

A Brief Introduction to Dendroecology

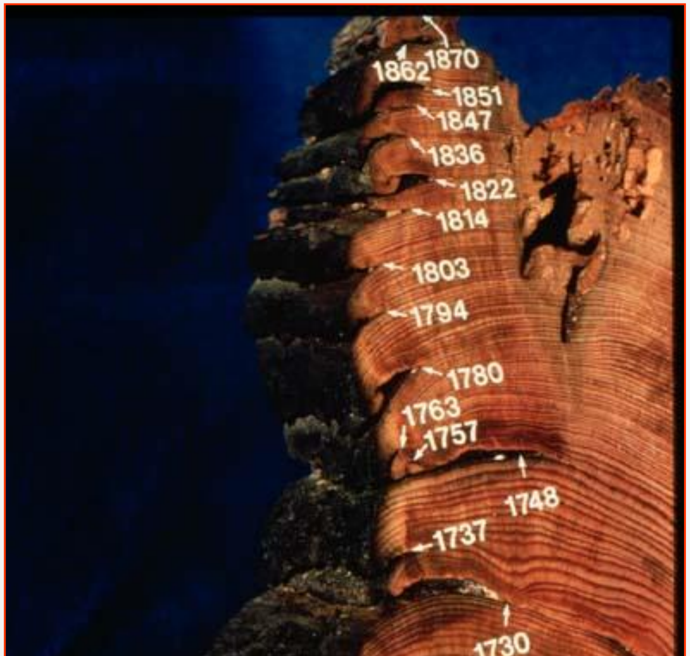


Unquestionably the central scientific <u>and</u> management "grand challenge" of our time:

How will organisms and ecosystems adapt to rapid reorganization of the Earth system?

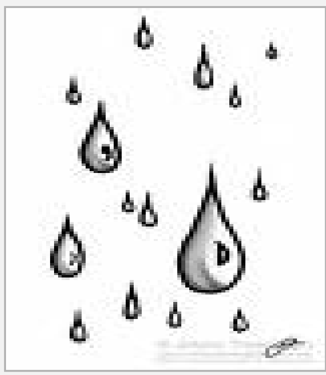
How will these changes affect our approach to ecosystem management?

Some salient attributes of the tree-ring record

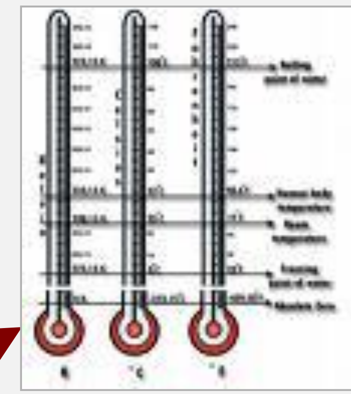


- Wide spatial distribution (>130º global latitudinal range) in multiple biomes
- Long temporal extent ($\geq 10^4$ yr) and preservation
- High temporal resolution ($\leq 10^0$ yr) and accuracy (exact, if crossdated)
- Reflects a wide array of ecological and climatic variables
- Direct, affirmative evidence of many ecological events (infer others)

Dendro<u>climatological</u> view: the tree as a recorder of climate



- Isolate interannual variation in "common signal"
- Correlate variability with climate drivers of limiting factor(s)
- Thus **tree growth** is the **independent** variable; **climate** is the **dependent** **(response)** variable



In dendroecology the equation is reversed:

- We use tree-ring analysis to **understand the influences on the tree itself**
- **Climate, soils,** and other variables that influence tree growth are <u>**independent**</u> **variables**
- Once calibrated, we can **use tree growth to reconstruct other ecological processes** (e.g. fire, insect outbreaks)

What is dendroecology?

Ecology: The study of the relationships among organisms, and between organisms and their physical environment.

oîkos: home, place

logos: knowledge, study

Dendro*:* <u>Tree</u>

Fritts 1971, *Quaternary Research*; Fritts and Swetnam 1989, *Advances in Ecological Research*

Reproduction

Light

Parasites

Herbivory

Competition

Mechanical damage

Diseases

Soil moisture

Nutrients

Fire

Soil chemistry

Internal and external (environmental) influences on tree processes

“Internal” influences:

- Genetic template
- Physiological state
- Biochemical kinetics and energetics
- Anatomical structure
- Intracellular signaling
- Reproductive allocation

“External” influences:

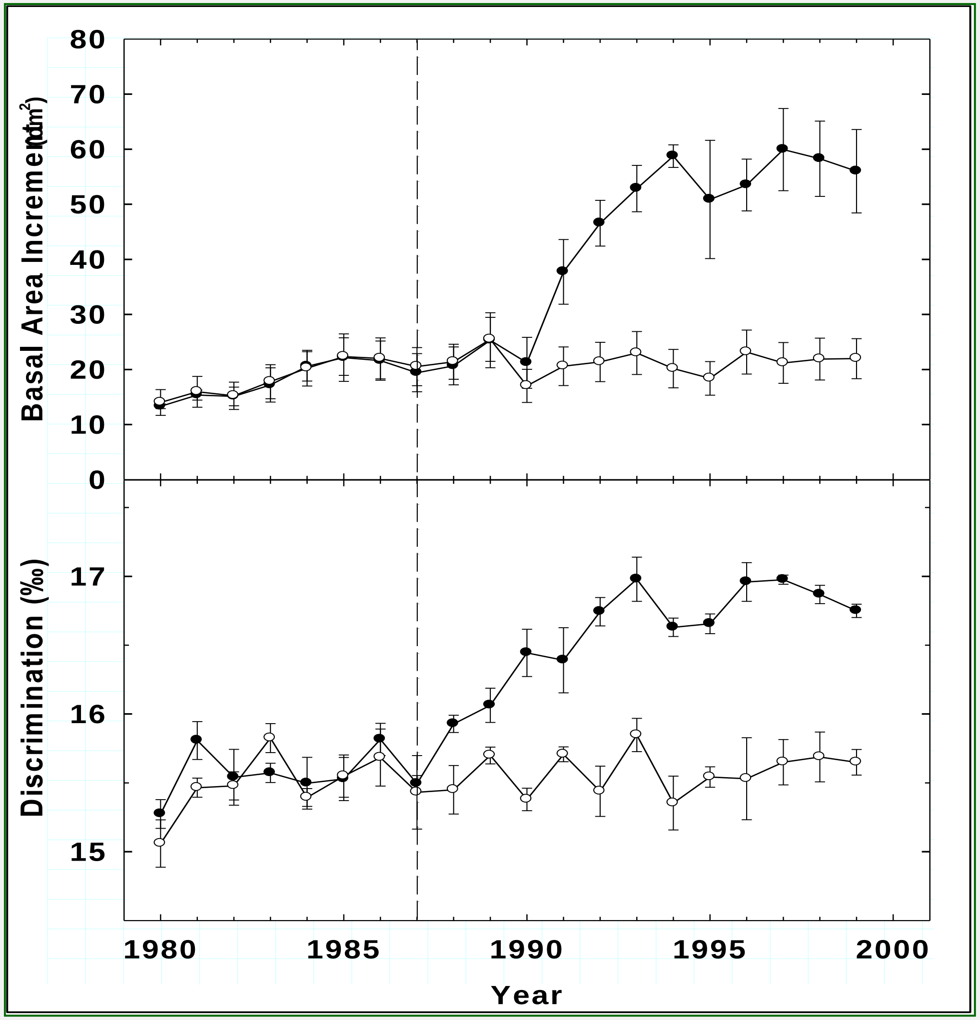
- Growth-limiting resources (light, water, nutrients)
- Competitive environment
- Rate-limiting conditions (temperature)
- Disease, herbivory

So what ecological variables can be reconstructed?

- Physiological ecology
- Population ecology
- Community ecology
- Ecosystem ecology
- Macroecology
- Evolutionary ecology
- Human-environment interactions

Physiological ecology

- Reconstruct tree-level water status
- "Limiting factor" is an ecophysiological variable (light, water, nutrients)
- Amenable to experimental approach



Changes in BAI and carbon isotope discrimination following thinning (McDowell *et al.* 2003)

Population ecology:

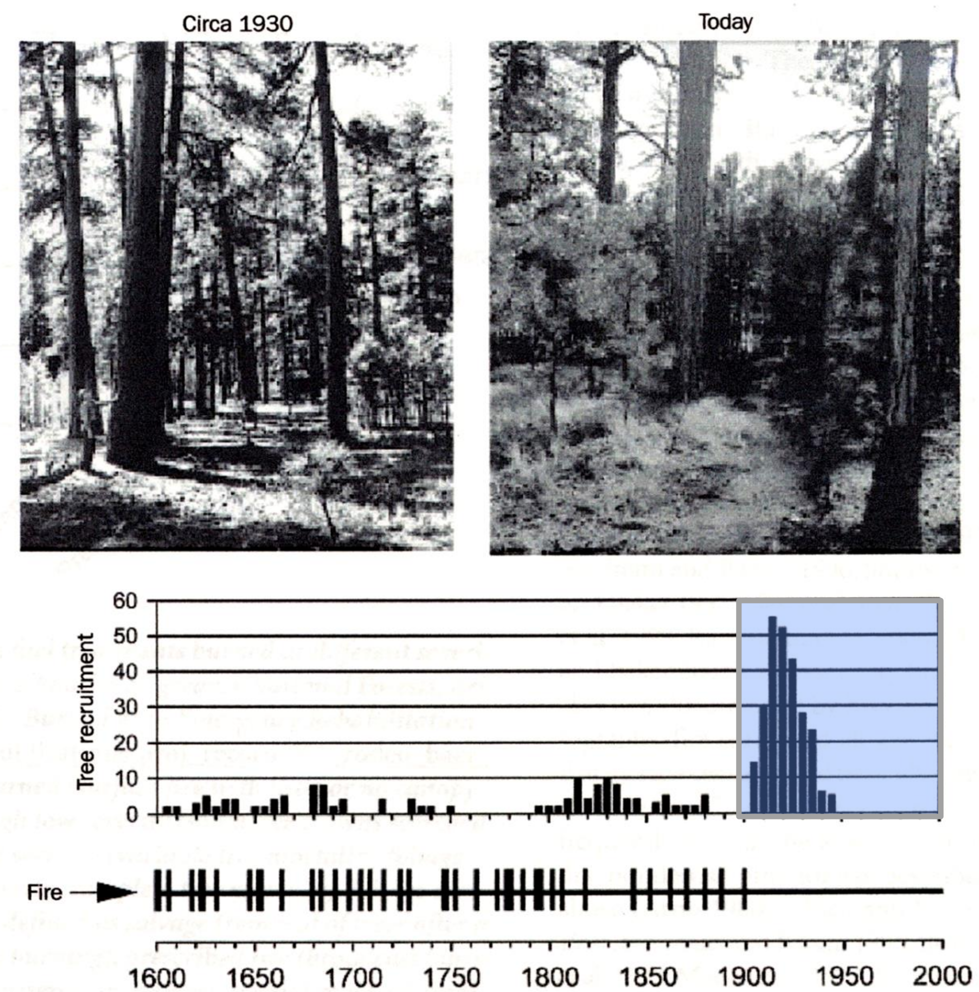
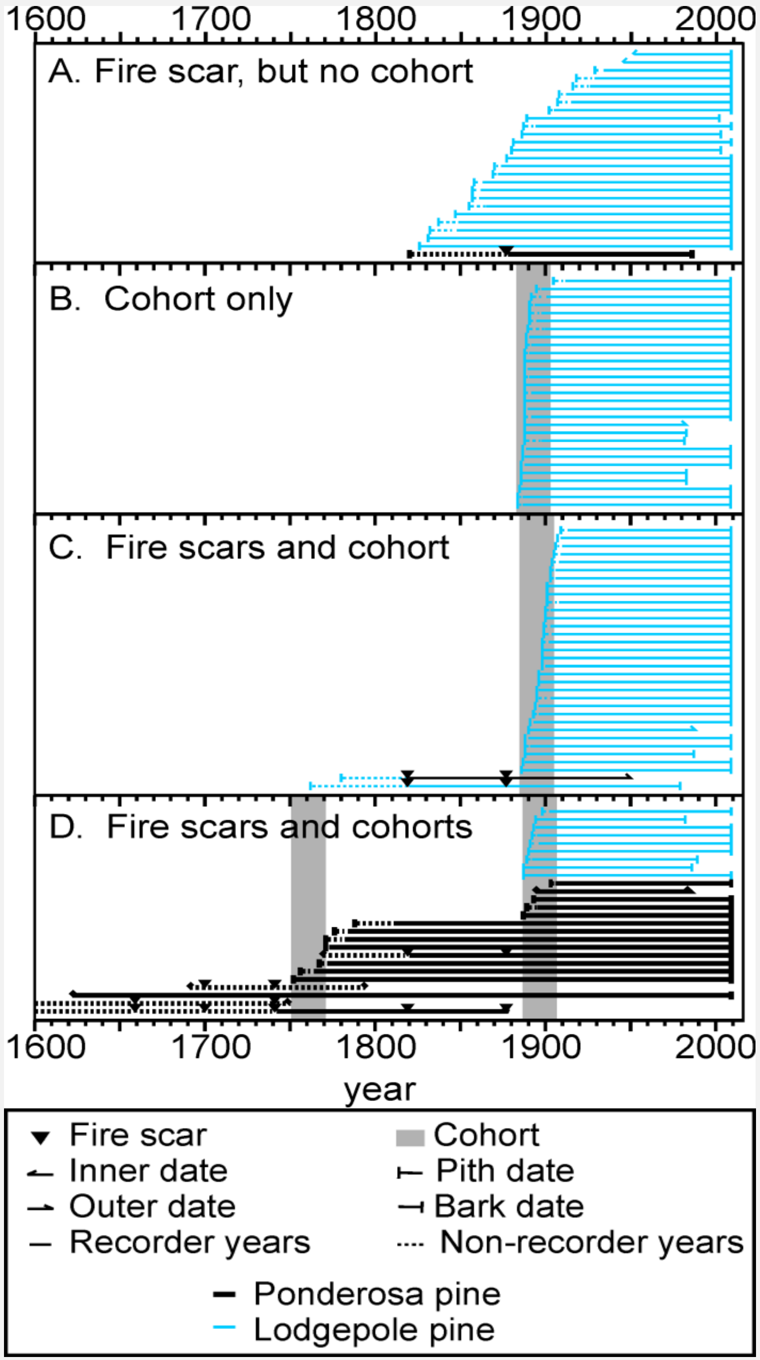


