Elements of talk

- Why restore?
- "Restoration ecology" *cf.* "Ecological Restoration"
- Restoring ecological composition, structure, functions and processes
- "Restoration" in a changing world
- Bringing people into the frame
- Your observations and questions

Definitions:

- **Ecological Restoration**: "The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." – *SER International Primer on Ecological Restoration*, Science & Policy Working Group, (Version 2, October, 2004)
- **Restoration ecology**: 1. The study of relationships among organisms and the abiotic environment, in a context of ecological restoration. 2. The scientific study of patterns and mechanisms operating in ecological restoration." – Falk *et al.*, 2006

Goals of Ecological Restoration

- Restore ecosystems to conditions consistent with their evolutionary environments
- Connect sustainable human communities with sustainable wildlands
- Conserve wildlands for present and future generations

Covington, 2000

Ecological theory and restoration ecology

- Ecological restoration (practice) is grounded in vernacular, pragmatic knowledge
- Restoration ecology seeks to explain, not simply to perform
- Increasing links to ecological theory and allied disciplines

Some relevant areas of ecological theory:

- Ecophysiology and autecology
- Population and ecological genetics
- Population and metapopulation dynamics
- Community interactions, species interactions, assembly processes
- Food webs and trophic cascades
- Disturbance ecology
- Ecosystem processes, biogeochemical and energy cycling
- Climate change and paleoecology
- Allied disciplines (hydrology, soil science, biogeochemistry)

The three fundamental elements of restoration:

1. **A defined reference condition.**
2. **A disrupted ecosystem.**
3. **A defined desire future condition.**

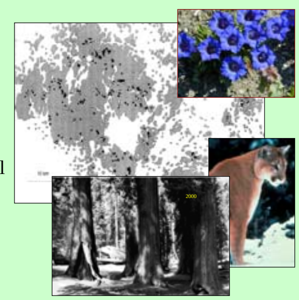
Ecological composition (who is there?)

- Census of species and functional groups
- Traditional focus of ER

Photos R. Robichaux and US Forest Svc.

Interactions of ecological structure and composition

- **Composition**: Census and relative abundance of species and functional groups
- Traditional focus of ER
- **Structure**: 3-dimensional arrangement of compositional elements
- Also applied to temporal distribution (*e.g.* "age structure")



Restoring ecological composition: Genetic diversity

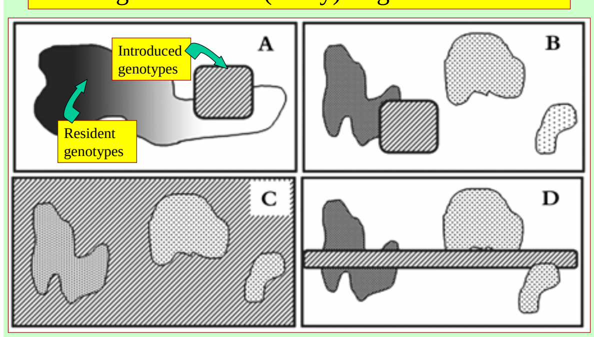
Within-population genetic composition:

H_o Average observed heterozygosity
H_e Average expected heterozygosity
P Percentage of polymorphic loci
A Average alleles per locus

Among-population composition:

Q_{ST} Proportion of quantitative trait variance among populations
F_{ST}, G_{ST} Proportion of total molecular marker variation among populations, averaged over loci
K_{ST} Proportion of mean substitutions per nucleotide site within populations, averaged over sites
Genetic distance: Fraction of alleles and frequencies not shared among pair of populations
Genetic similarity: Fraction of alleles and their frequencies shared among a pair of populations

Restoring genetic structure depends on the existing distribution (if any) of genetic variation



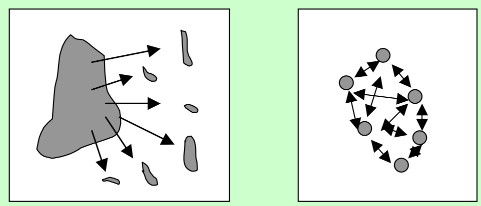
Falk *et al.* 2006

Restoring population and metapopulation dynamics

Argyroxiphium kauense photos courtesy Rob Robichaux and the Silversword Alliance

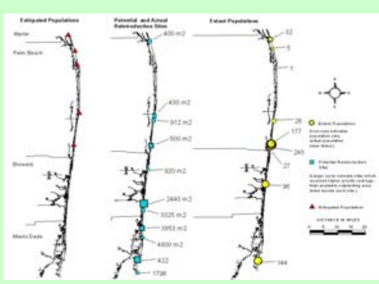
Amsinckia grandiflora restoration research: Bruce Pavlik

