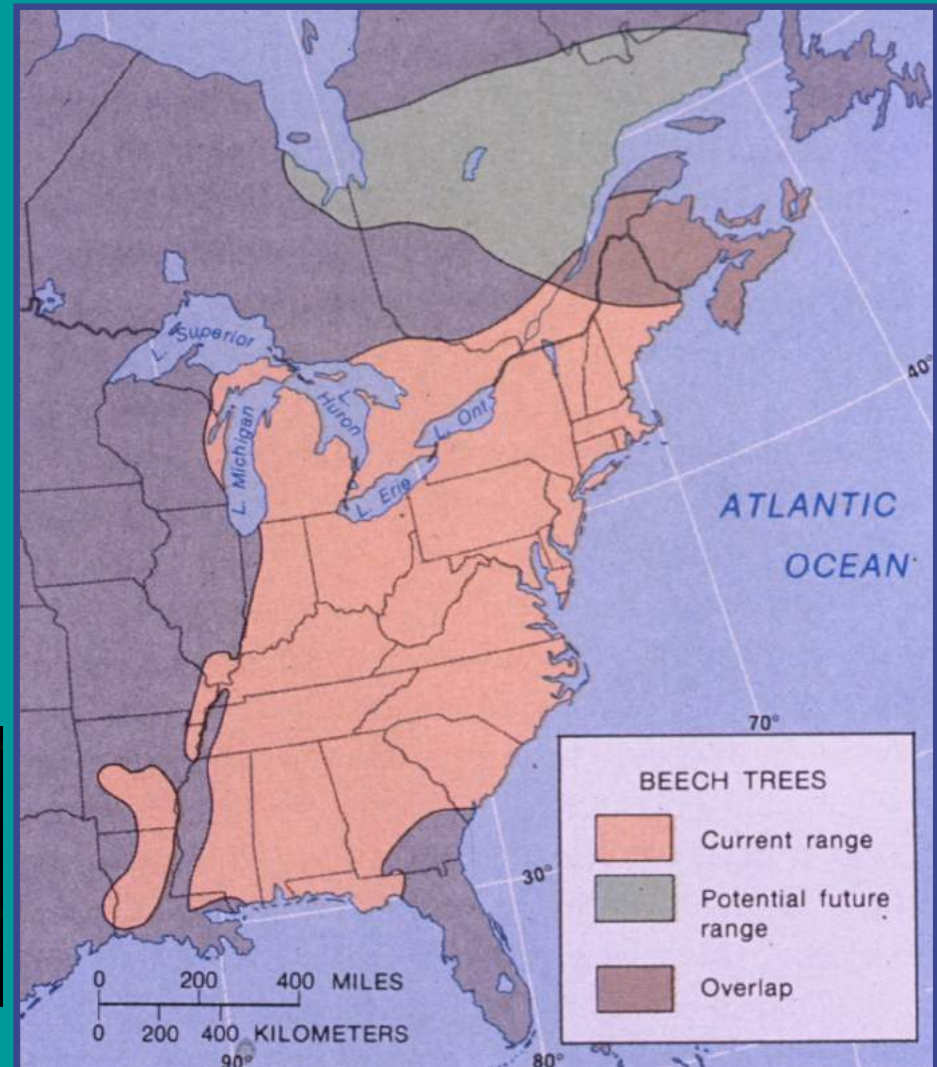


3. Individual species shifts in Great Lakes region

Dis-assembly of the forests?



