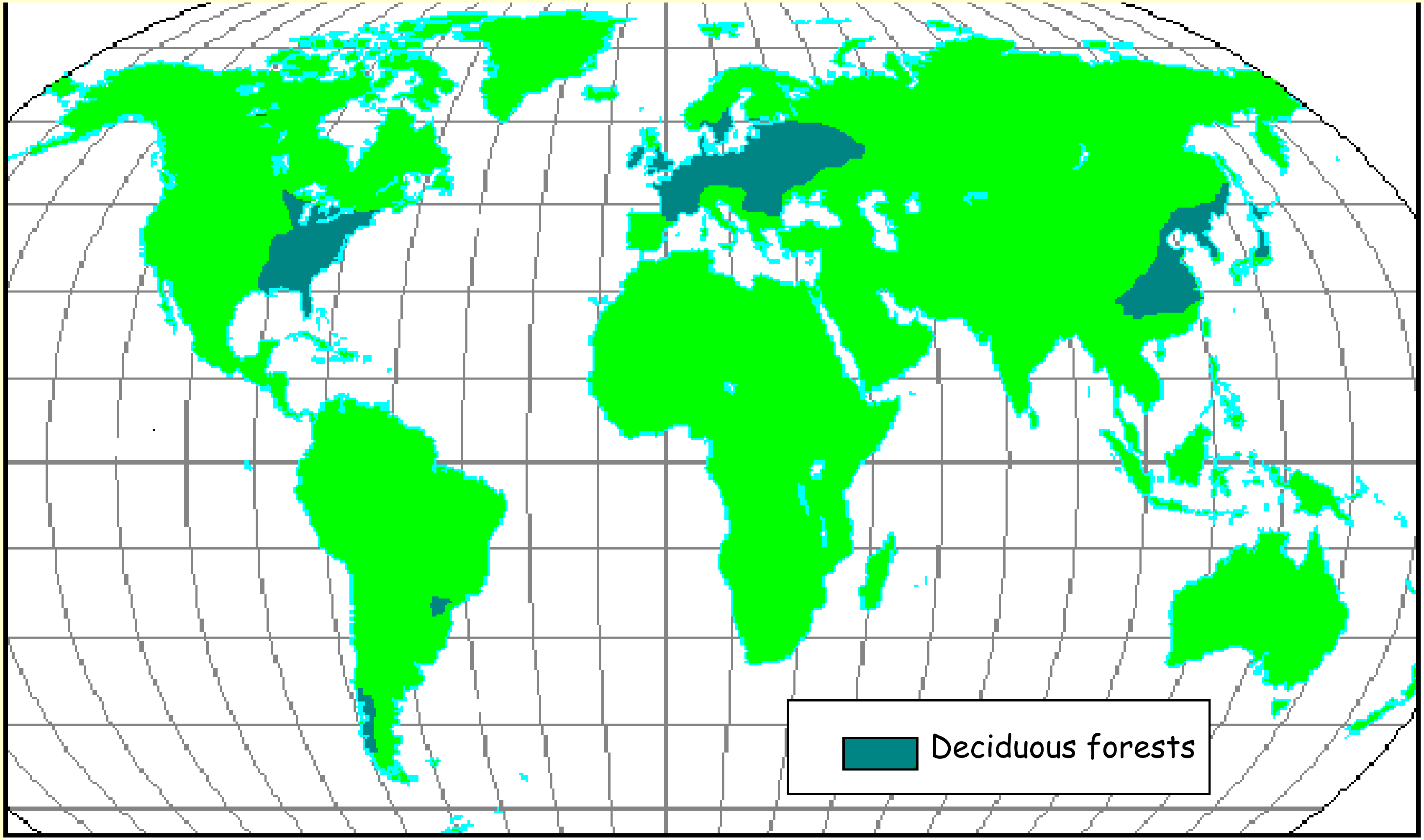
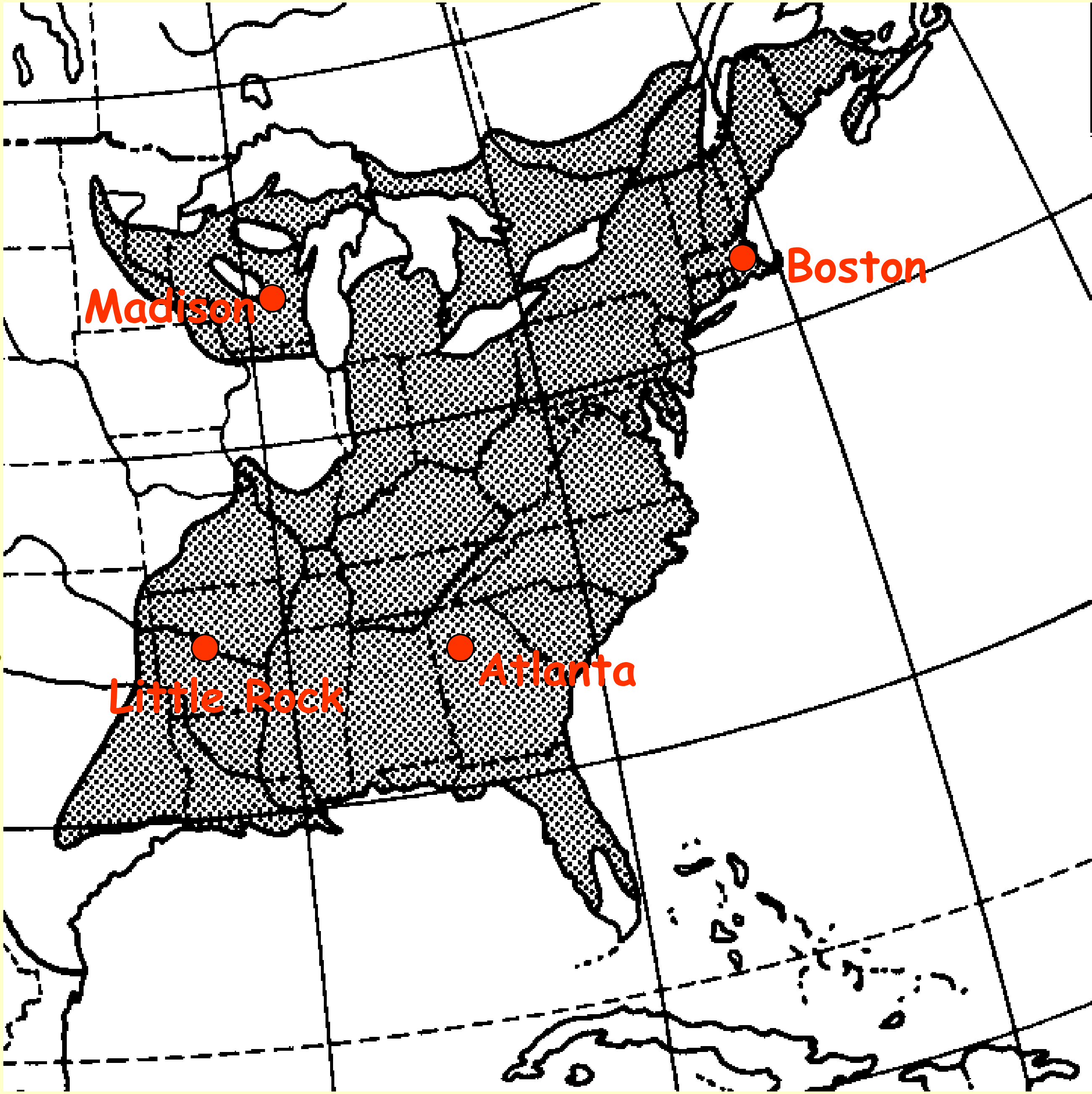
Temperate deciduous (mesophytic) forests

- Distribution
- Climate
- Soils
- Forest types and structure
- Plant ecophysiology
- Fauna
- History (Tertiary - PD)
- Disturbance
- Forest clearance
- Succession

Global distribution of the biome



North American distribution of the TDF and representative climate stations



Climate - monthly temperatures

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Climate - precipitation regimes

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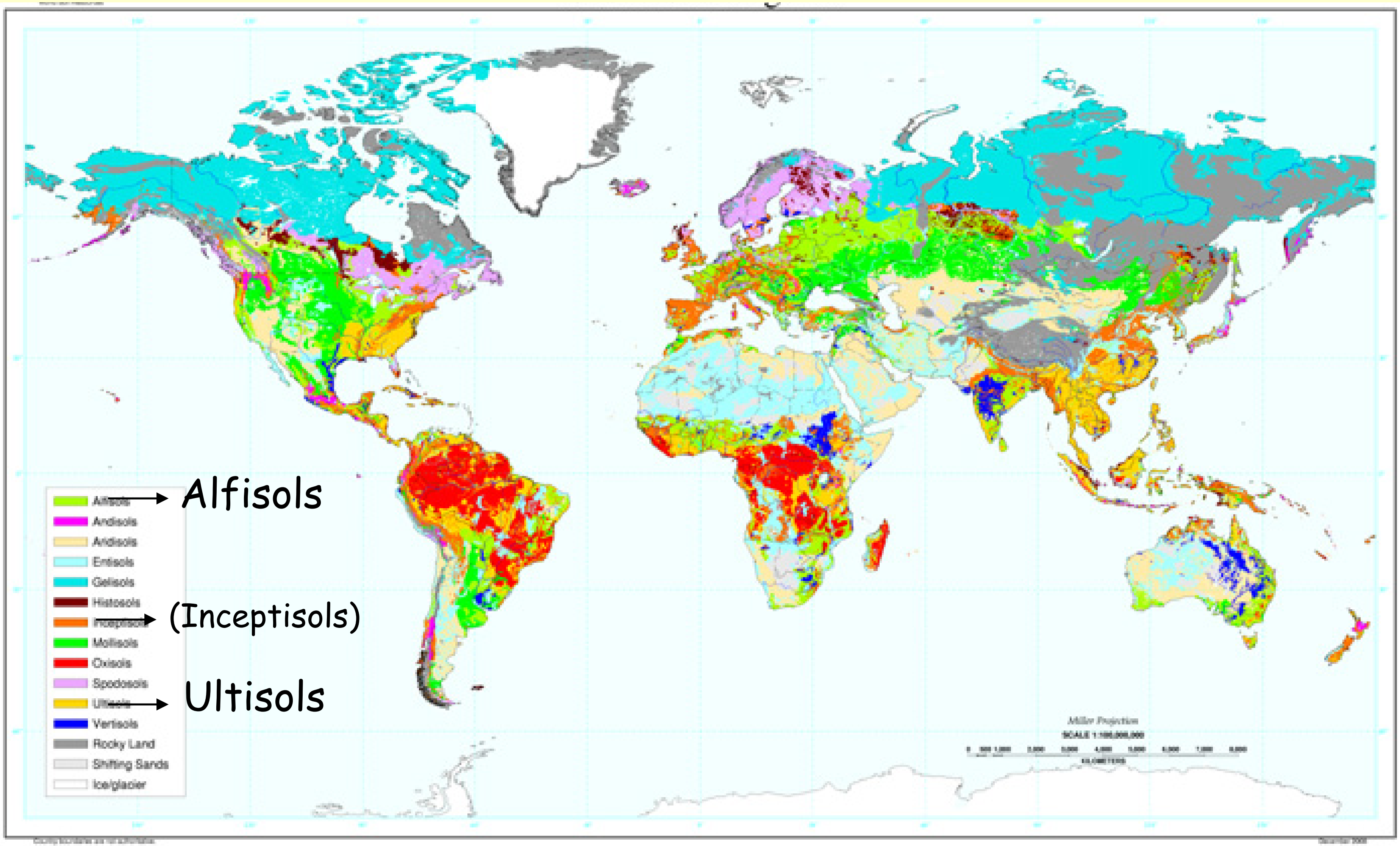
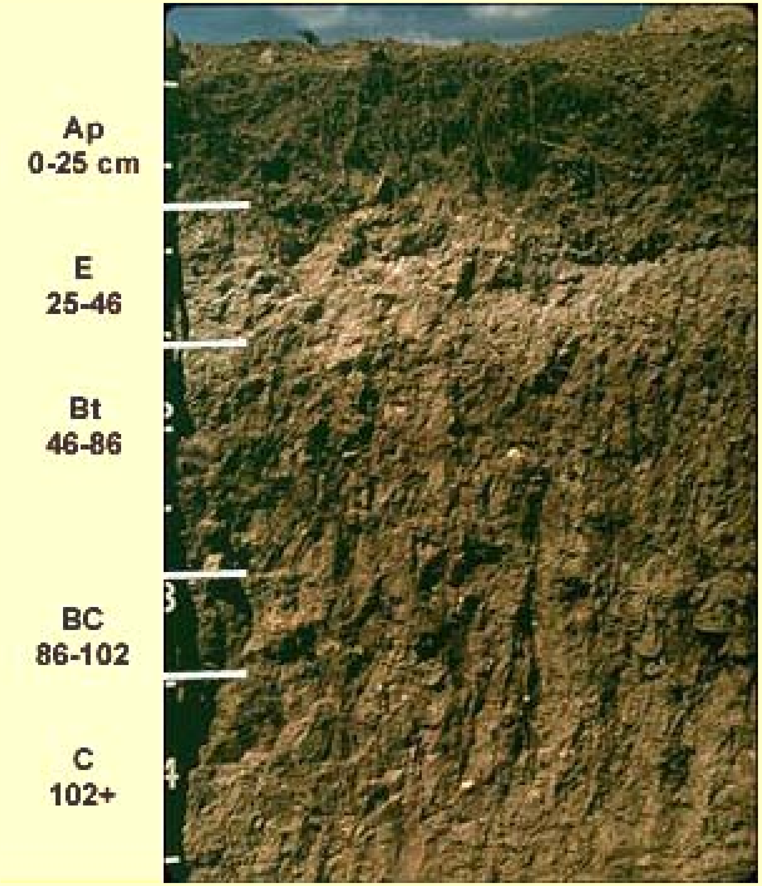
Soil types of the temperate deciduous forest

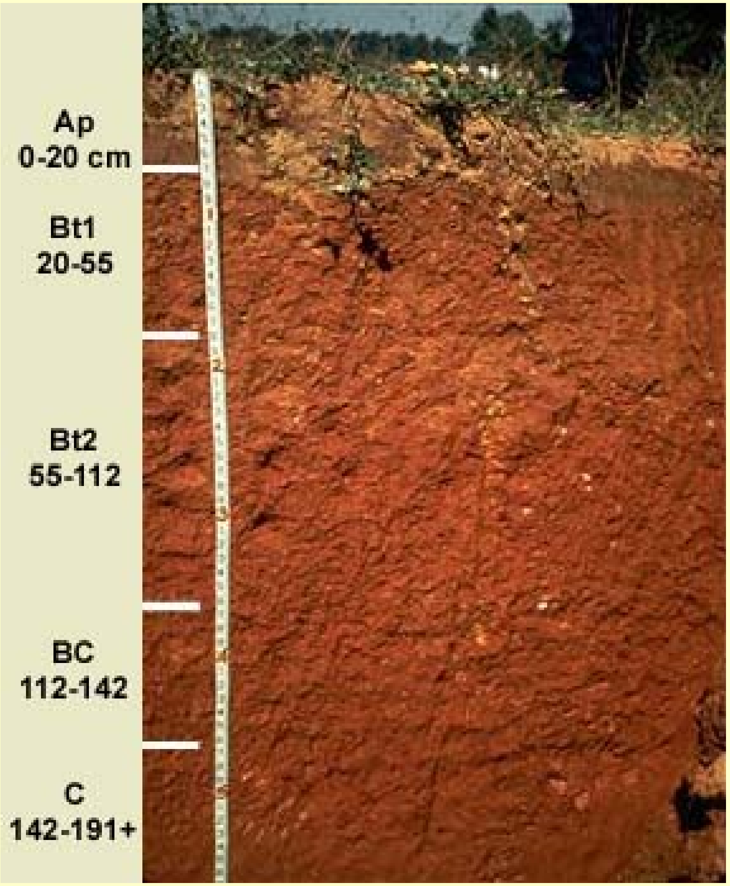


Soil profiles and soil-forming processes

Cool temperate areas:
Alfisols/Luvisols/Brown Earths



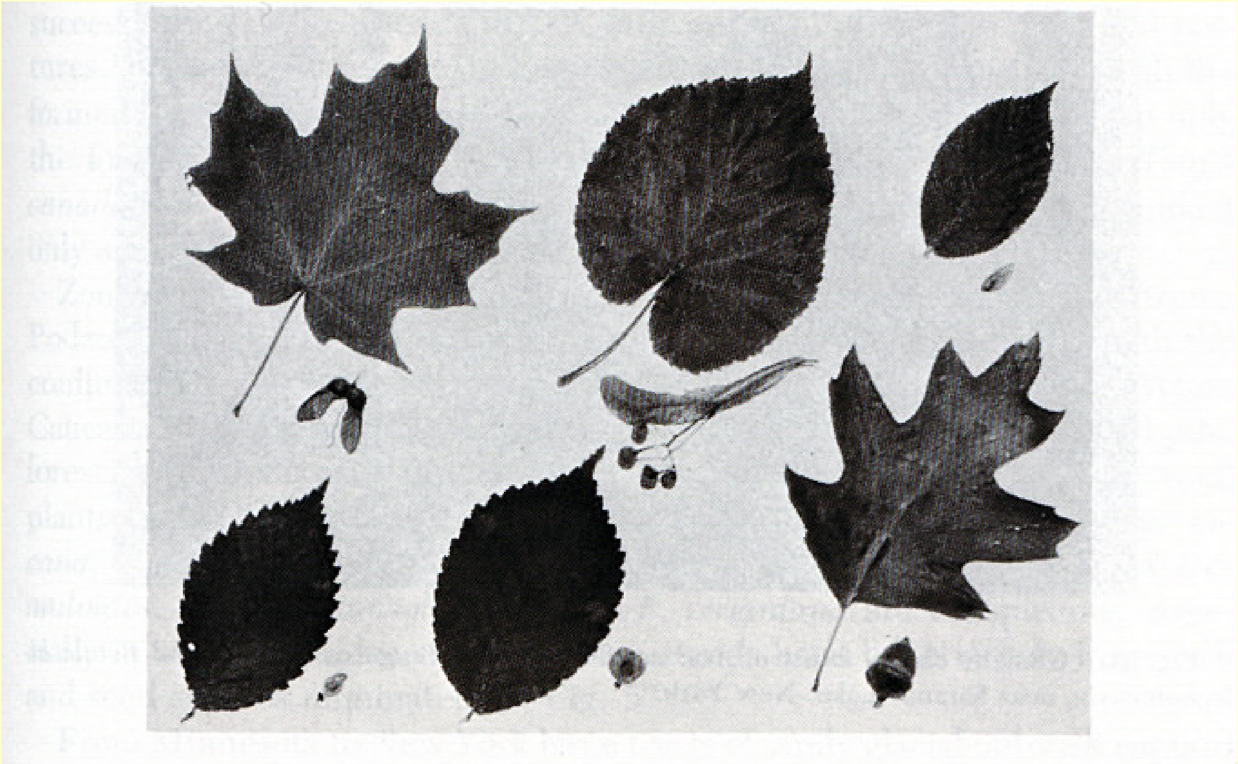
Warm temperate areas:
Ultisols



Soil formation

Alfisols (etc.) - the broadleaf deciduous trees exert a greater demand on soil nutrient resources than the conifers of the boreal forest, and their leaves are more base-rich. Incorporation of litter into the soil by earthworms produces humus-rich A and B horizons. Iron and aluminium are not mobilized, but clay particles, which tend to be dispersed in base-rich soils, are transported down to form a clay-rich B horizon. Ultisols replace alfisols in warm temperate areas as a result of more advanced weathering. Generally less fertile; often degraded in the southeastern USA by plantation agriculture.