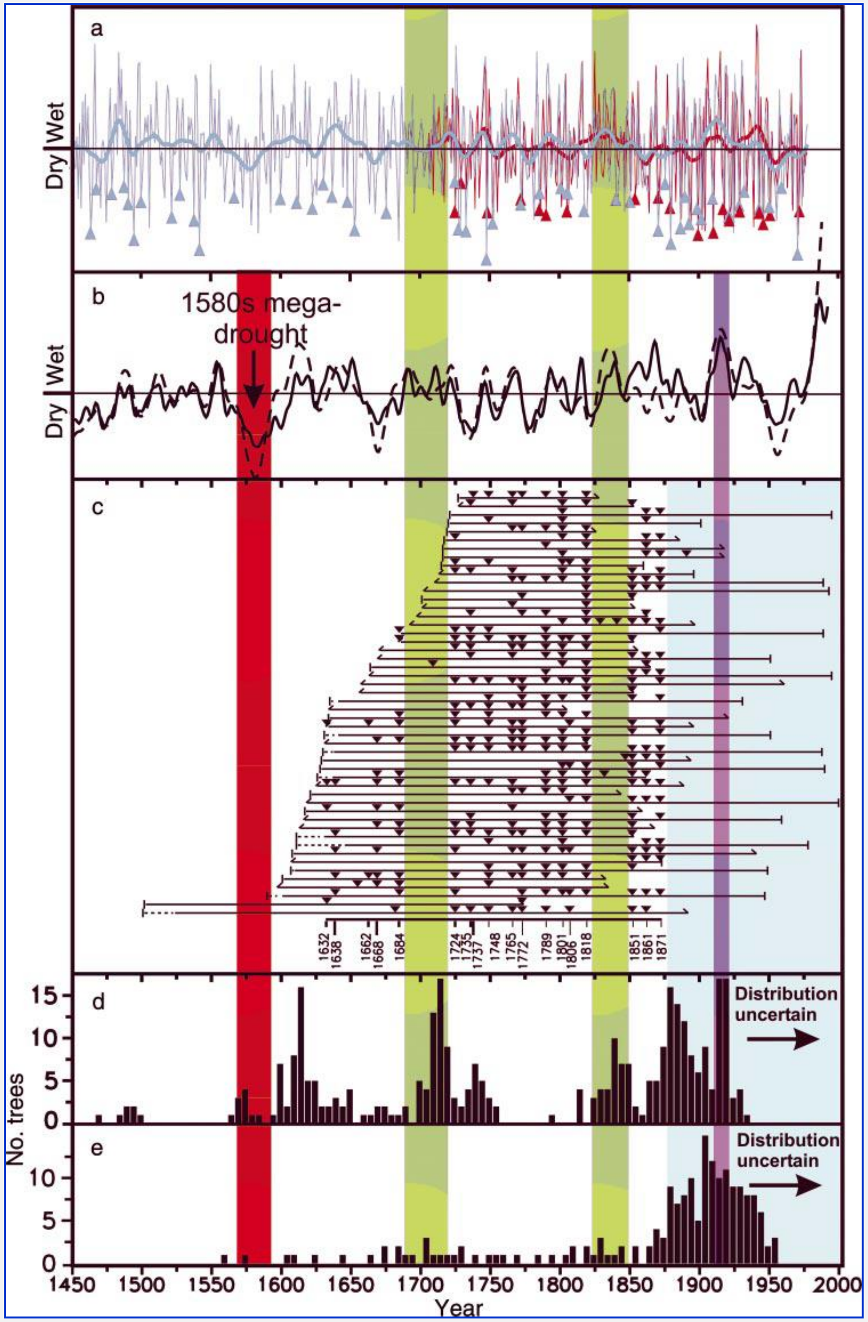
Figure 6. A comparison of historical and contemporary stand structure of dry ponderosa pine stands from the Jemez Mountains of New Mexico, and the relationship of this change to the frequency of low-severity surface fires. Source: Modified from Allen