American beech – model species



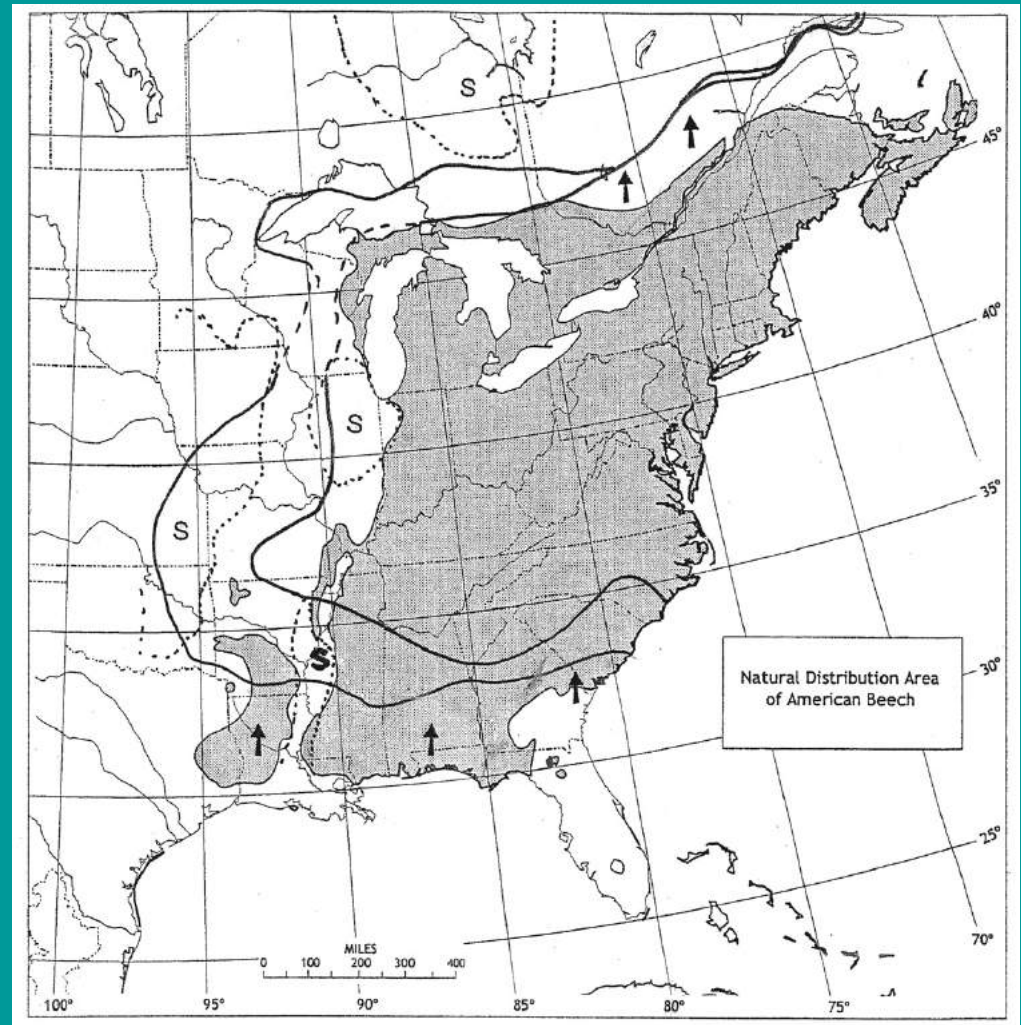
1989 Science paper based on CO₂ doubling

3. Individual species shifts in Great Lakes region

Dis-assembly of the forests?



American beech – model species



K. Jankowski – Ph.D. Nelson Institute 2001

3. Individual species shifts in Great Lakes region

Dis-assembly of the forests?



DOI: 10.1111/jbi.13491 updates

RESEARCH PAPER WILEY Journal of Biogeography

Assessing the environmental and dispersal controls on *Fagus grandifolia* distributions in the Great Lakes region