Restoring metapopulation structure and dynamics



Maschinski, 2006

Extirpated, extant and potential reintroduction sites for *Jacquemontia reclinata* along the eastern coast of South Florida

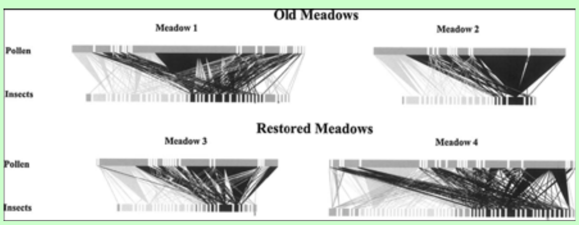


Maschinski, 2006

Restoring species interactions

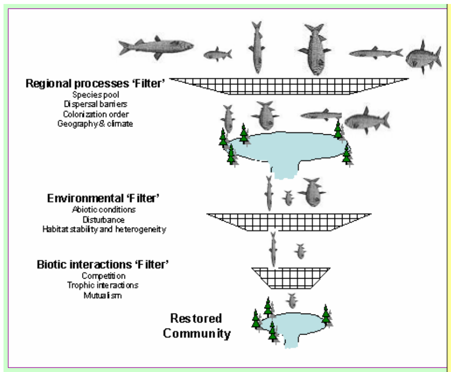
- Pollination
- Dispersal
- Herbivory, predation
- Competition
- Trophic structure and dynamics

An example of restoring species interactions: pollination ecology



Pollen transport webs for four hay meadows. Pollen groups are rectangles at the top of each web, insects at the bottom. Interactions link the pollen and insect species. Relative abundance of species is indicated by width of the rectangles; frequency of each interaction type is indicated by width of the line.

Forup and Memmot, 2005



Menninger & Palmer, 2006

Trophic interactions and structure can determine the resilience and function of restored ecological communities

Alternative Dynamic States

- Extreme events can push system into a new resistant state
- New domain dominated by disturbance process (constant disturbance in system)
- Examples: shifts from forest or woodland to shrub fields with radically different fire regime
- New state can exclude recolonization by previously dominant vegetation

Affirmative evidence of type conversions to new state

Pine with multiple surface-fire scars in what is now an oak shrub field, Rincon Mts following a major fire in 1867

Iniquez, 2006

Restoring ecological processes

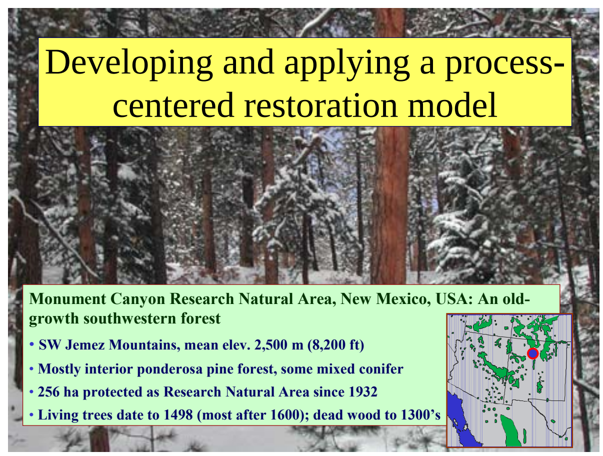
- More variable and difficult to characterize
- Functional ecology, demographic processes, species interactions, biotic-abiotic interactions, disturbance processes, biogeochemical and hydrologic cycles
- **A focus on ecological processes may provide a useful model for restoration ecology in many systems**

Naeem 2006; Falk 2006

What is a process-centered model?