What controls the distribution of the dominant tree species of the TDF?



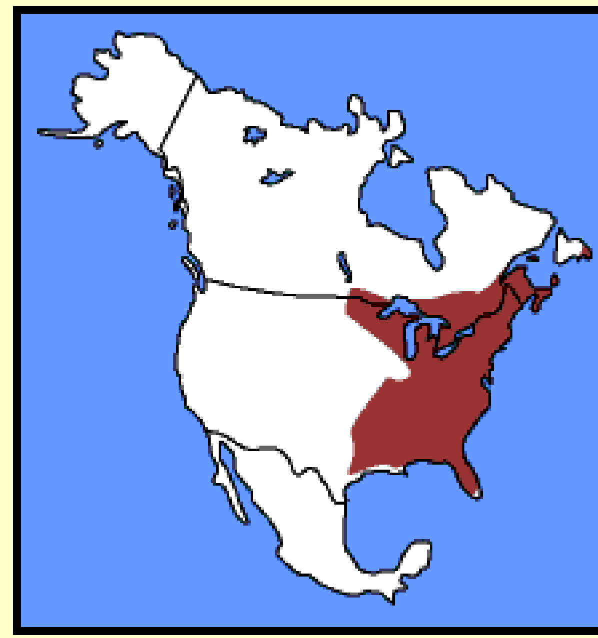
Clockwise, from top left:

Acer saccharum, Tilia americana, Ostrya virginiana, Ulmus americana, Ulmus rubra, and Quercus rubra

Temperate forest trees: similar western limits = similar drought intolerance?

American beech

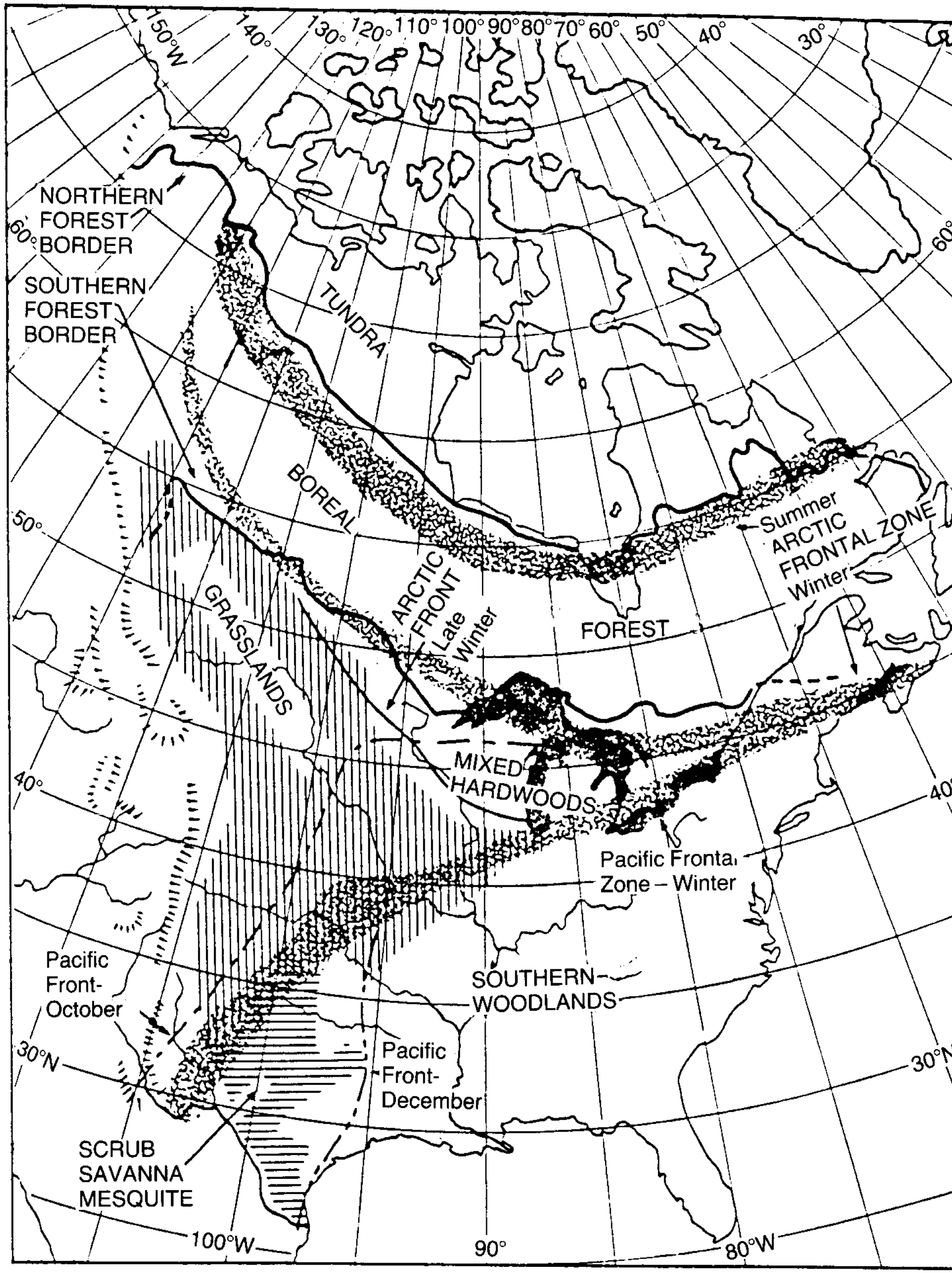
red oak



red maple

(plus white oak, black oak, 2 hickories . . . .)

Airmass climatology - biome boundaries



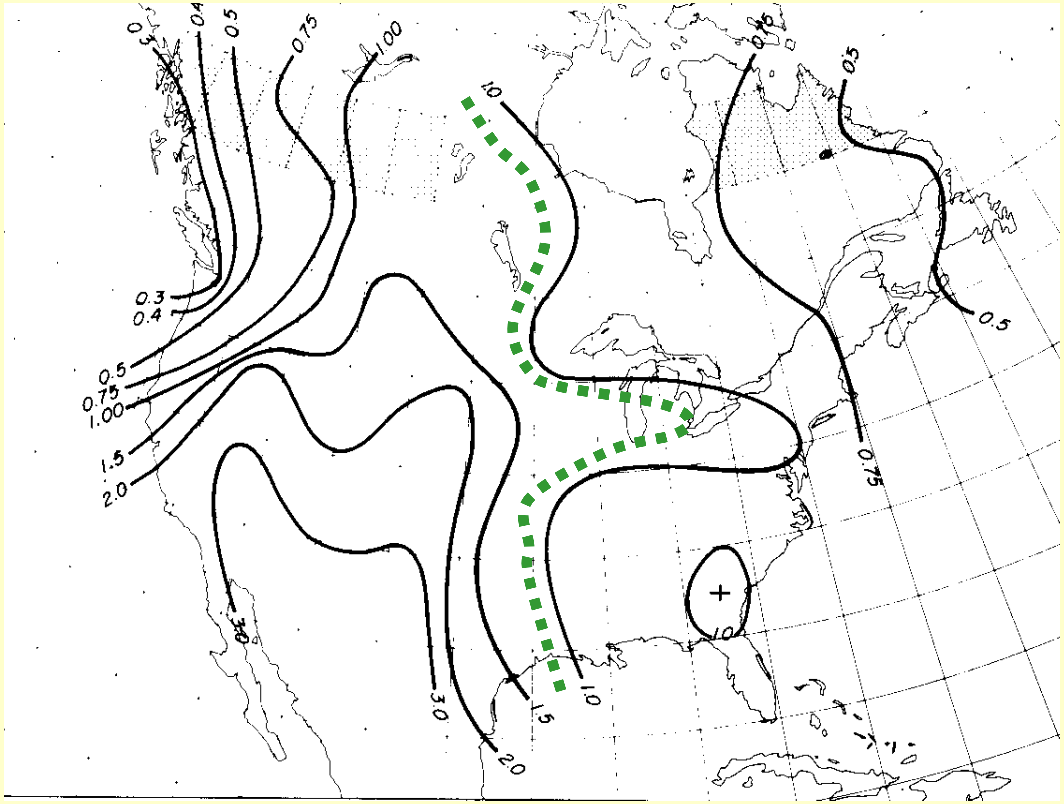
Budyko-Lettau dryness ratio

$$D = R / (L \times P)$$

where D = dryness ratio;
R = mean ann. net radiation;
P = mean ann. precipitation;
L = latent heat of vaporization of water

The forest- prairie boundary

Budyko suggested that the forest - grassland boundary in the midwest corresponds with a dryness ratio of 1.1 -1.2 (=dotted line)



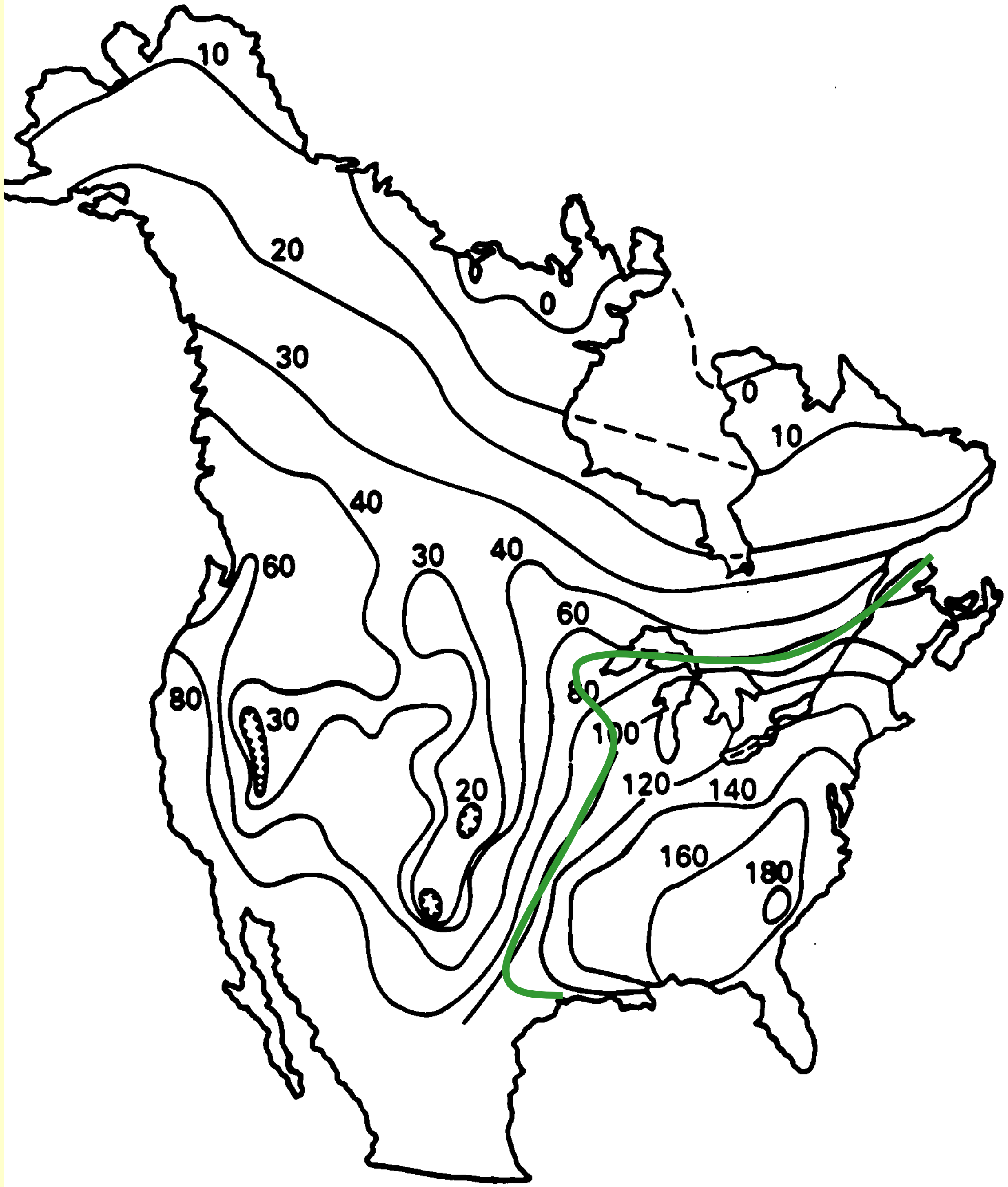
Budyko dryness ratio values, N. America

Hare (1980) Atmos.-Ocean 18, 127-153.

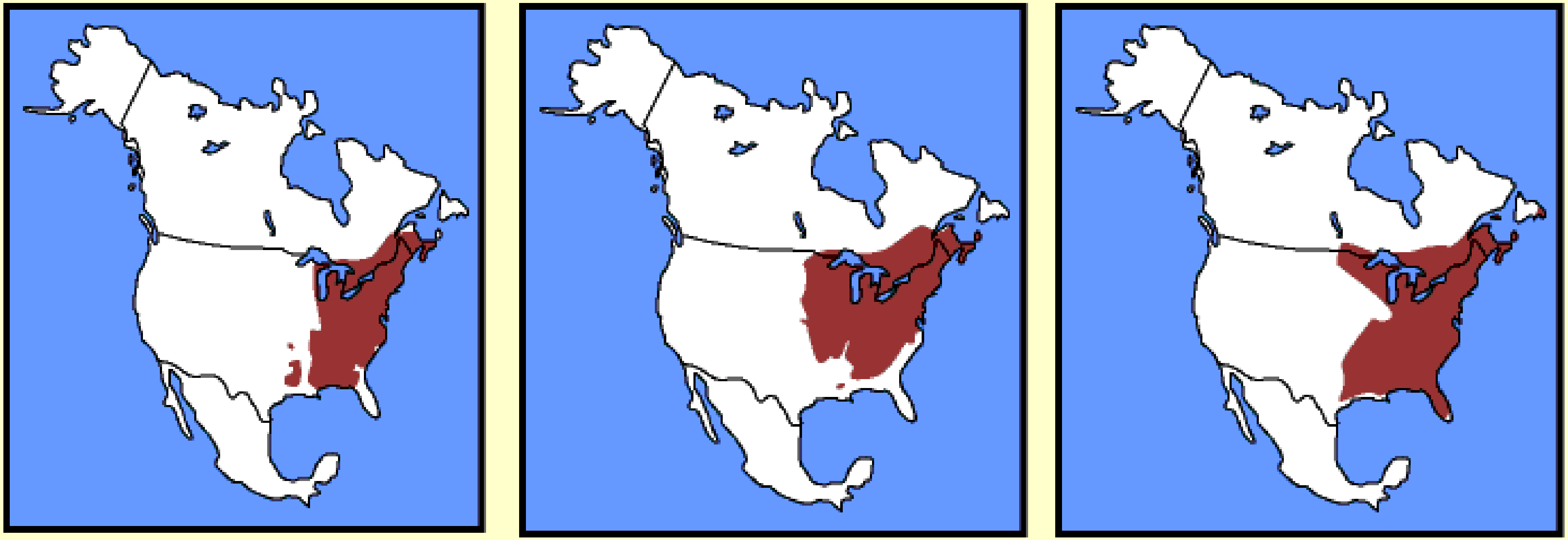
Tree species diversity

+++++++++

Is reduced diversity to northwest a result of the harsher climate?