Identifying forest regeneration cohorts:

- **Q: When we see even-aged recruitment, is this the result of disturbance, climate, or other factors?**
- Cohorts can be defined:
  - Number of trees recruiting
  - Time window
  - Preceding period without recruitment
  - Time since disturbance (e.g. fire)
  - Spatial scale of inference



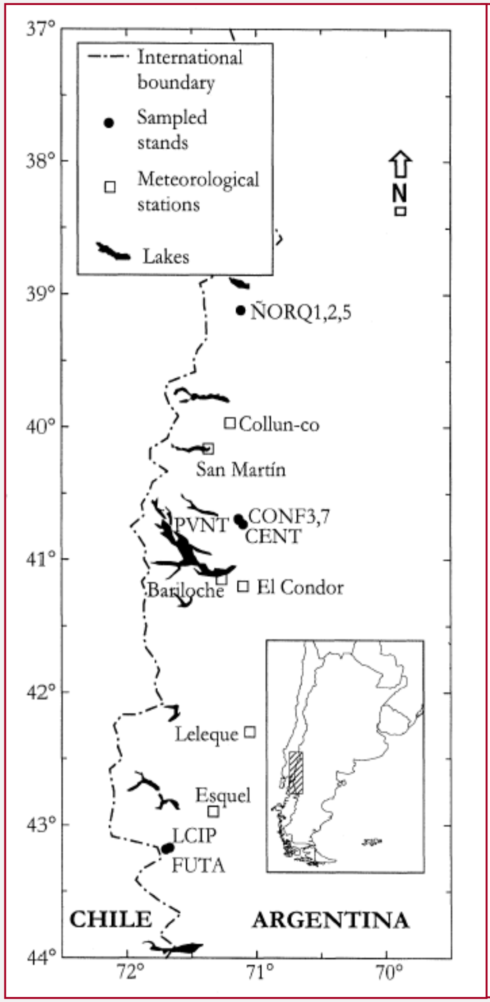
Demographic processes best interpreted in light of interacting effects of climatic variation and disturbance