- Ecological processes are placed at the center of restoration design
- A range of process values estimated (based on suitable reference)
- Composition and structure are varied as needed to bring process within targeted range, or left to equilibrate on their own

Falk 2006; Cortina *et al.* 2006

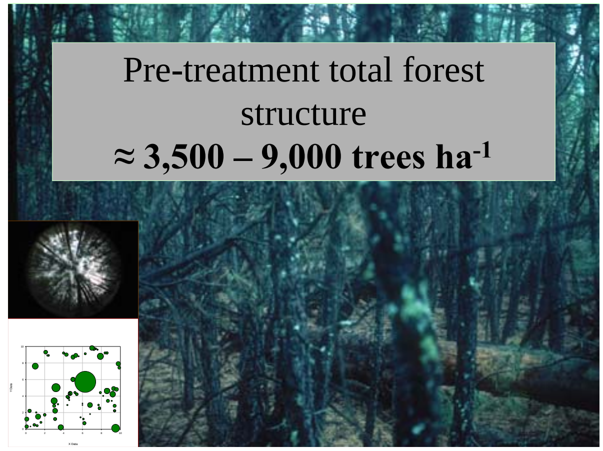


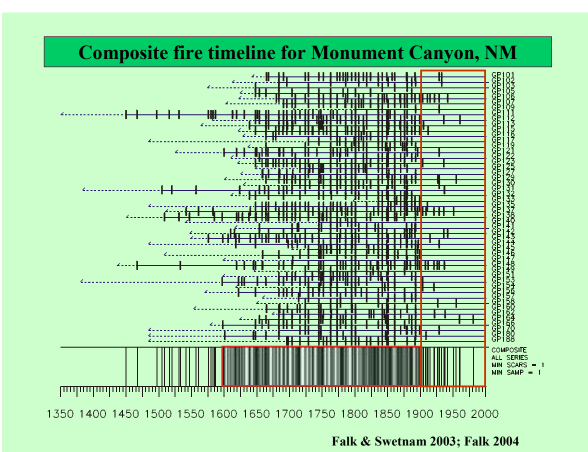
Composition

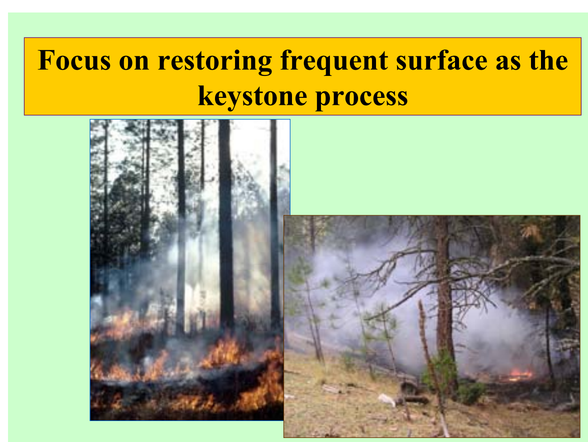
MCN species richness ~ 90 vascular spp. (mostly understory herbs and grasses)

Primary tree species	Common name
Abies concolor	White fir
Juniperis scopulorum	Rocky Mountain juniper
Pinus edulis	Piñon
Pinus flexilis	Limber pine
Pinus ponderosa	Ponderosa pine
Populus tremuloides	Quaking aspen
Pseudotsuga menziesii	Douglas-fir
Quercus gambelii	Gambel oak
Robinia neomexicanus	New Mexico locust


1990
Biondi, F. 1999. Ecological Applications 9: 216-227


Pre-treatment total forest structure
≈ 3,500 – 9,000 trees ha^{-1}


Composite fire timeline for Monument Canyon, NM
COMPOSITE
ALL SERIES
MIN SCARS = 1
MIN SAMP = 1
1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000
Falk & Swetnam 2003; Falk 2004


Focus on restoring frequent surface as the keystone process

PCR: Methods

1. Begin with bracketed estimates of (a) fire regime and (b) individual fire events under historical conditions
2. Model effects of structural treatments on fire behavior and effects across a range of prescriptions
3. Set structural prescription to achieve process target values
4. Test model on the ground and adapt

Covington *et al.* 2001; Fulé *et al.* 2004; Falk 2006

Modeling restoration outcomes

- Modeling in FVS 6.31, Nexus 2.0, Behave+
- 32-48 km hr^{-1} windspeed @ 6 m
- Slope 5%
- Surface fuel moisture:
  - 1 hr fuels 3-8%
  - 10 hr 4-10%
  - 100 hr 5-12%
- Live fuel moisture 80-100%
- Fuel models 9-10