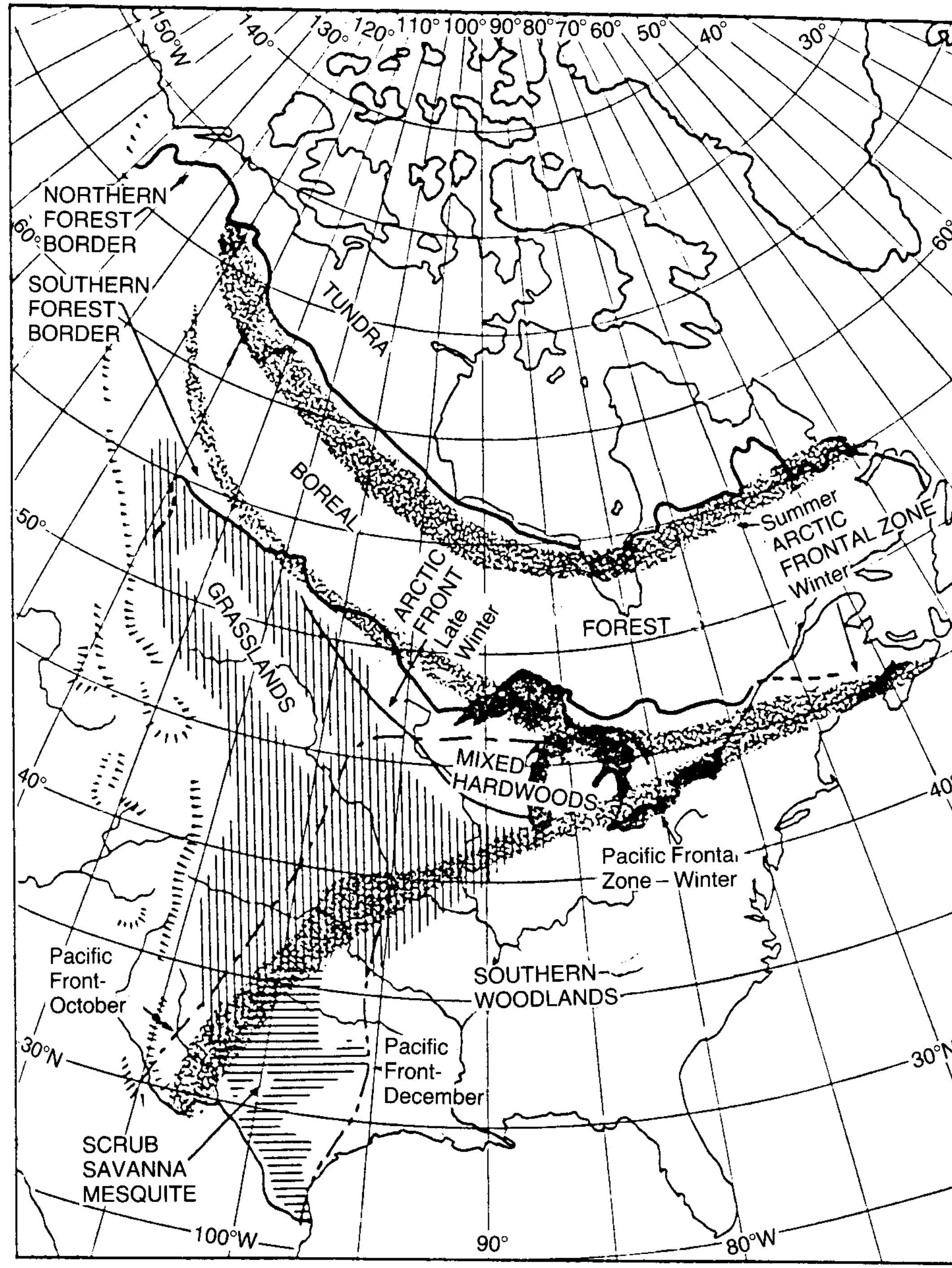
Temperate forest trees: common northern limits = similar limiting temperatures?



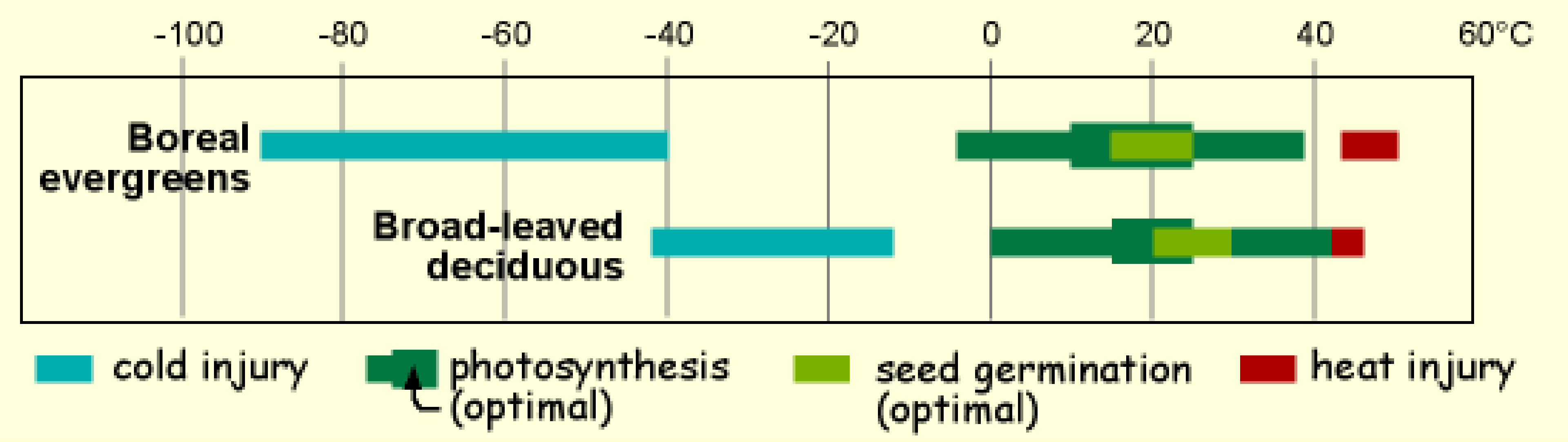
American beech red oak red maple

(plus white oak, black oak, 2 hickories . . . .)

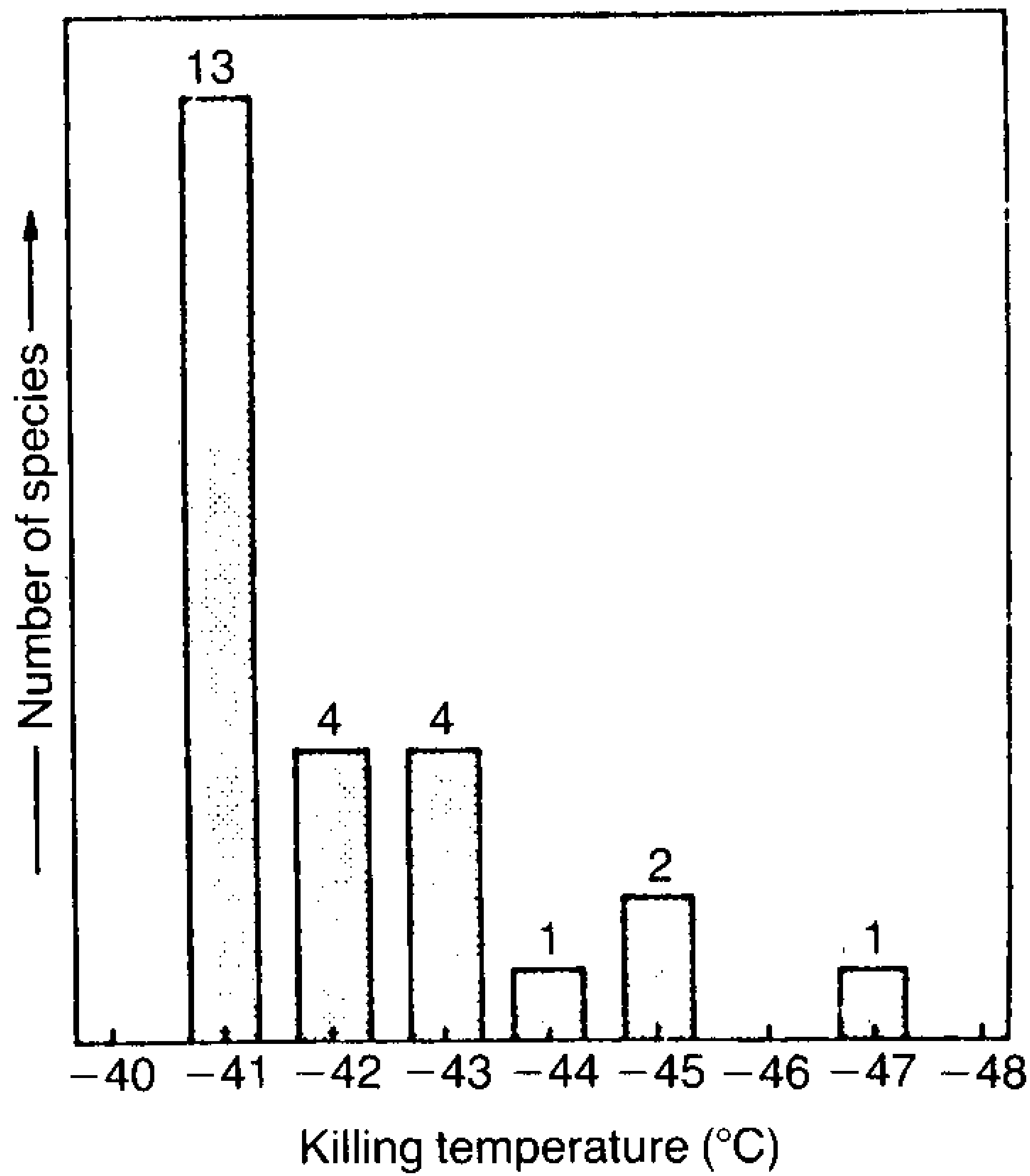
Airmass climatology - biome boundaries



Thermal limits and optima



Cold injury



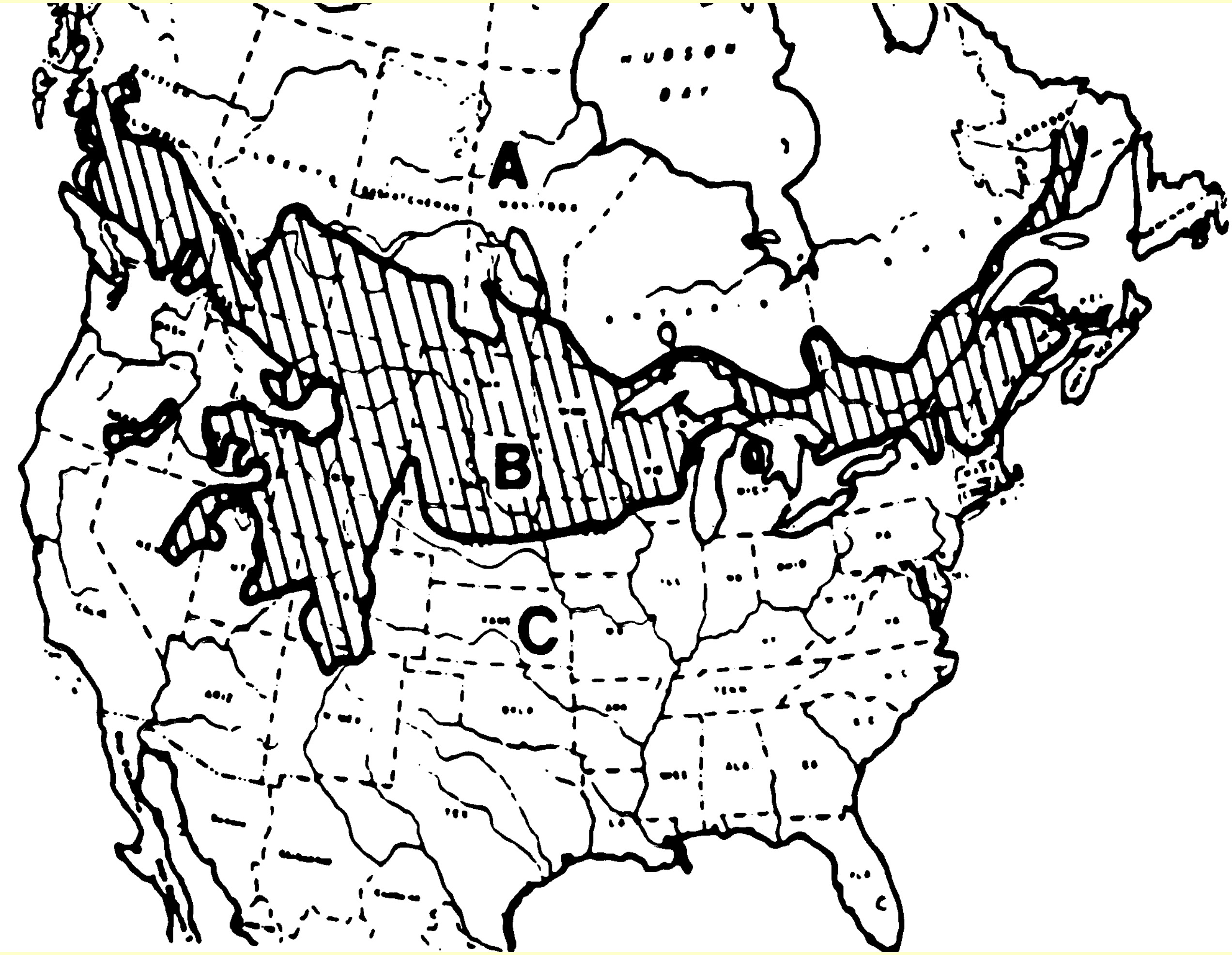
13
4
4
1
2
1
Number of species
−40
−41
−42
−43
−44
−45
−46
−47
−48
Killing temperature (°C)

Probability of temperatures falling below -40°C

A = common

B = rare

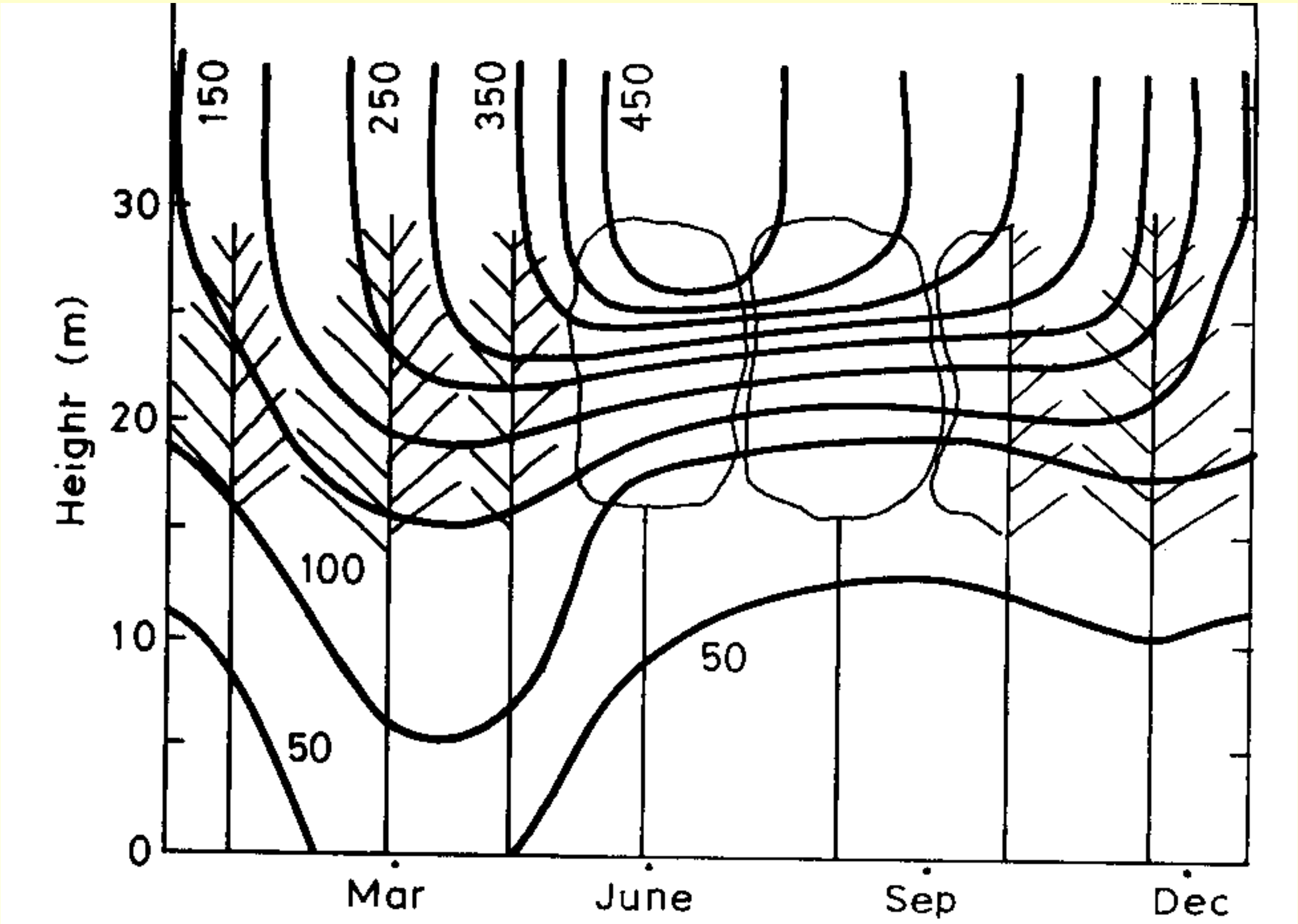
C = never



American beech

Winter-summer phases

Daily irradiance*: Liriodendron stand, Tennessee



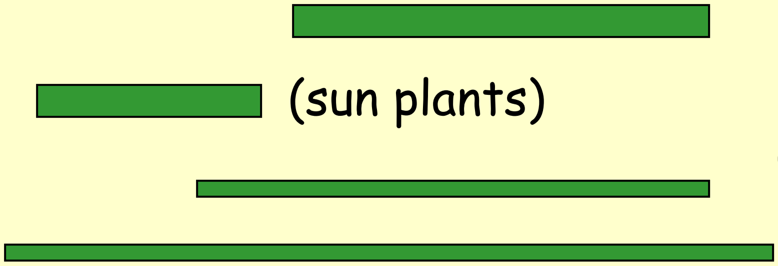
Photosynthetic activity

Trees

Vernal ephemerals (sun plants)