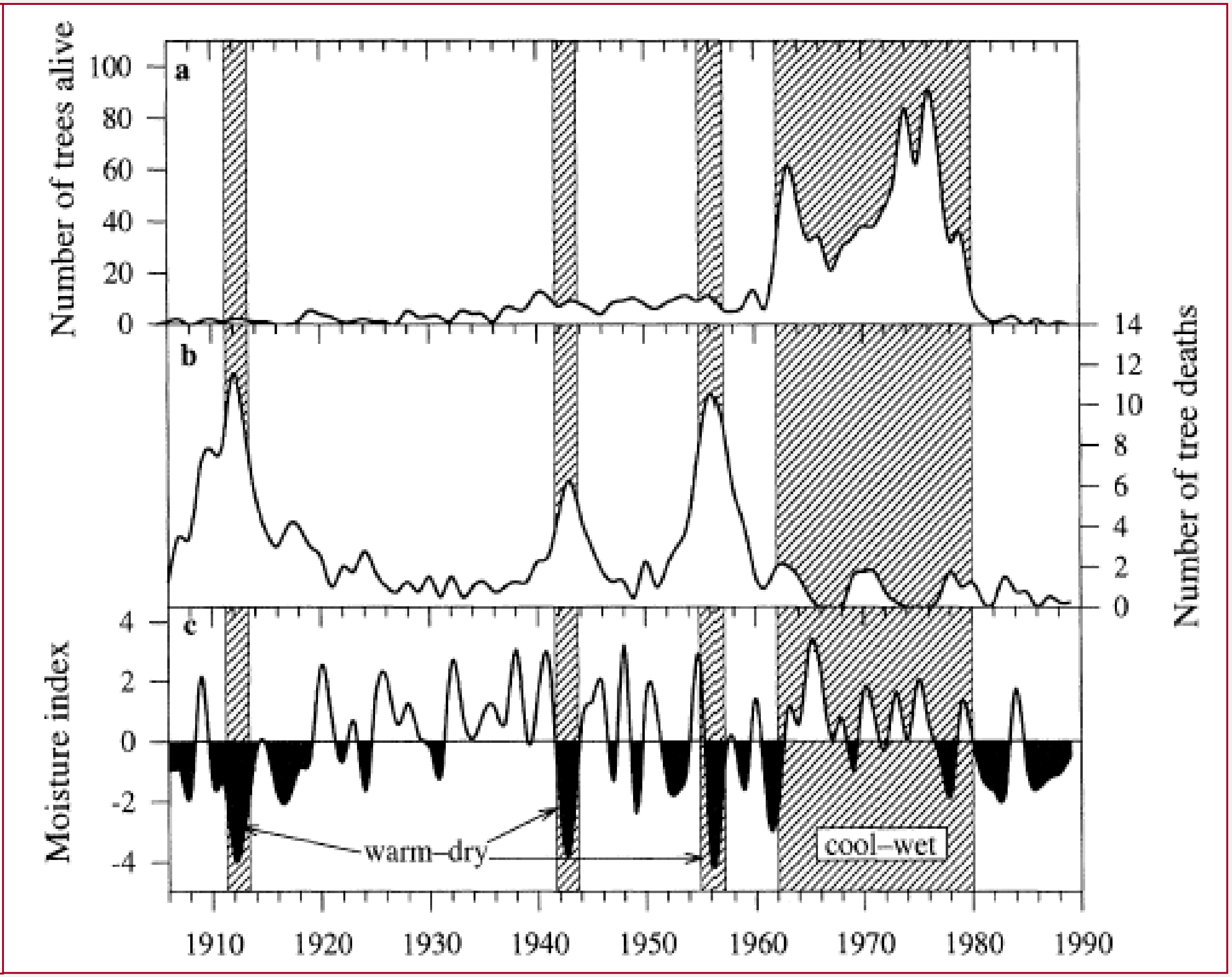


Brown & Wu 2005, *Ecology*

Mortality

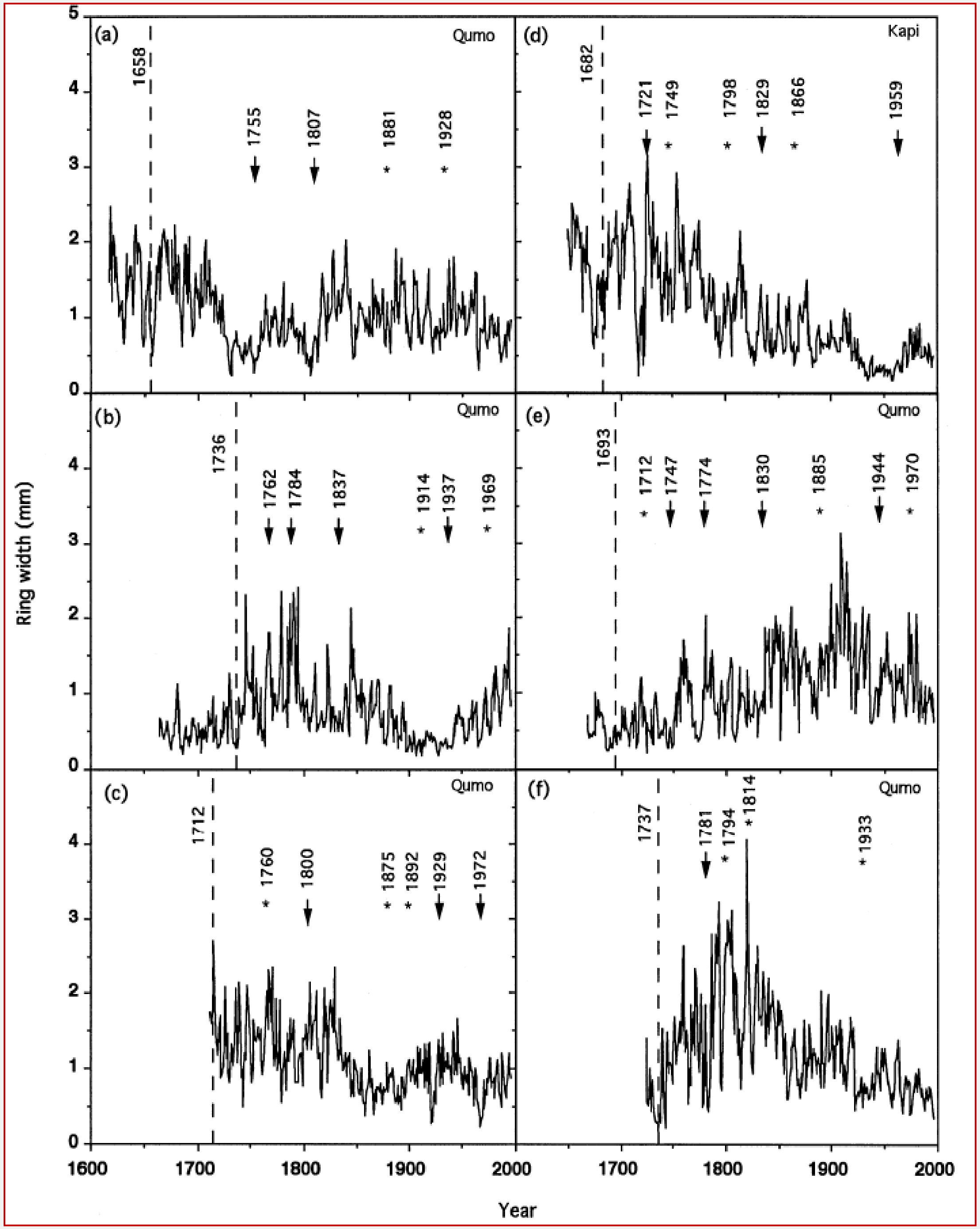
Correspondence between tree births and deaths and effective moisture in northern Patagonia (Villalba and Veblen, 1998)





Villalba R., and T. T. Veblen. 1998. Influences of large-scale climatic variability on episodic tree mortality in northern Patagonia. Ecology 79 (8): 2624-2640.