Fulé *et al.* 2004; Falk 2006

Target (reference) values for key fire behavior and effects (response) variables

- Primarily surface fire, occasional torching OK
- Overall flame height ≤ 2 m
- Headfire spread rate ≈ 3 - 4 m min^{-1}
- Fireline intensity ≤ 1000 km m^{-1}
- TI ≥ 40 km hr^{-1}, CI ≥ 65 km hr^{-1}
- Percent mortality by size class
  - ≤ 2% overstory trees (≥ 40 cm dbh)
  - ≥ 80% saplings and understory trees (≤ 15 cm dbh)

Agee 1993, Sackett and Haase 1996, Pyne, Andrews *et al.* 1996

Structural (input) variables

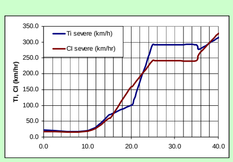
Thin progressively across a range of maximum thin diameters: unthinned – 40 cm (16 in). This alters:

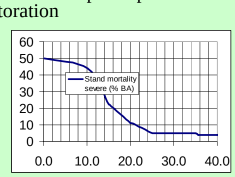
- Tree density (stems ha^{-1})
- BA (m^2 ha^{-1})
- Crown base height distribution (m)
- Crown bulk density (kg m^{-3})
- Size distribution (dbh, cm)

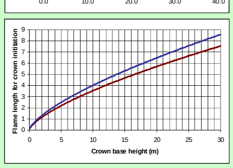
Graham *et al.* 2004; Peterson *et al.* 2005

Changes in fire behavior and effects

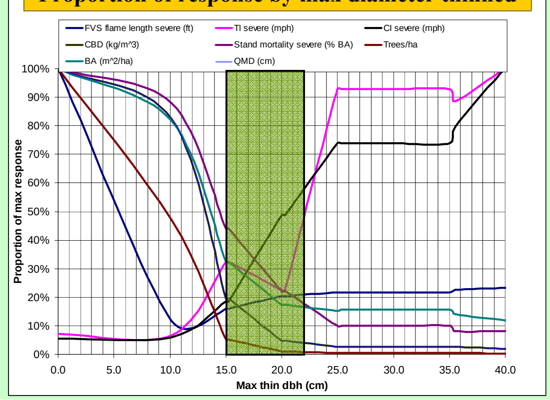
- Fire type shifted from active crown to surface fire
- Most target process values were achieved by thinning trees ≤ 22 cm (9 in) dbh
- Thinning into larger size classes did little to improve process restoration







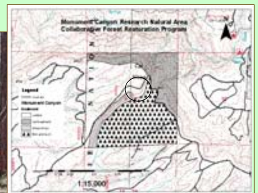
Proportion of response by max diameter thinned



Treatments

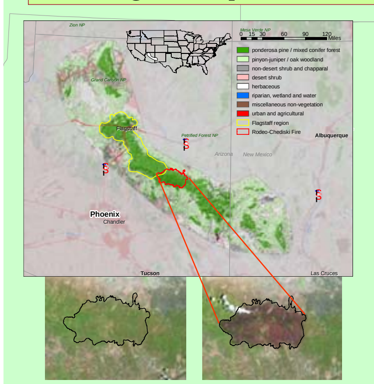
• 100 ha thinned 2006; half of site left as control

• Integrated into 3,500 ha (9,000 ac) San Juan/Cat Mesa rx fire area



Funding support: Collaborative Forest Restoration Program

Restoring landscape-scale structure and function



Rodeo-Chediski Fire, 2002

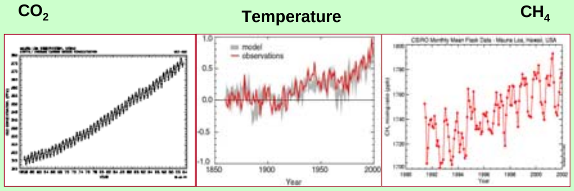
- **Functioned at scales that dwarf project-level management**
- **Restoration should be conducted at the scale at which key ecosystem processes operate**

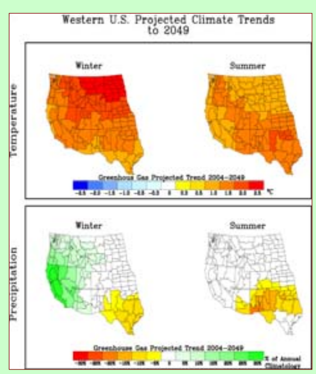
Sisk *et al.*, ForestERA Project, NAU

Q: Can restoration ecology rise to the challenge of ecology in a context of global change?