Summer herbs (shade plants)

Evergreens

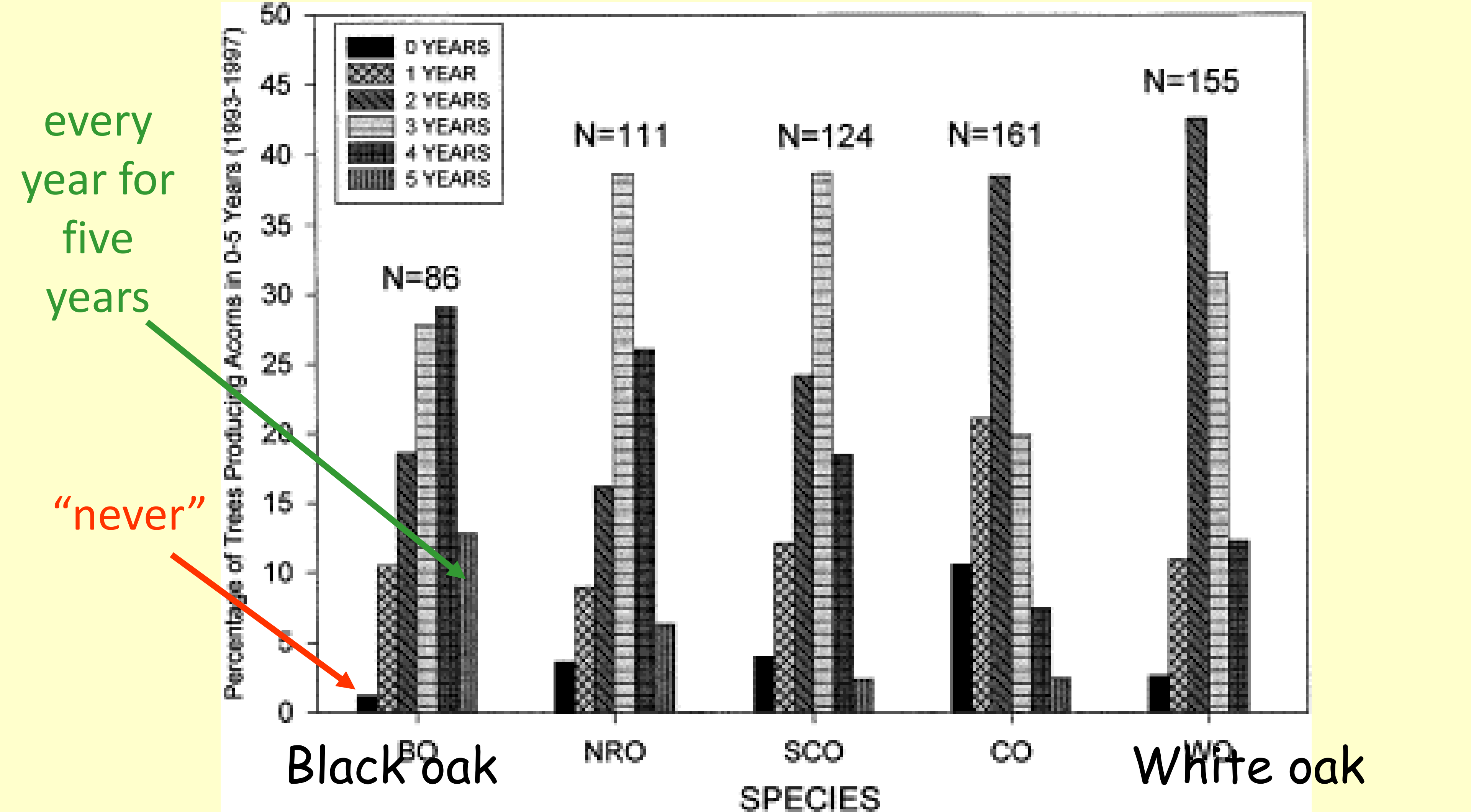


* values are langleys/day

Shade tolerance of N. American TDF trees

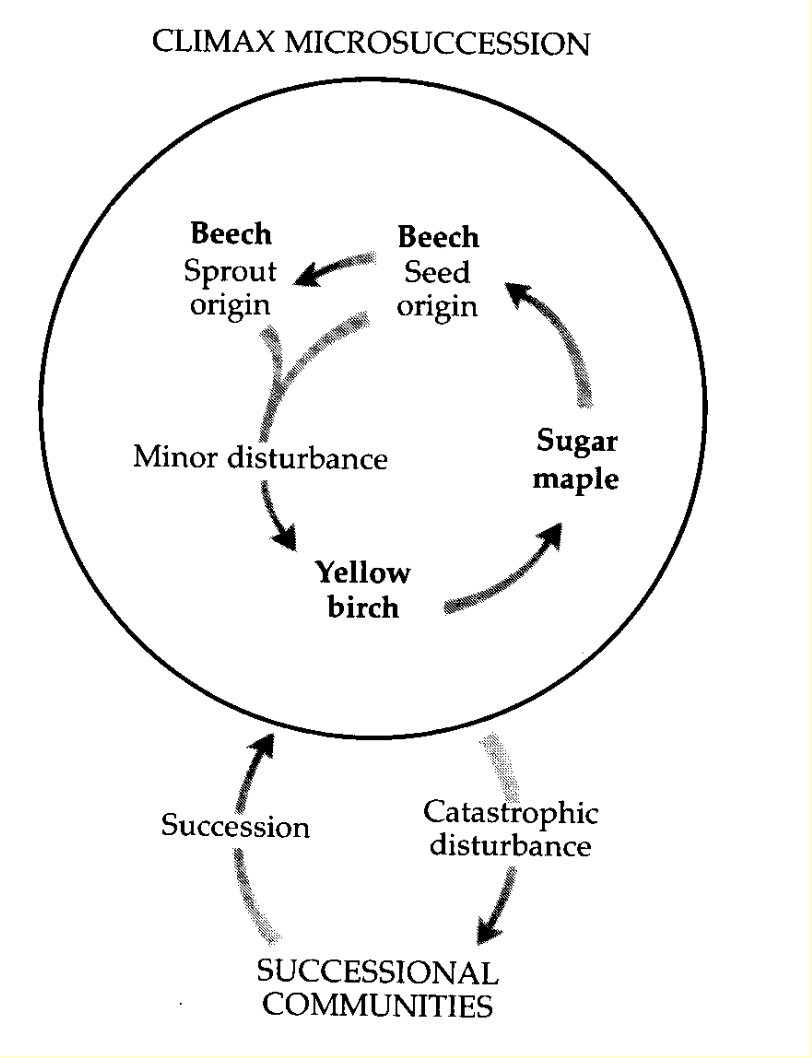
Intolerant	yellow poplar (*Liriodendron tulipifera)* **- pioneer** black locust (*Robinia pseudoacacia*) **- pioneer** black cherry (*Prunus serotina*) black walnut (*Juglans nigra*)
Intermediate	white ash (*Fraxinus americana*) red and white oak (*Quercus rubra, Q. alba*) hickories (*Carya* spp.)
Tolerant	sweet birch (*Betula lenta*) **- pioneer** basswood (*Tilia americana*) red maple (*Acer rubra)*
Very Tolerant	sugar maple (*Acer saccharum*) American beech (*Fagus grandifolia*) eastern hemlock (*Tsuga canadensis*)

Periodicity of acorn production
(note variable behaviour within and between oaks)



Old-field succession (Northern hardwoods)

Pioneer phase - 20 yr old stand of pin cherry (Prunus sp.) in S. Ontario. Bird dispersal.



Fire / old-field succession (mixed forests of the southeast)

Year

Oak - hickory
(tulip tree, magnolia, dogwood)

50 ↑

Pine
(shortleaf/longleaf)

5 ↑

weedy herbs

Modern forest fauna (N. America)

Characteristic animals are now either herbivores (predominantly seed eaters) or omnivores.

Herbivores: white-tailed deer, gray squirrel, chipmunk, blue jay (passenger pigeon - extinct).

Omnivores: raccoon, opossum, skunk, black bear.

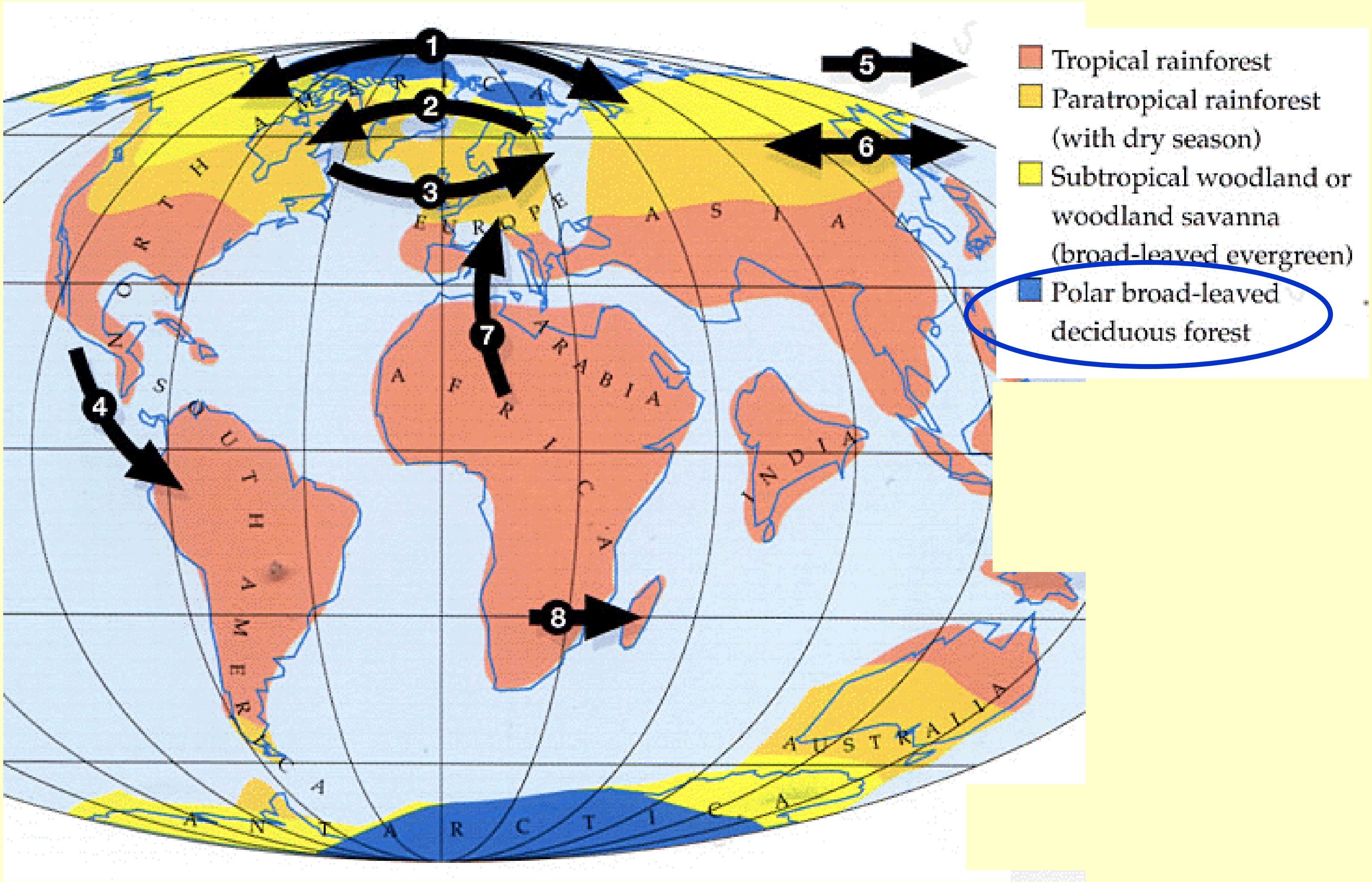
Carnivores: (wolf, cougar, bobcat - all largely eliminated by hunting and habitat destruction; replaced by coyote)

Many northern temperate forest tree genera are widespread

	E N Am	Europe	E Asia
Quercus (oak)	X	X	X
Acer (maple)	X	X	X
Fagus (beech)	X	X	X
Castanea (chestnut)	X	X	X
Carya (hickory)	X	F	X
Ulmus (elm)	X	X	X
Tilia (basswood/linden)	X	X	X
Juglans (walnut)	X	X	X
Liquidambar (sweet gum)	X	F	X
Liriodendron (yellow poplar)	X	F	X

X = extant; F = fossil

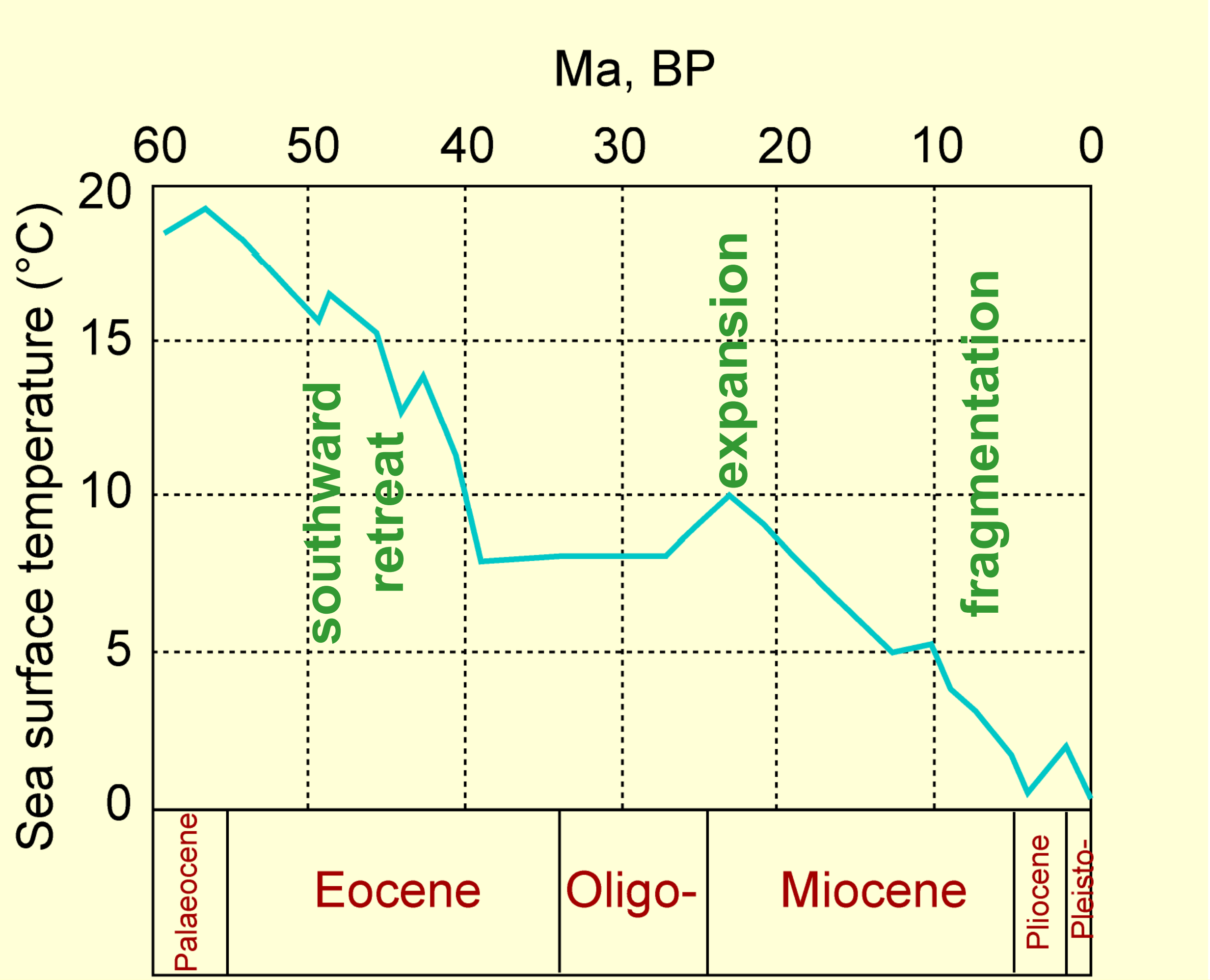
Biomes of the early Tertiary (~60 Ma)



Eureka Sound formation: Ellesmere Is*.