Remnant thickets approaching 9,000 trees ha^{-1} (~1 tree/1.1 m^{-2}).
Cohort establishment dates to the 1917-8 cool-wet period.
Image: Monument Canyon RNA, NM.



Ring width variation is used to understand dynamics and species recruitment patterns

400-year record from a mesic, montane, old-growth forest in Hokkaido, northern Japan

Frequent small-scale disturbances coupled with infrequent large-scale disturbances, influence tree growth and species recruitment.

Abrams et al. 1999, CJFR

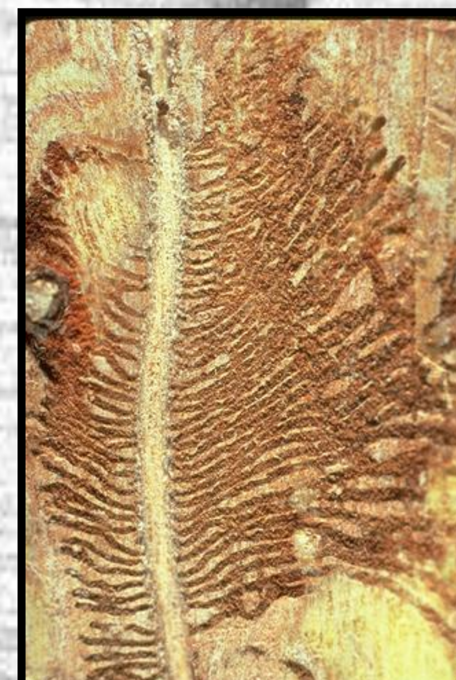
RECONSTRUCTING INSECT POPULATION OUTBREAKS

Insect damage: Effects on trees: lethal vs. non-fatal damage

