Forest Restoration Ecology

- Objectives:
  - Definitions
  - Restoration Ecology vs. Ecological Restoration
  - Restoration Ecology in the Ecological Hierarchy

- First, thoughts and insights from the reading assignments
Forest Restoration Ecology

• Terminology
  – Restoration ecology
    • “Science of restoration”
      – Science = Creation & dissemination of new knowledge
    • Requires a priori knowledge of and a strong basis in ecological theory
    • Application of ecological theory to restore ecological systems
      – “Acid test for ecological theory”
        » Restoration can guide theory as much as theory can guide restoration
      – Basis for Ecological Restoration
Forest Restoration Ecology

• Terminology
  – *Ecological restoration*
    • “Practice of restoration”
    • Attempt to return a system to an historical or reference state
      – Intentional activity
    • Implication → system has been transformed from some desirable state *(and that this transformation is not desirable)*
      – Value judgment
    • *Ecological restoration* assists or initiates recovery
      – Although often requires continued management
      – *Adaptive ecosystem management* helps guarantee the continued well-being of the restored system thereafter
Forest Restoration Ecology

• *Restoration ecology vs. Ecological restoration*

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**A. Ecological Theory**

Concepts, predictive models and mathematical models to explain pattern and processes in ecological systems.

**B. Restoration Ecology**

The scientific process of developing theory to guide restoration and using restoration to advance ecology.

**C. Ecological Restoration**

The practice of restoring degraded ecological systems.

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Benefits of linkages

• Offers opportunities to study ecosystem elements in a manipulative context
• Offers opportunities to test and expand theories that are central to ecology
• Offers opportunities for ecologists to contribute directly to vital restoration efforts worldwide
• Provides an intellectual framework for restoration
• Clarifies multiple interactions that may operate in even a simple restoration project
• Improves the quality and effectiveness of restoration efforts

Palmer et al. 2006
Forest Restoration Ecology

• Ecological restoration

Palmer et al. 2006
Forest Restoration Ecology

• Ecological restoration
  – Continuum of effort needed to restore a system
    • May be as simple as removing an unnatural disturbance (or reinstating a natural disturbance) and allowing nature to take over
    • In most systems, however, ecosystems have been pushed beyond the point of spontaneous recovery
      – Necessitates anything from active outplanting to removal of invasive species to major topographic work (e.g. reclaimed mines, wetlands)
      – Typically involves more than a single treatment or activity in time
Forest Restoration Ecology

• Terminology
  – *Reference ecosystem*
    • Model for planning restoration projects
      – Desired outcome
      – Can be an actual site, written description, etc.
      – Ideally is multiple sites and/or descriptions
    • A reference ecosystem may represent only one of many possible natural states
      – Ecosystems characterized by high temporal variability
        » Historic range of variation (HRV)
      – In turn, the restored ecosystem can return to any number of possible states
        » Alternative stable states
Reference ecosystem
Forest Restoration Ecology

• *Reference ecosystem*: Source of information
  – Ecological descriptions, species lists, etc.
    • Prior to becoming degraded, damaged or destroyed
  – Remnants of the site to be restored
  – Ecological descriptions & species lists of similar ecosystems in other locales
  – Historical and/or recent photographs
  – Herbarium and museum specimens
  – Historical accounts and oral histories
  – Paleoecological evidence
Forest Restoration Ecology

• Restoration planning steps (SER)
  1) Clear rationale as to why restoration is needed
  2) Ecological description of the site to be restored
  3) Statement of goals & objectives of the restoration project
  4) Designation and description of the reference system
  5) Explanation of how the proposed restoration will integrate with the landscape and surrounding ecosystems
  6) Plans, schedules & budgets for site prep., installation & post-installation activities, including a strategy for making mid-course corrections (adaptive management)
  7) Well-developed & explicitly stated performance standards, with monitoring protocols for project evaluation
  8) Strategies for long-term protection and maintenance
Forest Restoration Ecology

- Human and cultural elements are crucial to viability of restoration projects in many areas
  - N. Am. focus on restoring “pristine” systems is unviable in many areas of the world
  - Ecological restoration should encourage, and may often be dependent upon, [long-term] participation of local people
Forest Restoration Ecology

• Terminology
  – *Conservation biology*
    • Save it *before* it becomes damaged, degraded, or destroyed
    • As with restoration ecology, based on fundamental ecological and evolutionary principles
    • *Restoration ecology is to ecological restoration what conservation biology is to biological conservation*
Forest Restoration Ecology