Gymnosperms:
Cedrus, Picea, Pinus, Tsuga
Angiosperms:
Acer, Betula, Carya, Corylus, Castanea, Fagus, Quercus
Fauna:
turtles, alligators,
boid snakes, salamanders,
tortoises

Tertiary cooling and the temperate mesophytic forest

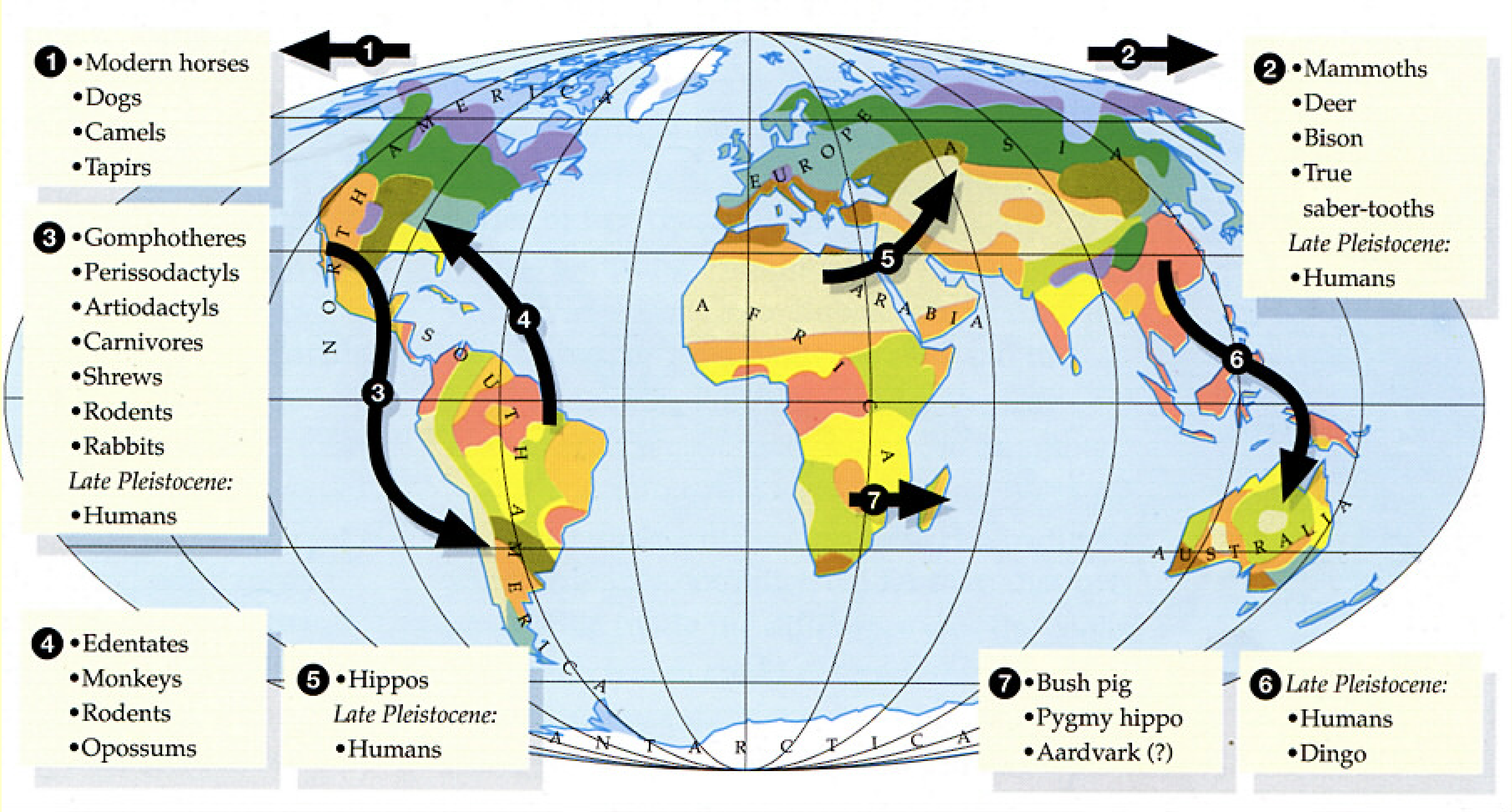


Eurasian - North American temperate forest divergence (from genetic evidence)

Liriodendron chinense
Liriodendron tulipifera
(Magnoliaceae)

Xiang et al., 2000. *Mol. Phylogenet. and Evol*. **15**, 462-472.

Pliocene fragmentation



Full-glacial refuges (R) and Holocene migrations

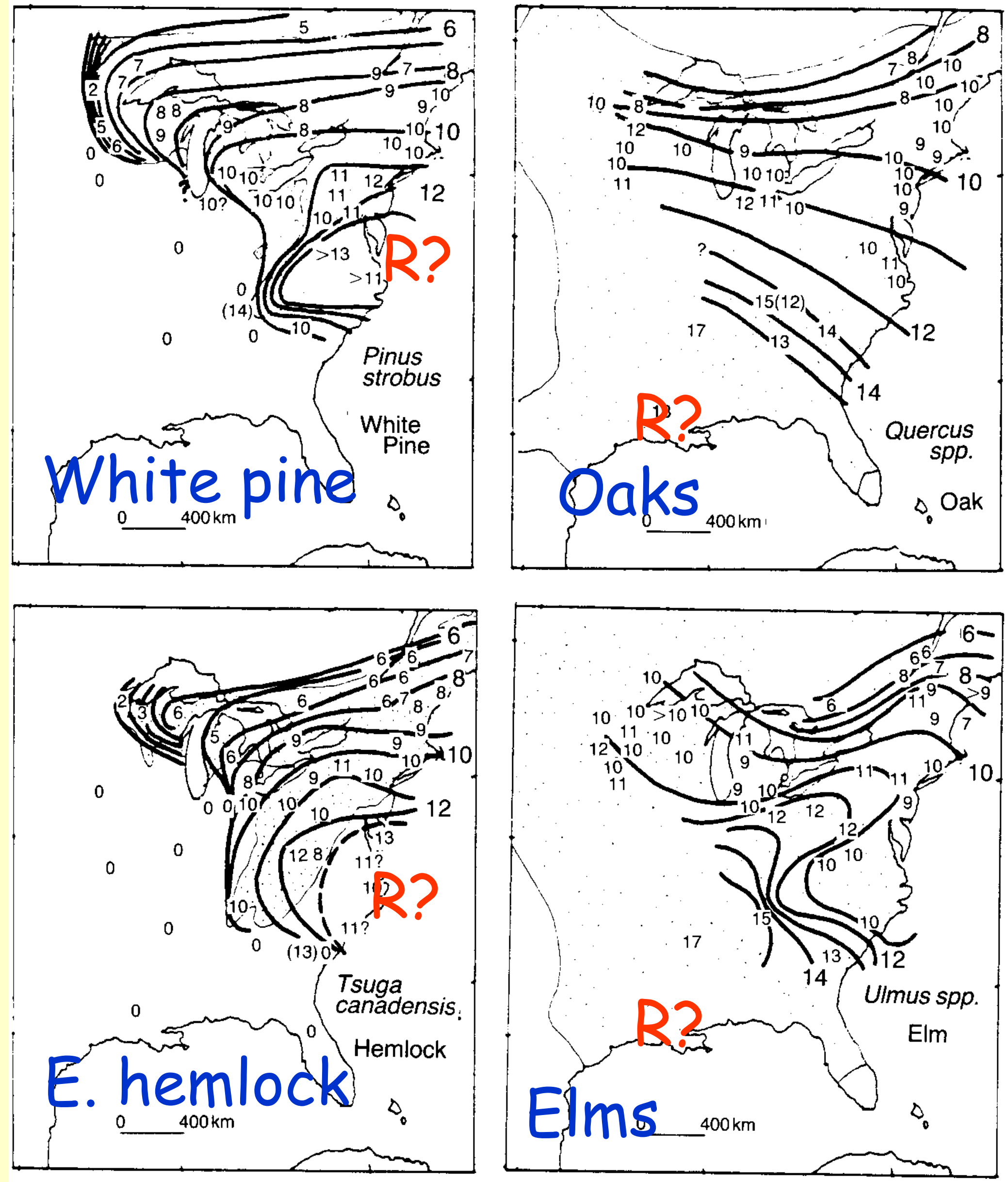


Figure 4.15 Changes in nothern and western range limits for four important eastern North American tree taxa during the late Quaternary based upon radiocarbon-dated pollen records from lake sites. Numbered lines represent range limits at times in the past in thousands of years B.P. The area with stippled pattern represents the modern distributional range of the tree taxa. From Davis (1983).

Table 2.1 Estimates of Holocene migration rates of nut trees

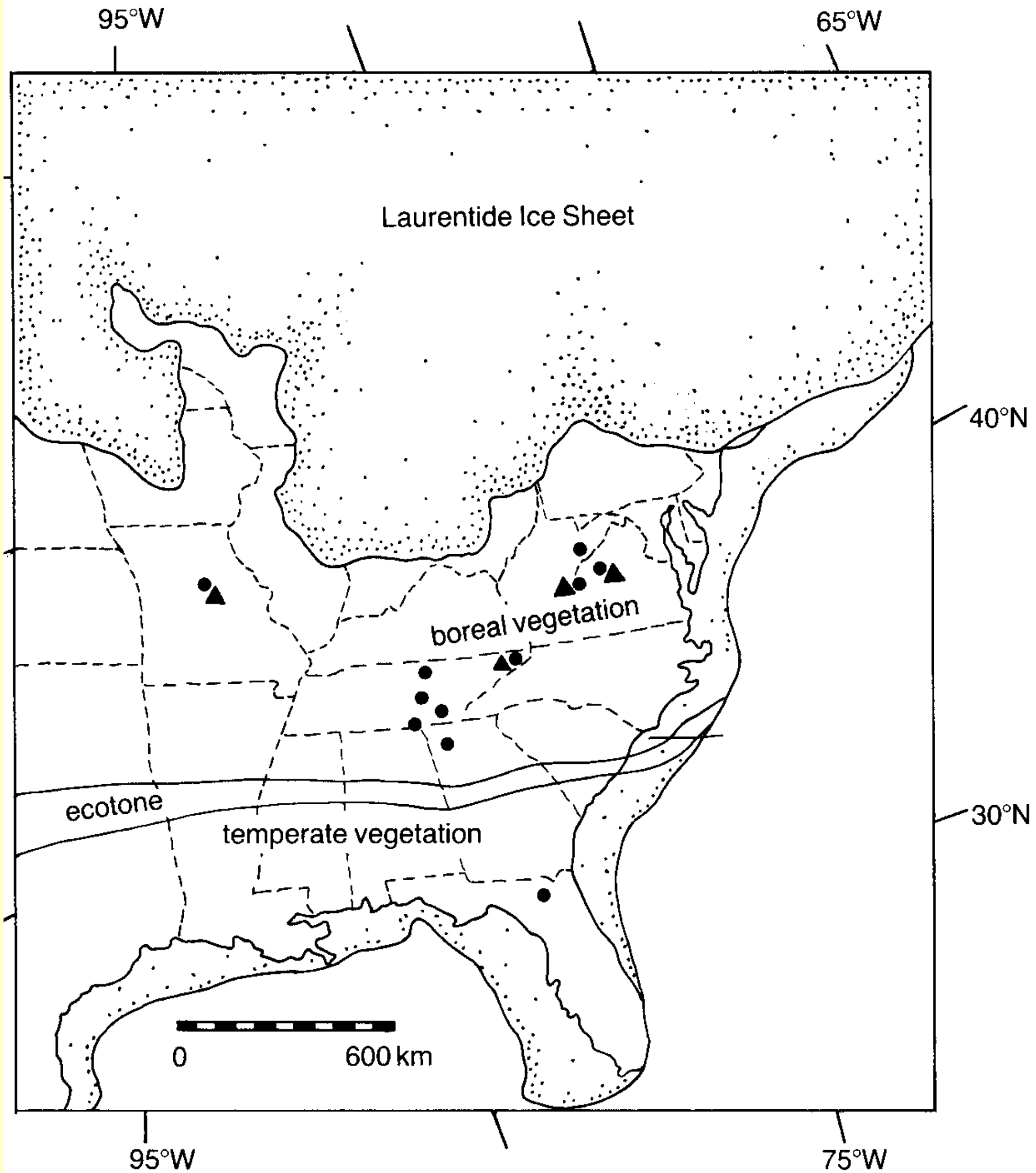
	Beech (Fagus grandifolia)	*Oak (Quercus)*	*Hickory (Carya)*
Minimum age of seed production	40 yr	20 yr	30 yr
Average rate of postglacial range extension	(a)		
Fossil-pollen data (M. Davis, 1976, 1981a, 1983)	200 m/yr	350 m/yr	200 to 250 m/y
Quantitative forest composition based on fossil-pollen data (Delcourt and Delcourt, 1987a)	(b) 169 m/yr	126 m/yr	119 m/yr
Average dispersal distance	(c)		
Based on fossil-pollen data (S. Webb, 1986)	8 km/gen (=a x b)	7 km/gen	6 to 7.5 km/ge
Based on quantitative forest composition as reconstructed from fossil-pollen data (Delcourt and Delcourt, 1987a)	6.8 km/gen (=a x c)	2.5 km/gen	3.6 km/gen

Quercus macrocarpa

Fagus grandiflora

Rapid post-glacial migration: are seed-caching birds responsible?
What role do they play in long-distance dispersal at present?

Postglacial fossil finds: passenger pigeon (dots) and blue jay (triangles)

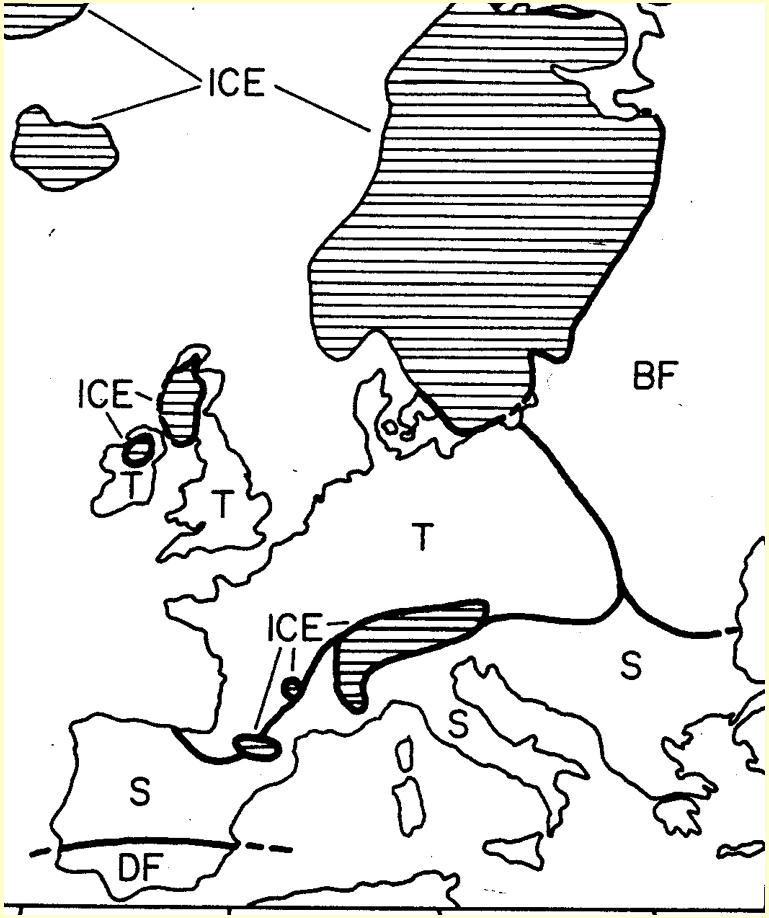


Why is the European TDF depauperate?