Temporal factors: outbreaks may be short or persist for many years, even decades

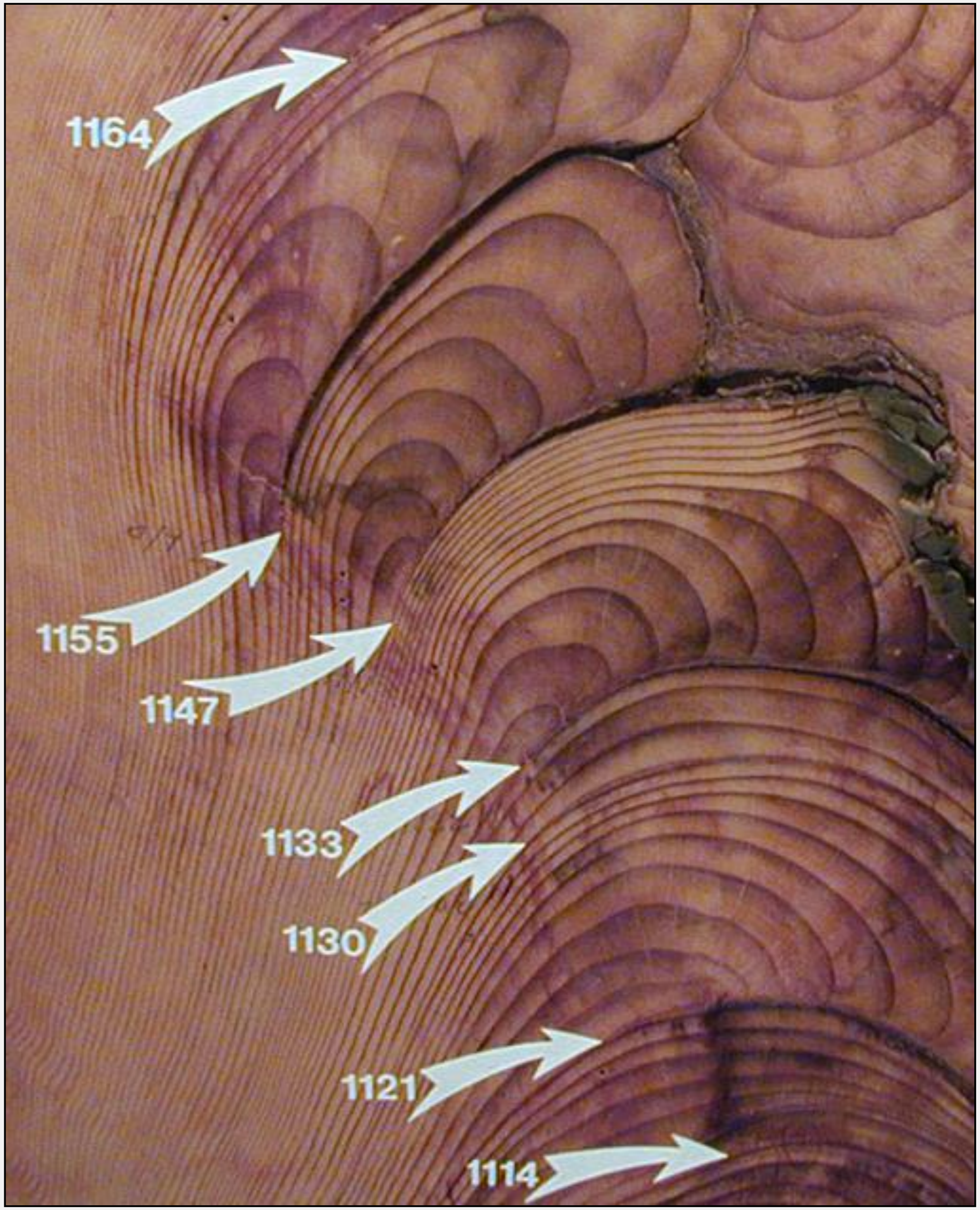
Images courtesy Dr Ann Lynch, LTRR/USFS

Growth suppression from defoliation




Ecosystem ecology

- Disturbance processes
- Biogeochemical cycles
- Hydrologic processes



Tree scale

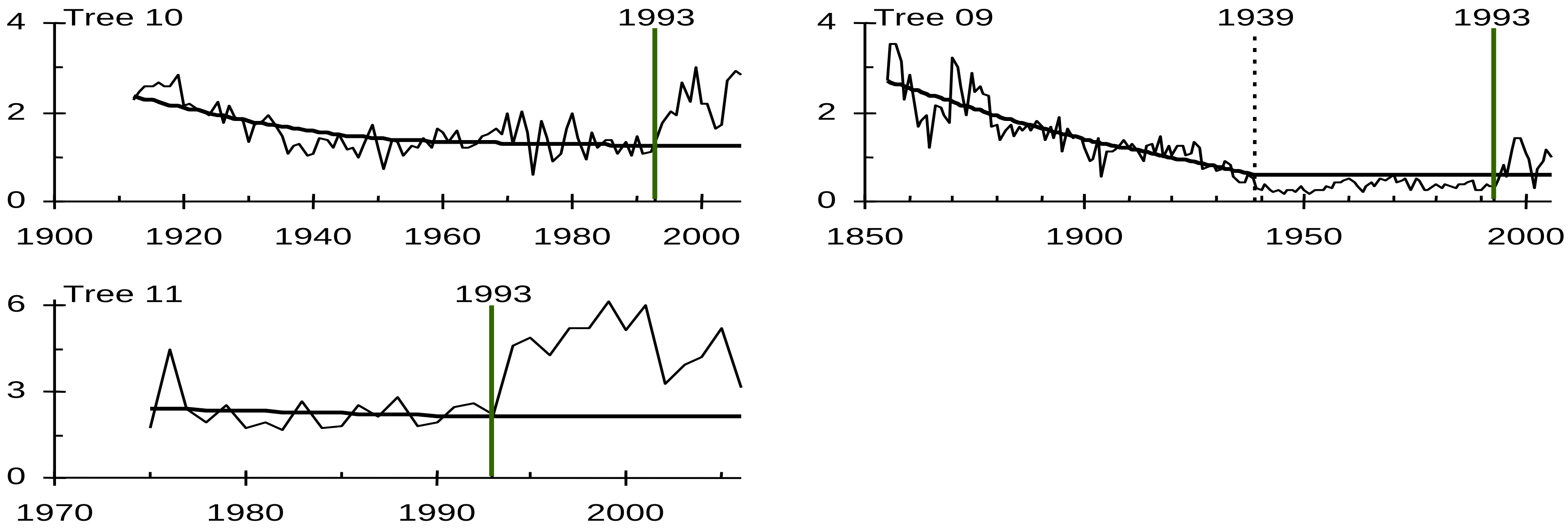
Fire scars form on living trees when portions of the cambium (growing surface of the stem) are killed by heat flux through the bark

Multiple fire scars in *Sequoiadendron giganteum*, Giant Sequoia. T. Swetnam and C. Baisan, UA-LTRR

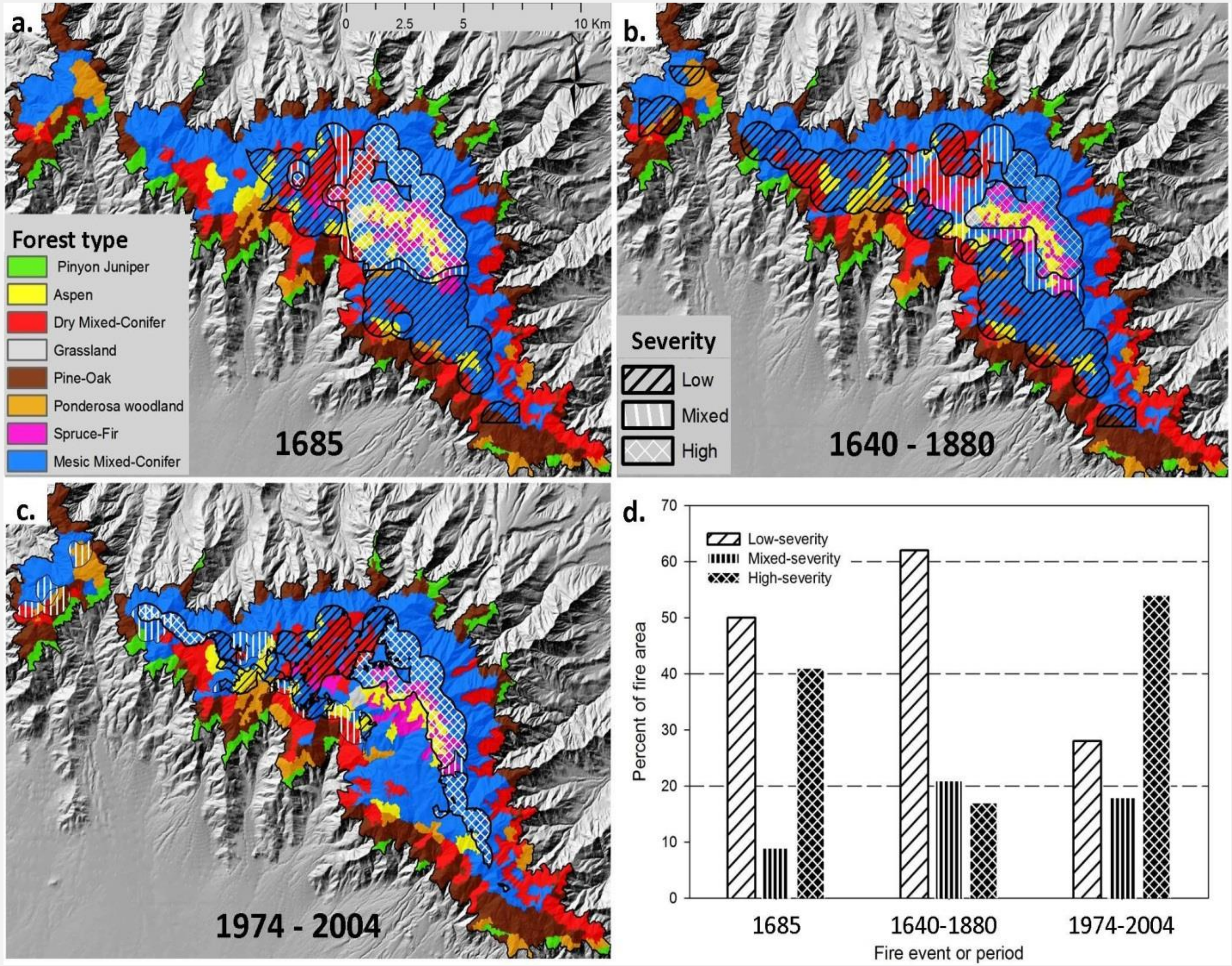
Growth series may contain information about ecological response to other events