Megan Seeley¹ | Simon Goring¹ | John W. Williams^{1,2}

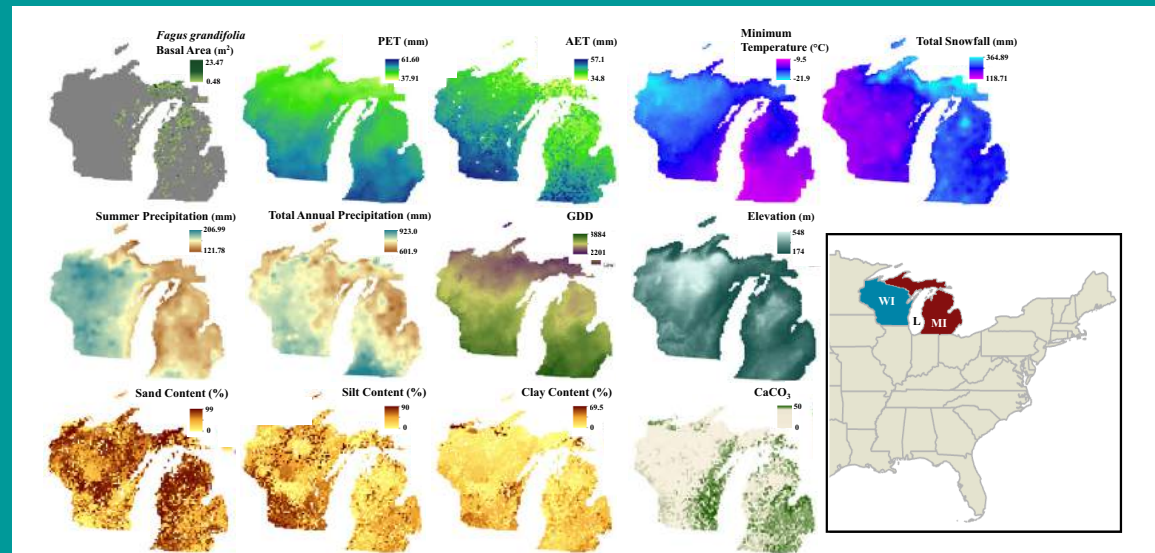


FIGURE 1 Maps of *Fagus grandifolia* basal area at the time of EuroAmerican settlement, environmental variables for Wisconsin and Michigan from PRISM climate data (1895–1924) and SSURGO soil variables, and location of study area within the eastern continental United States (L: Lake Michigan, MI: Michigan, WI: Wisconsin)

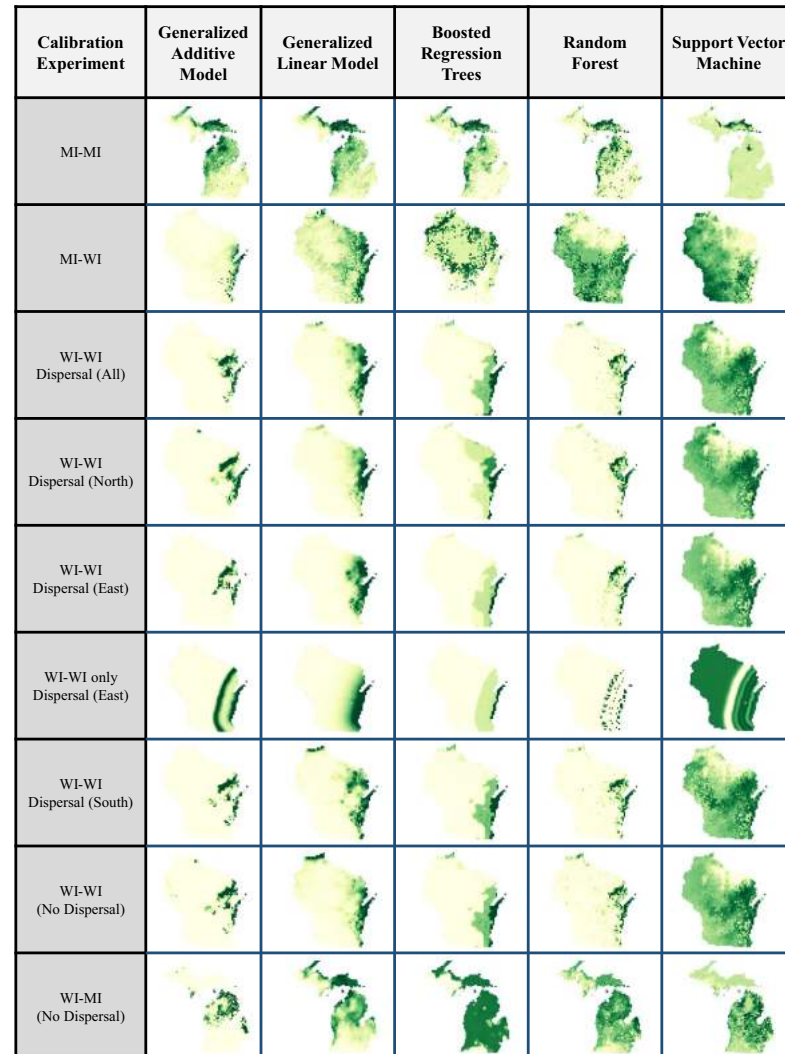
American beech – model species

3. Individual species shifts in Great Lakes region

Dis-assembly of the forests?



American beech – model species



Low High

FIGURE 6 Mapped probabilities of *Fagus grandifolia* presence in Wisconsin and Michigan for each combination of calibration experiment and SDM

3. Individual species shifts in Great Lakes region

Dis-assembly of the forests?



American beech – model species



*Epifagus
virginiana*

Beech drops

(root parasite only
on American
beech)

No matter what model of global warming is used, whole vegetation units need to migrate

Beech drops must track beech migration or go extinct.

3. Individual species shifts in Great Lakes region