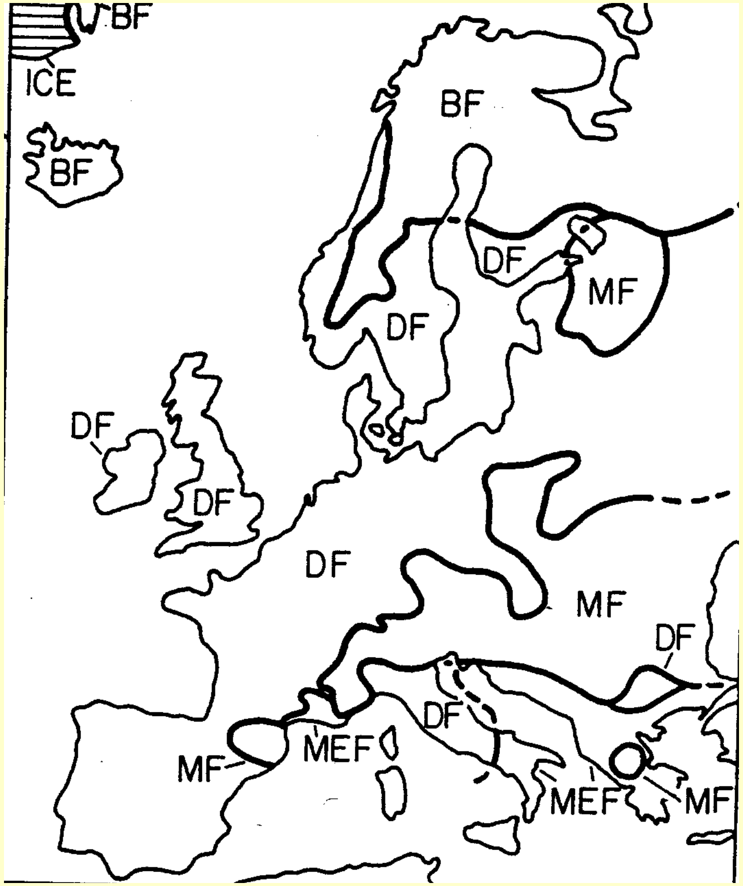
	E N Am	Europe	E Asia
Quercus (oak)	X	X	X
Acer (maple)	X	X	X
Fagus (beech)	X	X	X
Castanea (chestnut)	X	X	X
Carya (hickory)	X	F	X
Ulmus (elm)	X	X	X
Tilia (basswood)	X	X	X
Juglans (walnut)	X	X	X
Liquidambar (sweet gum)	X	F	X
Nyssa (sour gum)	X	F	X

X = extant; F = fossil

Late Quaternary dynamics (Europe)



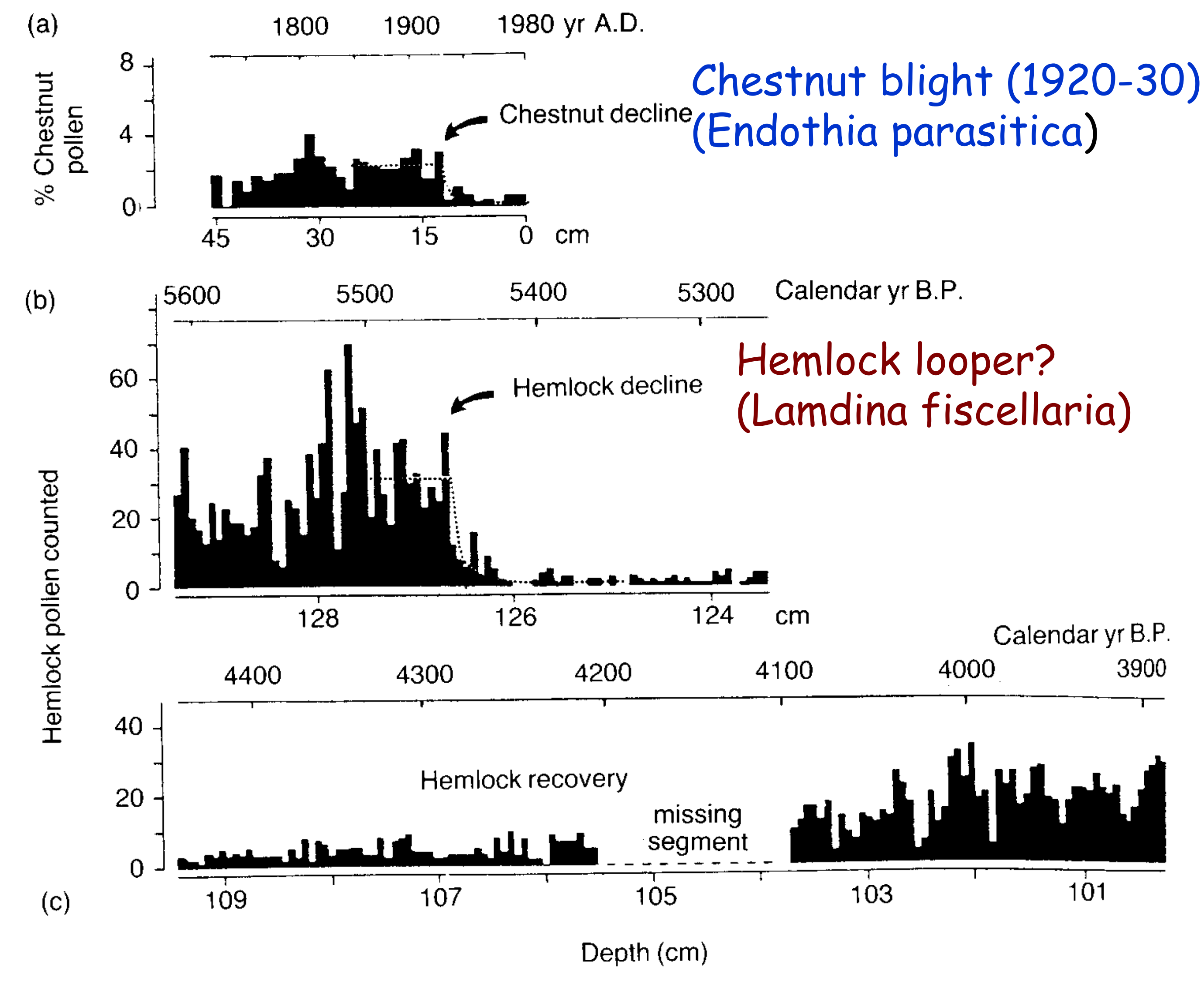
13 000 yrs BP



present

Recent species fluctuations: pest-pathogen effects on species dynamics

(+ Dutch elm)



Chestnut blight (1920-30) (*Endothia parasitica*)

Hemlock looper? (*Lamdina fiscellaria*)

What effects do these die-outs have on the success of competitors?

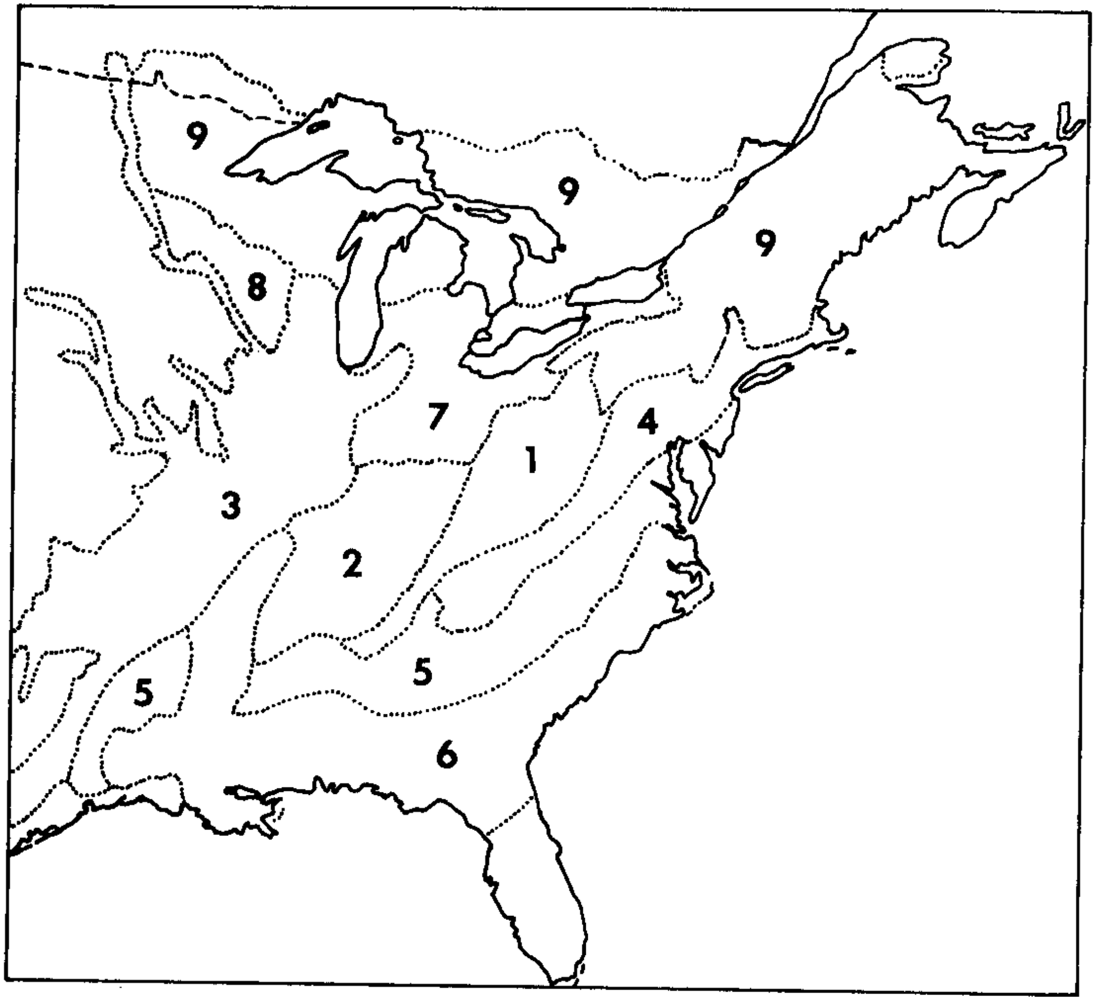
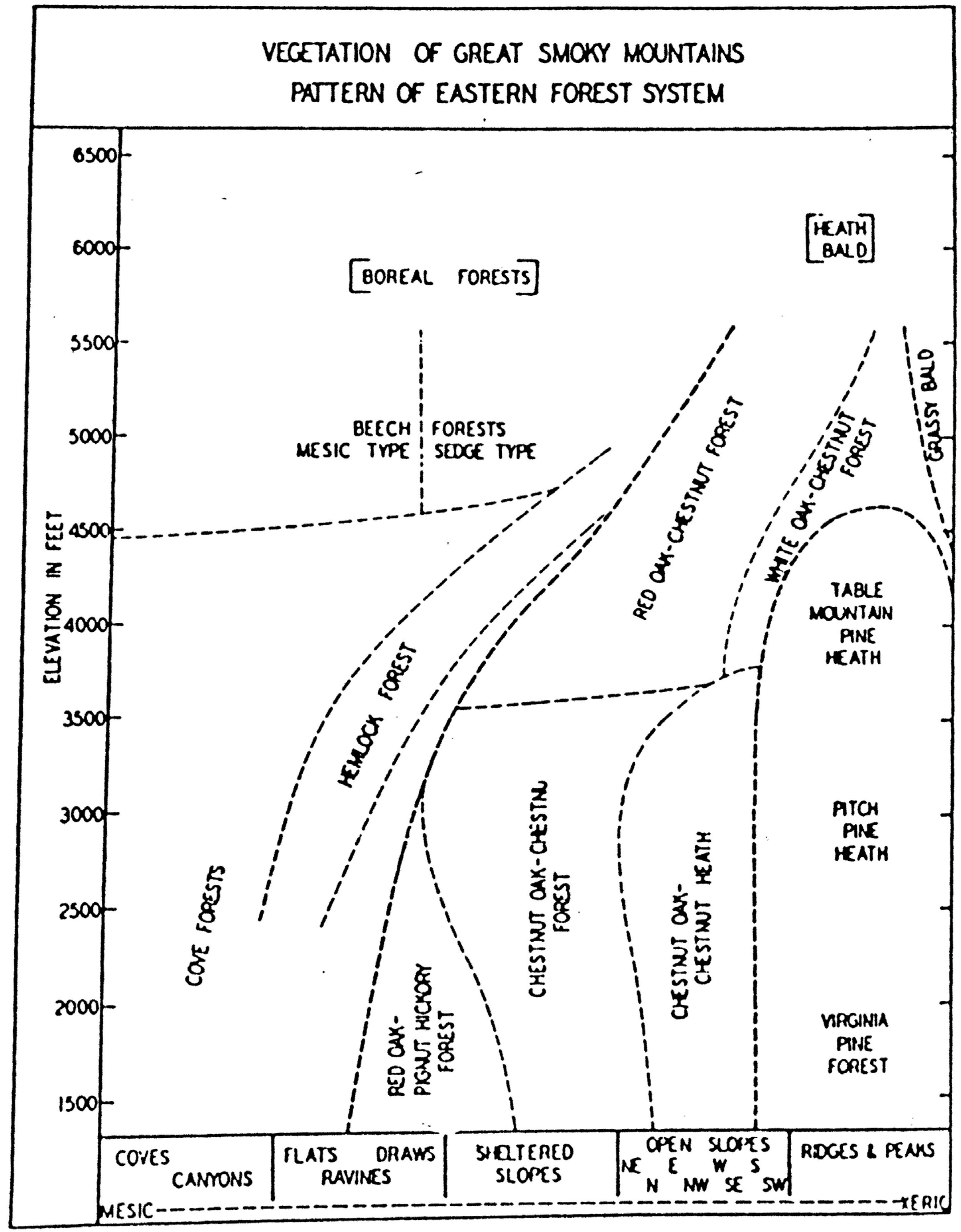
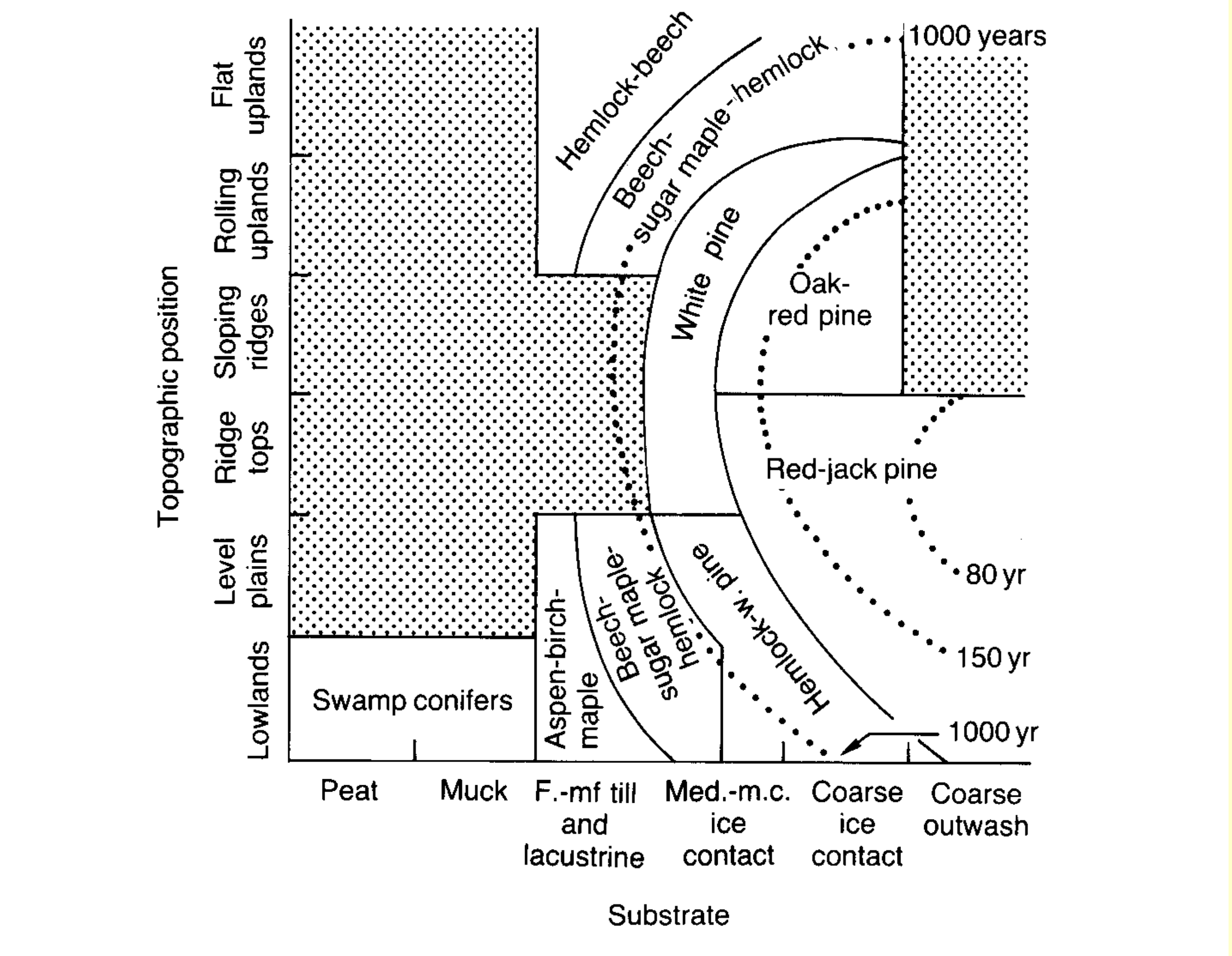


Figure 12.2 Major plant community association within the Eastern Deciduous Forest biome: (1) mixed mesophytic forest association; (2) Western mesophytic forest association; (3) oak–hickory association; (4) oak–chestnut association; (5) oak–pine association; (6) Southern mixed hardwood association; (7) beech–maple association; (8) maple–basswood association, (9) Northern hardwoods association. (Braun, 1950; Vankat, 1979)

Plant community structure as a function of topography and elevation in the Great Smoky Mountains