• *Conservation biology vs. Restoration ecology*
  – “conserving what is left” vs. “restoring what once was”
  • target endangered species vs. habitat structure and function
  • zoological (fauna) vs. botanical (flora)
  • short vs. long-term objectives
  • theory and description vs. replicable practice
• In reality, they are quite complementary & often overlap
  – Widespread habitat loss has made conservation difficult or impossible in many cases → Restoration is necessary
Forest Restoration Ecology

• Environmental Values of Restoration (SER)
  – “…offers hope of recovery from much of the environmental damage inflicted by misuse or mismanagement of Earth’s natural resources” (Palmer et al. 2006)

1) Retention and enhancement of biodiversity
2) Augmentation of habitat (harbors the genetic diversity required for future adaptability)
3) Diversification of habitat
4) Maintenance of integrity of $H_2O$ cycle
5) Stabilization of substrates to prevent erosion & promote topsoil formation
6) C sequestration
7) Preservation of land-based cultural traditions
Forest Restoration Ecology

• Attributes of restored ecosystems (SER)
  1) Contains a characteristic assemblage of the species that occur in the reference ecosystem
  2) Consists of native species to greatest practicable extent
  3) All functional groups necessary for the continued development and/or stability are represented
  4) Capable of sustaining reproducing populations
  5) Functions normally for ecological stage of development
  6) Suitably integrated into larger ecological matrix
  7) Potential threats have been eliminated or reduced
  8) Sufficiently resilient to endure normal periodic stress
  9) Self-sustaining & has the potential to persist indefinitely within the norms of ecosystem development
Forest Restoration Ecology

• Ecological Foundations
  - “Restoration ecology ideally provides clear concepts, models, methodologies, & tools for practitioners…” (Palmer et al. 2006)
Forest Restoration Ecology

• How can population biology inform restoration ecology / ecological restoration?
  – Population viability analysis
    • How many individuals are needed to start a new population?
    • Is the restored population sustainable over the long term?
  – Metapopulation analysis
    • What value do individual restored patches have for a species’ overall persistence on the landscape?
  – Population and ecological genetics
    • How similar is the source population to the population we wish to restore?
    • Should we combine material from multiple source populations?
How can community ecology inform restoration ecology / ecological restoration?

- Restoration almost always involves multiple species
  - Populations of co-occurring species
- In this light, restoration must be informed by community ecology theory:
  - Species interactions
  - Habitat and resource dynamics
  - Disturbance regimes
  - Succession
- Community ecology provides the opportunity to integrate across these concepts in restoration
Forest Restoration Ecology

• How can ecosystem ecology inform restoration ecology / ecological restoration?
  – Provides organizing framework
    • Forces ecological consideration of:
      – Spatial and temporal boundaries
      – Connections to adjacent ecosystems
      – Input, cycling & loss of materials and energy
      – Functional connections among organisms, & between biota and the physical environment
    • Sets limits on the biotic community & important processes
    • “Build it and they will come” paradigm
      – Does restoration of abiotic environment lead to restoration of species assemblages and/or function?
Forest Restoration Ecology

• How can ecosystem ecology inform restoration ecology / ecological restoration?
  – Provides conceptual tools to monitor & evaluate
    • Energy & material inputs/outputs
    • Trophic dynamics
    • Productivity & C cycling
      – Biomass pools (live & detrital) & C fluxes
    • Hydrologic cycle
    • Intra-system cycling
      – Decomposition, nutrient cycling, turnover, transfers
    • Disturbance regimes & succession
    • Ecosystem Stability
      – Resistance and resilience
• What is a (natural) disturbance?
  – Relatively discrete event in time that disrupts ecosystem, community and/or population structure, and changes substrate and resource availability, and the physical environment
Disturbances in a restoration context

- Natural disturbances
  - Play a large role in shaping ecological communities
  - Eliminated from, introduced to, and/or drastically changed in many ecological systems
    - Restoration often involves restoring natural disturbance regimes and/or eliminating those that are not natural

- Anthropogenic disturbances
  - Most often detrimental
    - Restoration will typically involve removing disturbance
      » Fire
      » Nonnative herbivores
What is ecological succession?