"The global consequences of human activity are not something to face in the future -- they are here with us now....We are changing Earth more rapidly than we are understanding it." -- **Vitousek *et. al* (1997)**

CO_2 **Temperature** **CH_4**





Climate change is a fundamental context for ecological restoration in the 21st century

A question for you: What does changing regional and global climate mean for restoring ecosystems?

Courtesy Henry Diaz, NOAA and US Forest Service

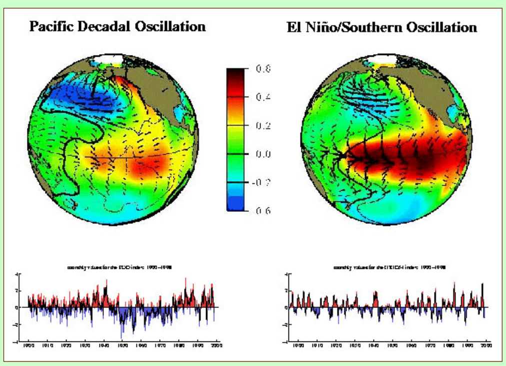
May 17, 2003 North of San Francisco Peaks, AZ

Trees are long-lived dominants; once established they tend to tolerate environmental stress and persist. Forests are often thought of as slow-changing, gradually adjusting to new conditions through competition and establishment (Allen, Swetnam, *et al.*)

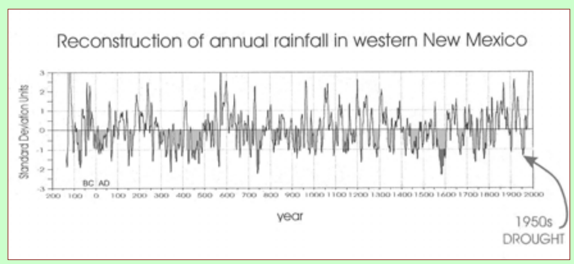
September 20, 2003 North of San Francisco Peaks, AZ
(4 months later)

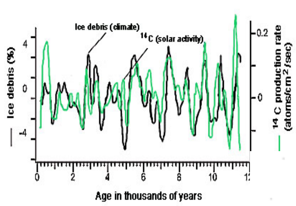
But, once thresholds of environmental stress are exceeded, rapid changes can occur through *massive forest dieback*.

Temporal change in the climate envelope on the scale of decades to years…

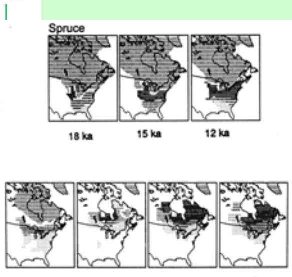


…centuries…

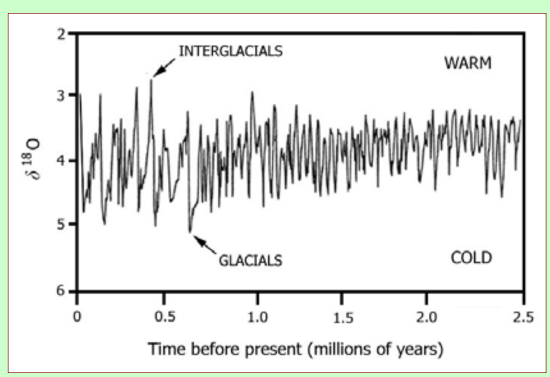




…millennia…



…millions of years…



Restoration offers:

- ✓ A way for people to be involved directly in healing their local ecosystem
- ✓ A way of learning the sense of place by direct experience
- ✓ A way of teaching how ecosystems work, and where their limits are
- ✓ A way of building loyalty and affection for where people live

Some closing thoughts…

- ✓ The need for restoration is driven by ongoing degradation of ecosystems
- ✓ Restoration is a global undertaking, practiced locally
- ✓ Restoration ecology, the science of restoration, is in its infancy
- ✓ Restoration includes the interactions of ecological composition, structure, and processes
- ✓ Restoration can bring people into the frame in a positive way
- ✓ Changing climate presents huge challenges – and an equally huge opportunities – for "restoration"