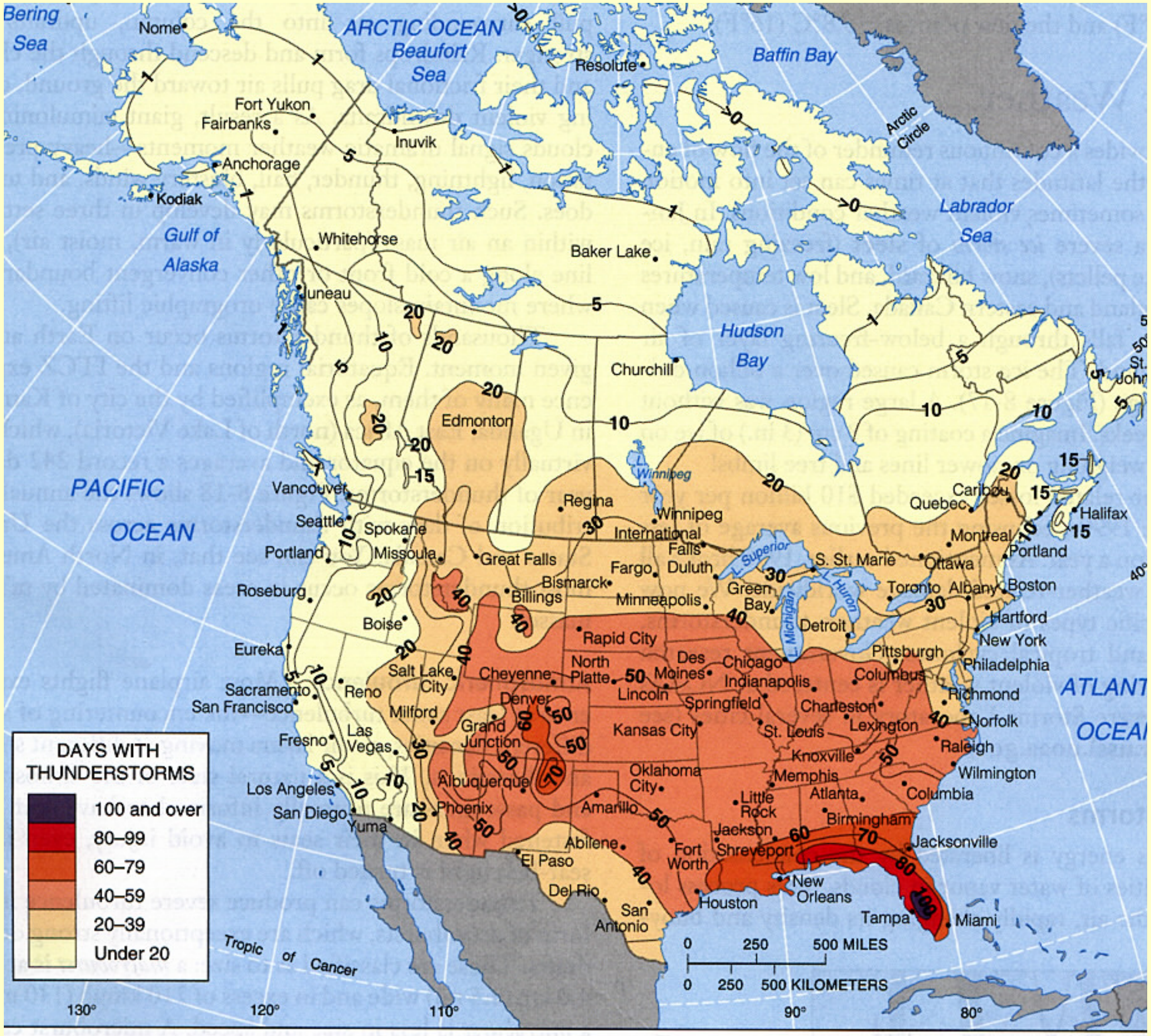
Plant community structure as a function of topography, substrate and disturbance frequency in Michigan

Disturbance and ecological succession

Examine the roles of:

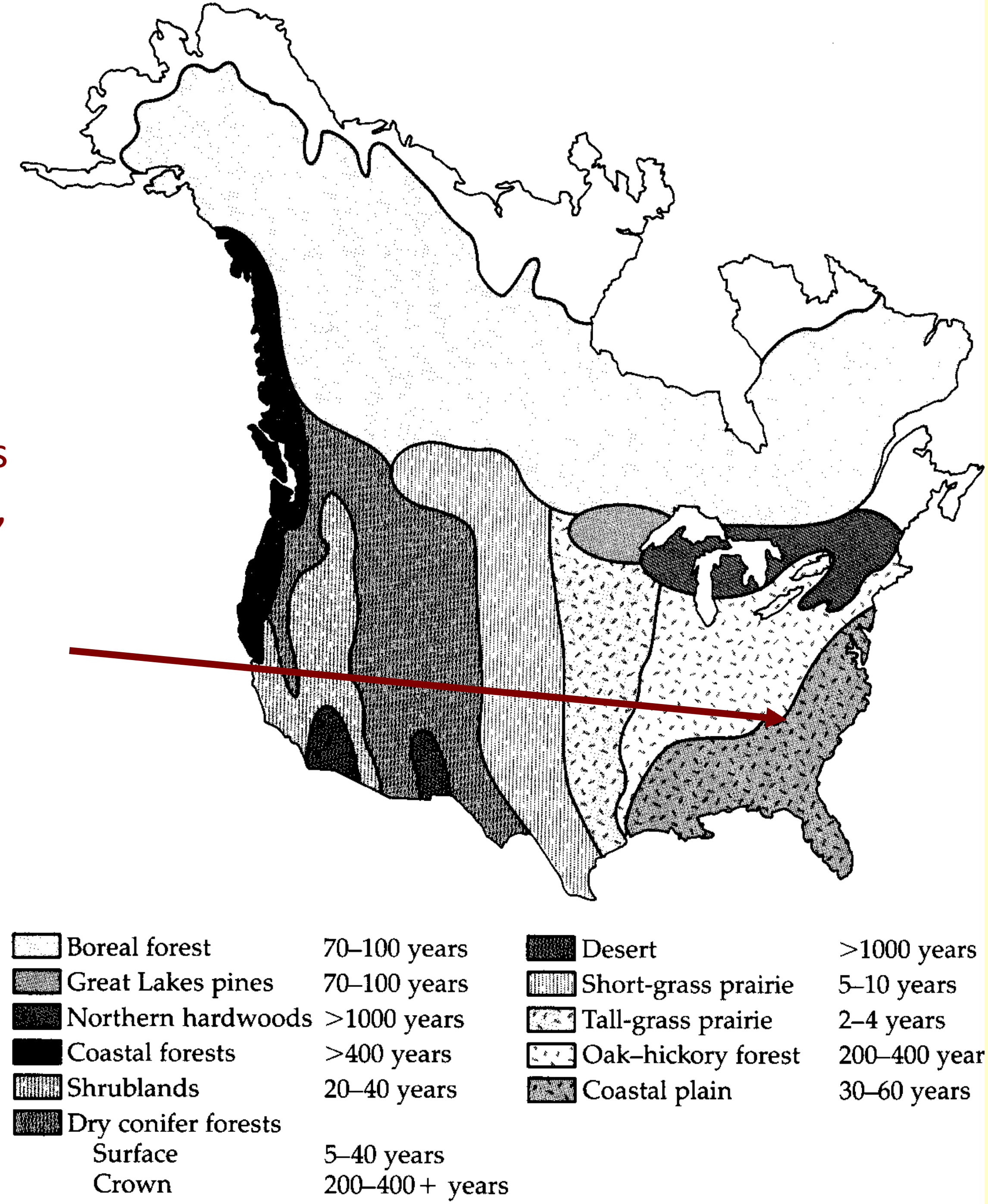
- Fire
- Wind
- Anthropogenic (forest clearance)

Natural disturbance: lightning-strike fires



Natural fire recurrence

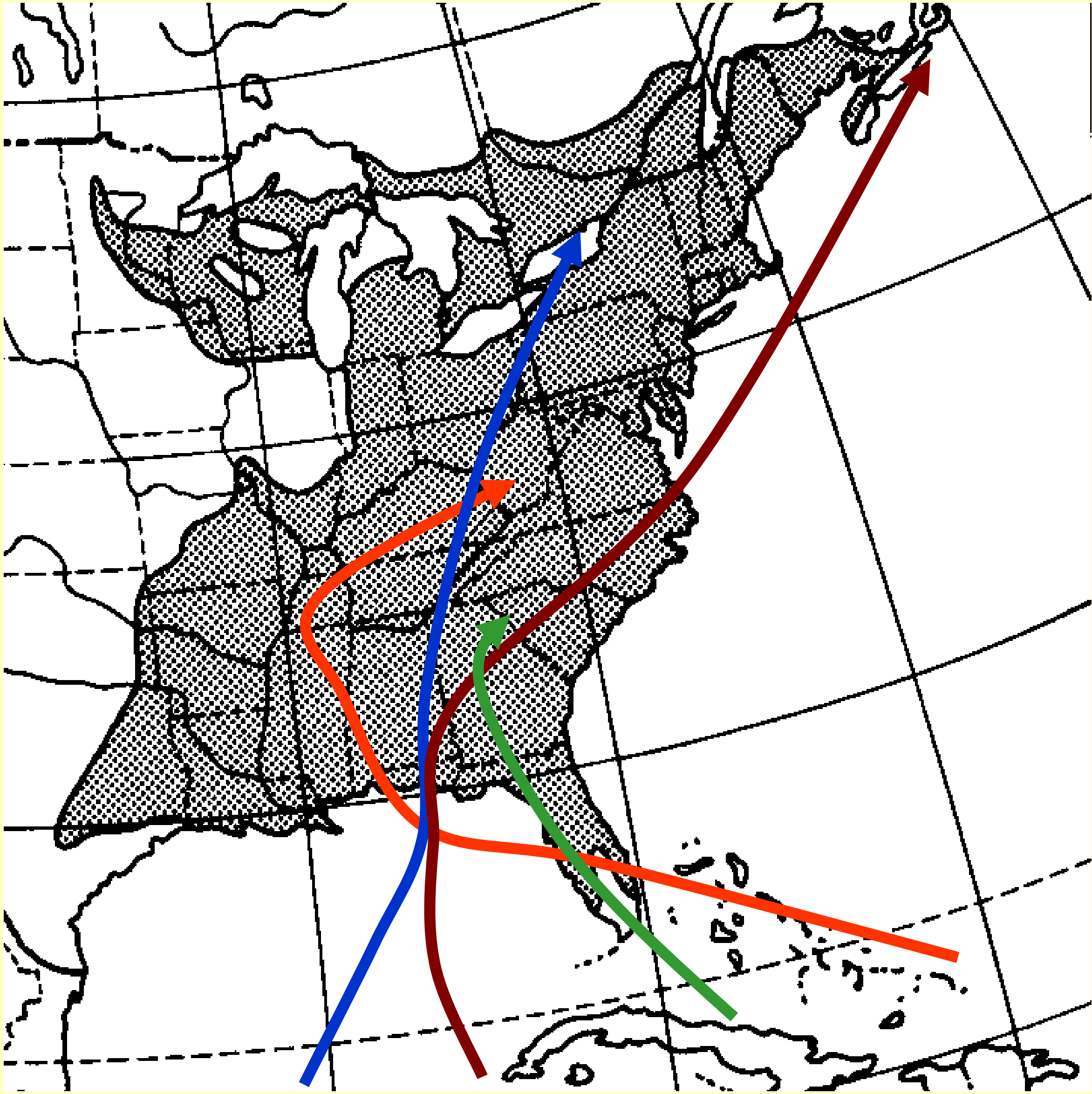
"from 1955 to 1994 only 5 years had records of lightning-set fire, with an average of 7 years between fires. Lightning strikes occurred on ridge tops and along xeric upper hillslopes (and) did not spread into lower sheltered coves or stream valleys."



Delcourt, H.R. & Delcourt, P.A. 1997.
Conservation Biol., **11**, p. 1010.

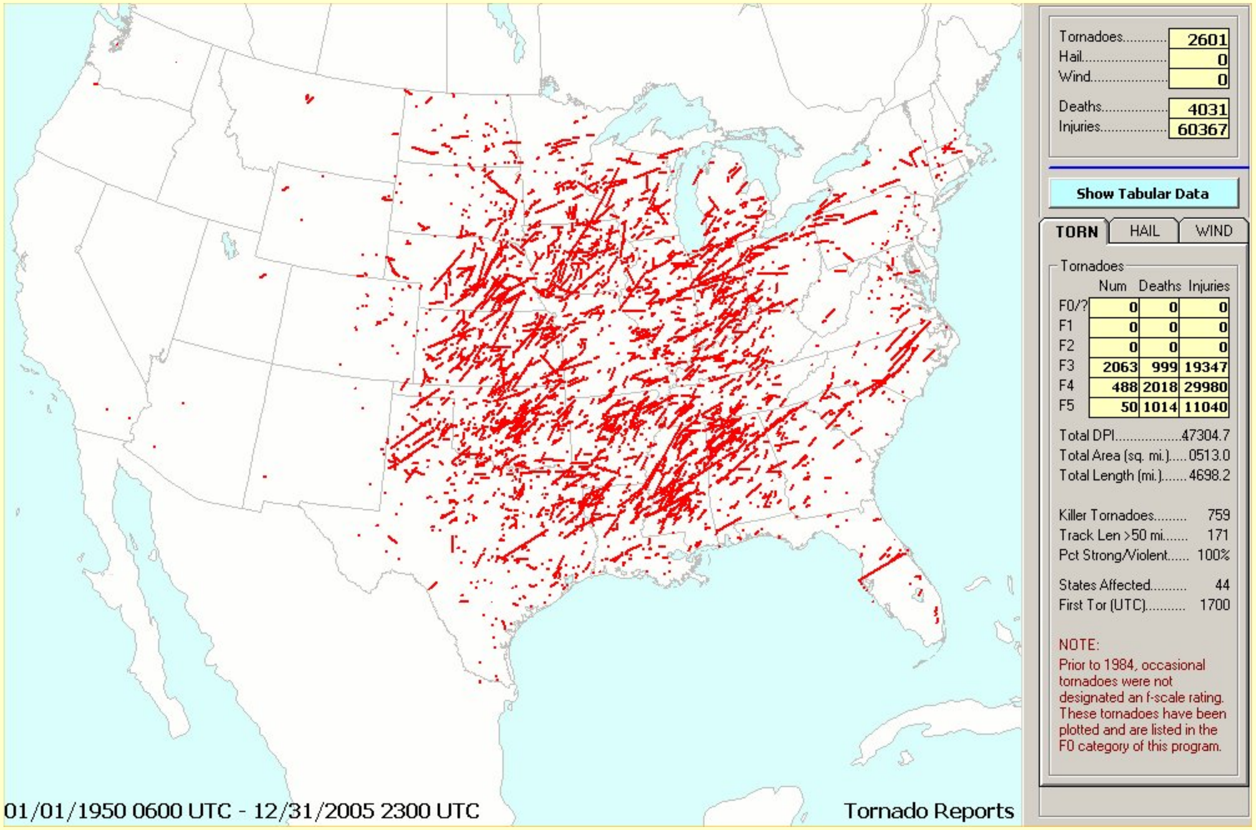
Natural disturbance: hurricane windthrow

Paths of tropical storms in 1995, and their maximum wind speed in km/h.



Erin (160) Dean (70) Alison (120) Jerry (65)

Natural disturbance: tornado windthrow



Paths of F3-F5 tornadoes in USA: 1950-2005

Graphic: www.hprcc.unl.edu/nebraska/

Windstorm disturbance: local and regional

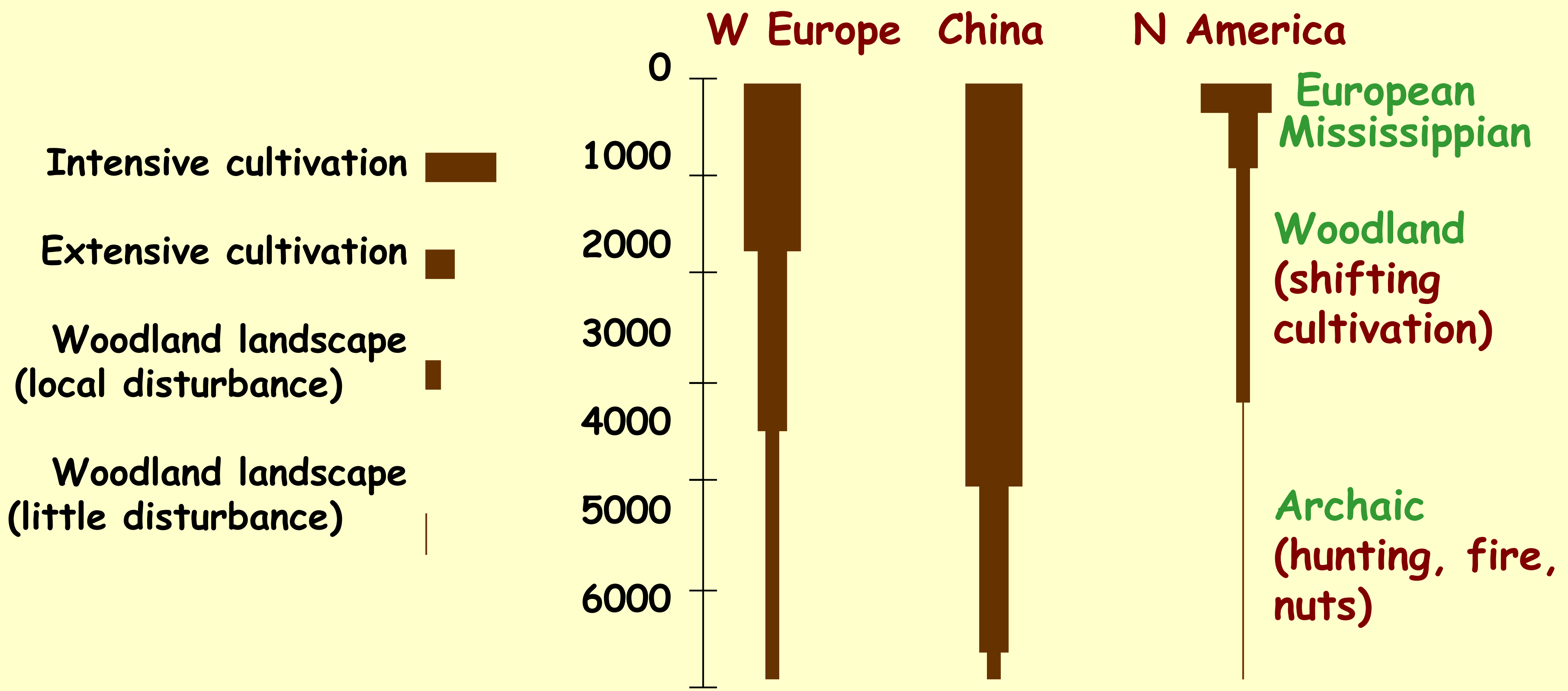
Path almost 1 km wide

Tornado path (above: satellite image) and forest damage (below) in Menominee Reservation, Wisconsin, June 2007