<u>Synchrony</u> is often the key to finding the cause

Competitive release in trees surviving a 1992 tornado (Sheppard *et al.* 2005)



Georeferenced tree ring collections allow detailed mapping of deep-time ecological processes across scales



Fire and demographic history in the Pinaleño Mountains, Kit O’Connor (in rev.)

Macroecology and evolutionary ecology

Below: Boreal forest migration, MacDonald *et al.* 1998. Right: Western Juniper migration, Lyford et al. 2003

- Changes in species ranges over time
- Informs modeling by revealing realized niche space

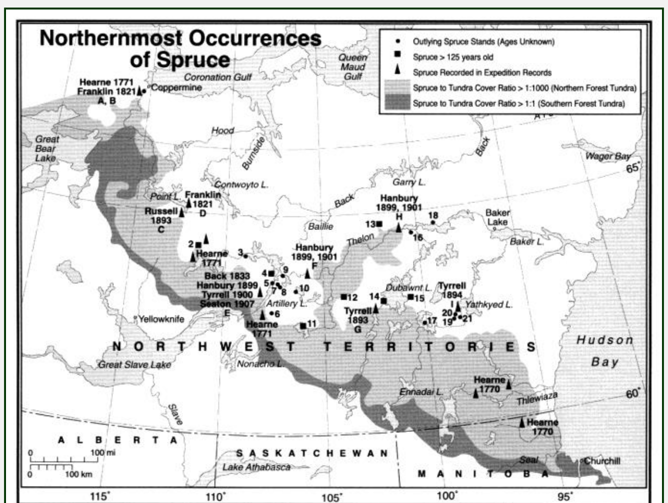
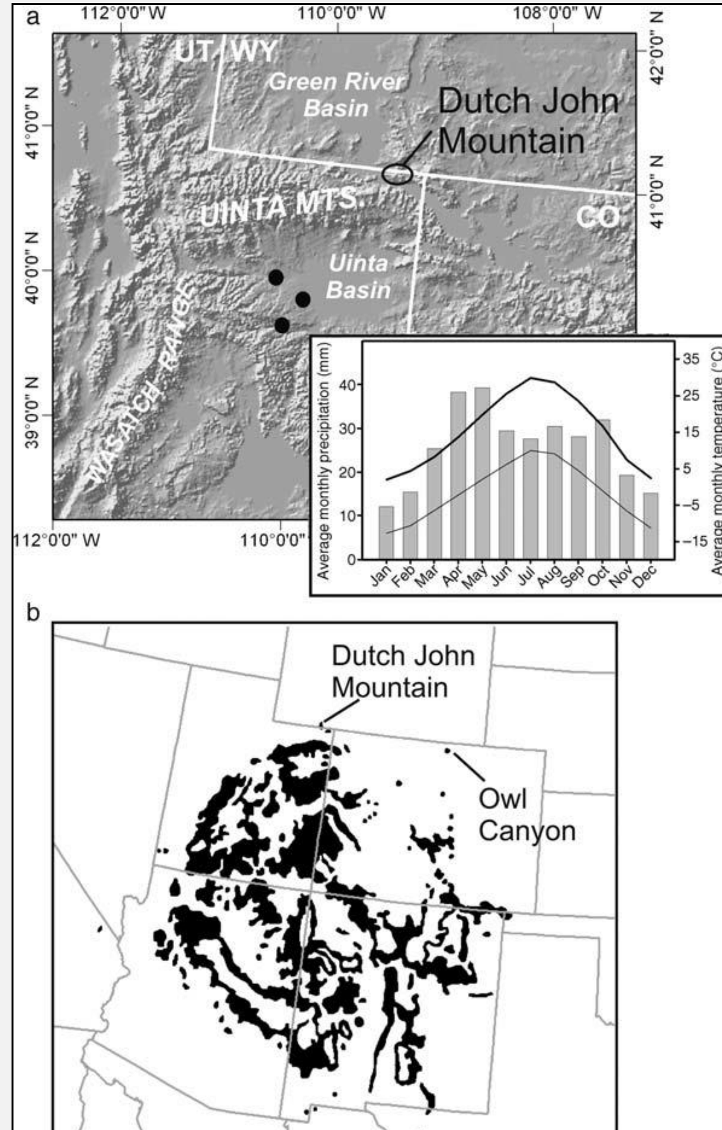


Figure 13. Location of first or last trees encountered by eighteenth, nineteenth and early twentieth-century explorers. Location of northernmost trees observed during late twentieth century (from Table 3) and locations where trees >125 years in age occur.



Using tree rings to teach ecology

- Provides a way to understand longer time periods than we can observe
- Trees integrate multiple processes, internal and external
- Tree-ring record best in forests, but available from other ecosystem types (savannahs, riparian systems, even grasslands)