90 knots = 170 km/h

Great Storm of 1987:
15 million trees blown over in southern Britain

Anthropogenic disturbance: agricultural clearance

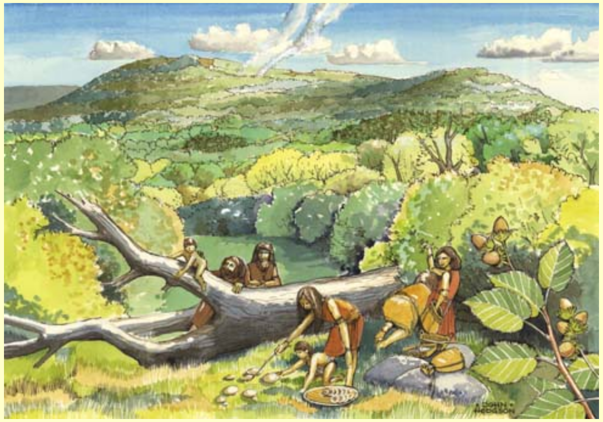


Anthropogenic disturbance and forest remnants (Europe)

Forest patches on steeper slopes and distant from villages

Clearing the forest primeval: northern England

Mesolithic (8000 BP)



Late Bronze Age (4500 BP)

Roman (2000 BP)

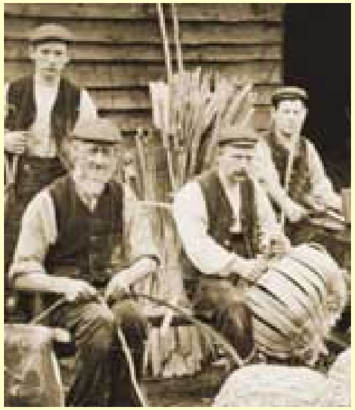
Medieval (6000 BP)

www.lancashire.gov.uk/environment/archaeologyandheritage/

Forest management: coppicing and charcoal production

~10,000 poles/acre

baskets, farm implements, barrels, soap (from ash)



Dried poles

Forest management: animal husbandry

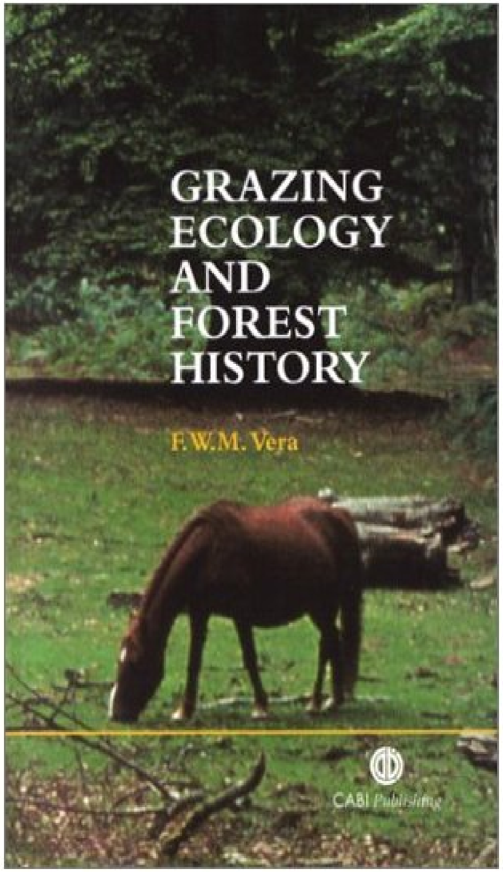
acorns, beechmast, sweet chestnuts → **Pannage**

Right to feed pigs in the forest

Or was the primeval forest "open"?

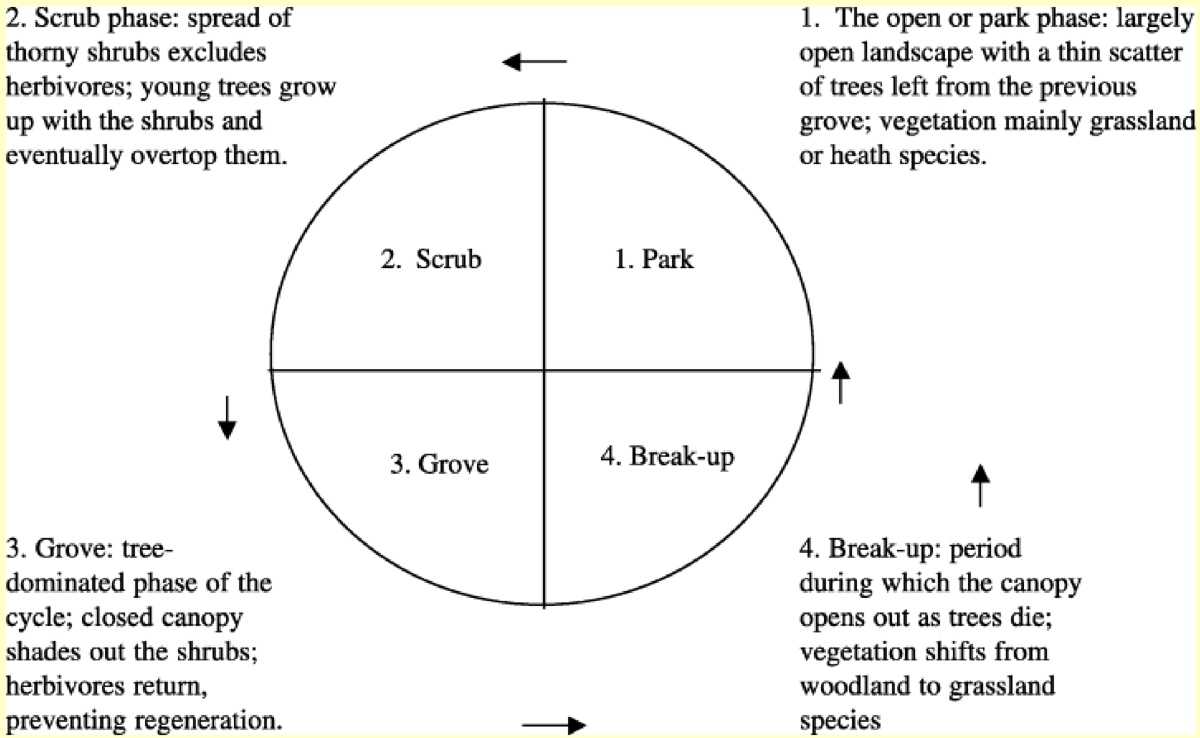
Vera (2000) argues that the early forest was "open", primarily based on these lines of evidence:

- palynology (lots of hazel pollen)
- abundance of oak (mid-successional species)
- presence of large herbivores (aurochs, bison, horses, etc.)
- Classical and medieval descriptions of "forestis"



Late Quaternary forest fauna (Europe)

The Vera hypothesis



Should large grazers be re-introduced as a tool of forest management?

Graphic: Mitchell, F.J.G. 2005. *J. Ecol.*, **93**, 168-177.

Testing the Vera hypothesis:
distribution of European herbivores in early Holocene

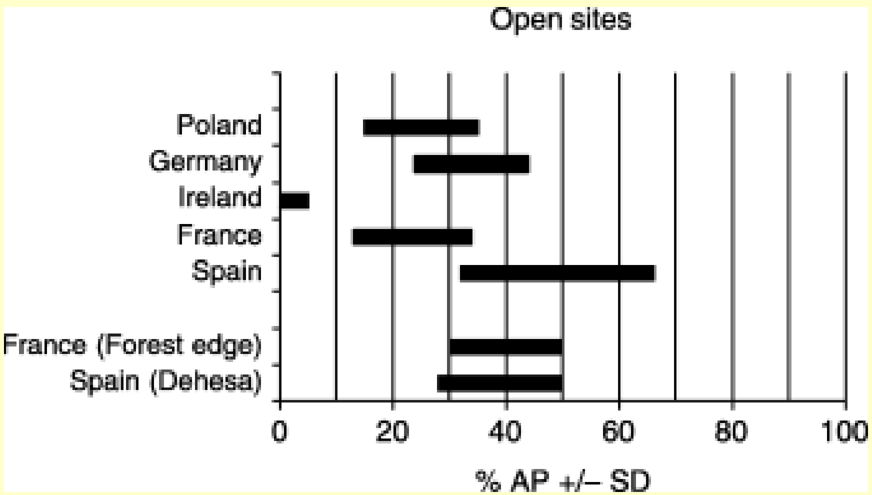
Species	NW Europe	Britain	Ireland
Wild boar (Sus scrofa)	**yes**	**yes**	**yes**
Red deer (*Cervus elaphus*)	**yes**	**yes**	**yes**
Roe deer (*Capreolus capreolus*)	**yes**	**yes**	**no**
Elk (*Alces alces*)	**yes**	**yes**	**no**
Reindeer (*Rangifer tarandus*)	**yes**	**yes**	**no**
Horse (*Equus caballus* s.l.)	**yes**	**yes**	**no**
Aurochs (*Bos primigenius*)	**yes**	**yes**	**no**
Beaver (*Castor fibre*)	**yes**	**yes**	**no**
Bison (*Bison* spp.)	**yes**	**no**	**no**
Fallow deer (*Dama dama*)	**yes**	**no**	**no**

Mitchell, F.J.G. 2005. *J. Ecol.*, **93**, 168-177.

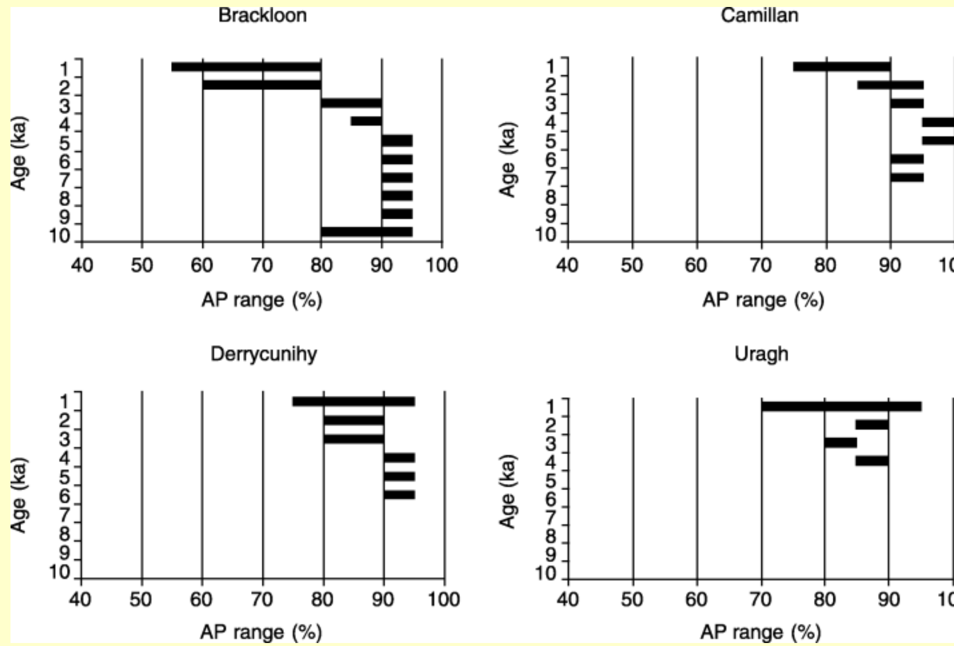
Testing the Vera hypothesis: pollen in small forest hollows

Mitchell, F.J.G. 2005. *J. Ecol.*, **93**, 168-177.

S. Sweden



Percent (mean ±1σ) tree pollen in modern "forest-parkland"



Ireland

Fire regimes?

Data from southwestern Germany

*

Fires in mid-Holocene at ~250-yr intervals;

successional sequence:

Corylus avellana **(hazel)** / ***Fraxinus excelsior*** **(ash)** **>> Quercus (oak) >>** ***Ulmus*** **(elm)** / **Tilia (lime)** **>>** ***Fagus (beech)***

**"Atlantic" in the Blytt-Sernander sequence*

Clark et al., 1989. *J. Ecol.*, **97**, 897-922.

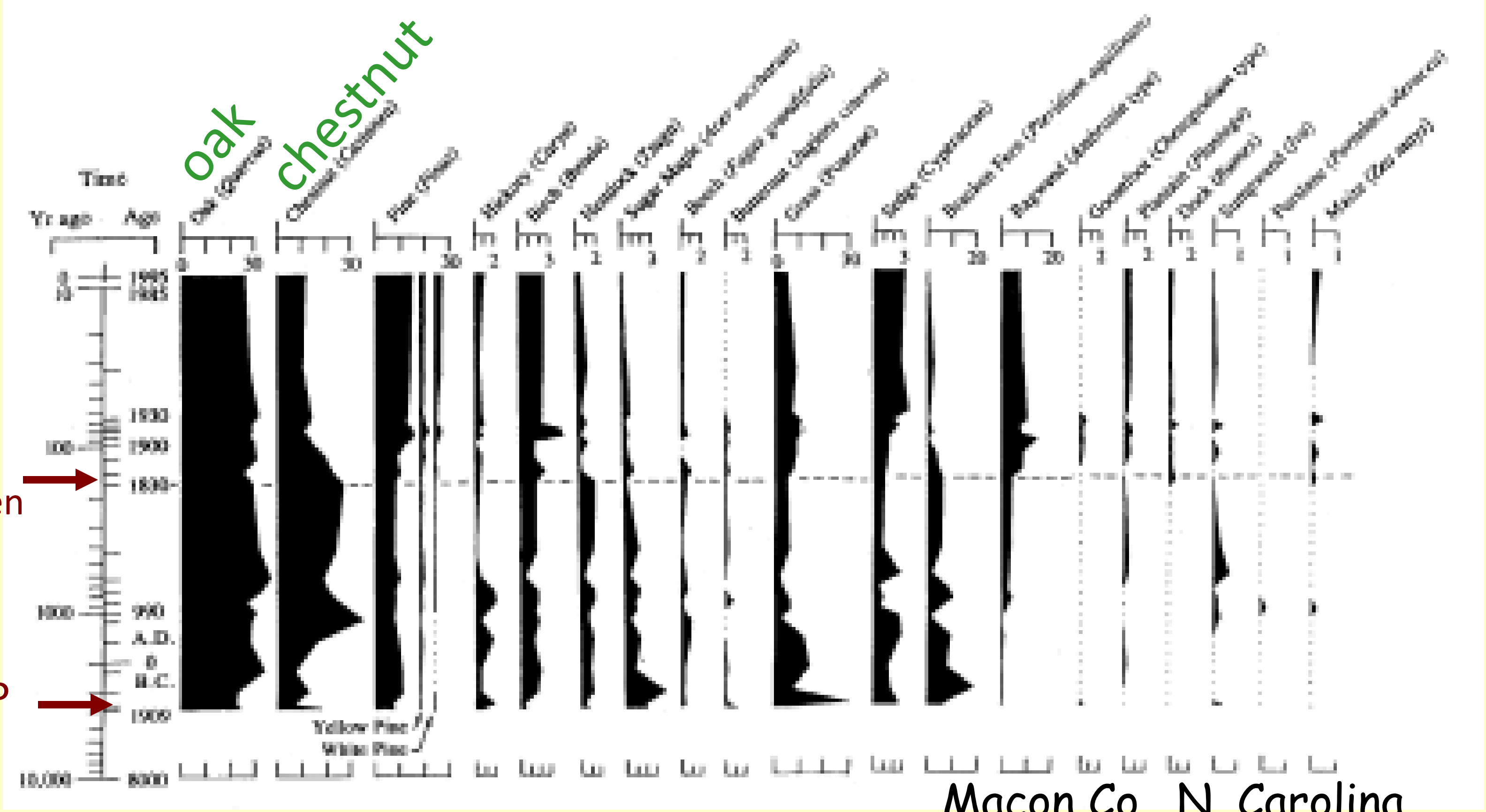
If oak is a mid-successional tree, and natural fire is rare, why are oaks a dominant species in the TDF of the eastern USA?

Tree and sapling diameters,
Watertower stand,
Fishburn Forest, VA

Tree and sapling diameters,
Radio Tower stand,
Fishburn Forest, VA

Source: Copenheaver, C.A., et al., 2006. *Northeastern Naturalist*, **13,** 477-494.

Forest constancy because of anthropogenic fire?



Delcourt, H.R. & Delcourt, P.A. 1997. *Conservation Biol.*, **11**, p. 1010.

Indians as ecological agents in the forests of northeastern America

- In 1669 Galinée visited a Seneca village (in modern NY State). The village was in an agricultural clearing about 6km wide;
- Village sites were abandoned every 10-20 years as the soil became exhausted
- Forests near villages were burned each spring and fall to remove undergrowth and improve grazing for deer and elk.

An Algonkian village

Abstracted from:
Day, G.M. 1953. *Ecology,* **34**, 329-346.