- Directional change in species composition, structure, and resource availability over time that is driven by biotic activity and interactions, and changes in the physical environment.
Restoration Ecology: Succession & Disturbances

Single Steady State

Multiple/Alternative Steady States

Toward a fixed climax
Toward a dynamic climax
Succession
Yearly and longer cycles
Seasonal and shorter cycles

A new herbivore
Fertilization
Seeding
Grazing intensity altered

PERCENT OF CLIMAX

TIME FOR SUCCESSION

Tzero Tclimax

TOWARD SEVERAL CLIMAXES

24
Single Equilibrium Endpoint
- Return to a pre-disturbance state following disturbance
  - Steady directional change to a single endpoint
  - Predictable consequence of species interactions
  - Strong internal regulation via negative feedback mechanisms
- Restoration can accelerate succession by skipping some points along the continuum
  - e.g., Restoring fire and flood regimes
  - Depends upon level of degradation
• Multiple Equilibrium States
  – Change over time is discontinuous, abrupt and has multiple trajectories
  – System can become so degraded that it is very difficult to restore
    • Ecological thresholds
  – Irreversible shifts in species composition
  – Restoration must identify + feedbacks that maintain a degraded state, and eliminate them
    • e.g., invasive species/wildfire cycle in Hawai‘i
Ecological Threshold

- The point at which a relatively small change in external conditions causes a rapid change in an ecosystem.
- When an ecological threshold has been passed, the ecosystem typically cannot return to its ‘natural state’
Restoration Ecology: Succession & Disturbances

• Succession and natural disturbances
  – Must understand disturbance theory to restore ecological systems
    » Types, rates, etc.
    » Natural vs. anthropogenic
  – Can restoration be accelerated by manipulating succession and/or disturbances?
    » Eliminating vs. restoring disturbances
    » Fast-forwarding succession
  – Multiple states, ecological thresholds, and restoration trajectories
    » The ever-changing nature of ecological systems
Ecological systems are dynamic and in continual flux

- Disturbance regimes are natural and often beneficial
- Increasingly altered by human activities
- No simple or universal answers to guide restoration
  - Often system dependent
  - General conceptual framework still debated
Example 1: Grassland/Shrubland Fire Suppression and Woody Encroachment by Pinyon Pine and Juniper

**Problem:** Reduced fire frequency → change in species composition

**Solution:** Restore fire regime – pinyon pine and juniper do not survive frequent fire
Example 2: Sand Barren Prairie (Midwest) Fire Suppression and Woody Encroachment by *Salix*

**Problem:** Reduced fire frequency & grazing → change in species composition

**Solution:** Restore fire regime  
*Salix* resprouts – fire alone will not remove woody vegetation  
Need mechanical or chemical removal
Example 3: Nonnative Tropical Grassland (Hawaii) – Nonnative grass invasion and increased fire frequency

Problem: Invasion, increased fire, ecological threshold crossed

Solution: Remove fire
• System is ‘stuck’
• Remove invasive species (fuels)
• Restore Native Woody Composition
Restoration Ecology: Invasive Species

• What is an invasive species?

  – *Invasive species (USDA – NISIS)*:
    • (1) nonnative to the ecosystem under consideration, **and** (2) whose presence causes or is likely to cause economic or environmental harm, or harm to human health

  – *Alien, nonnative, exotic, naturalized, weed*
– ‘Cost’ of Invasive Species
  • Economic
    – >$120 billion annually in the U.S. (Pimentel et al. 2005)
  • Health
    – Introduced pathogens and diseases (e.g., West Nile virus; Am. chestnut blight; Dutch elm disease; ohia rust; etc.)
Restoration Ecology: Invasive Species

– ‘Cost’ of Invasive Species
  • Biodiversity
    – 2\textsuperscript{nd} most important cause of loss of biodiversity
    – In the U.S., \( >\frac{1}{2} \) of the species listed as threatened or endangered are at risk due to competition with or predation by nonnative species
Restoration Ecology: Invasive Species

– ‘Cost’ of Invasive Species
  • Ecological systems, processes, goods and services
    – Changes in disturbance regimes
    – Alterations of biogeochemical cycles
      » Nutrient cycling
      » Hydrology
      » Carbon cycling
Restoration Ecology: Invasive Species

- Invasive species impact almost all restoration
  - Present in almost all ecological systems
    - Island ecosystems particularly vulnerable
  - Lots of past focus on biodiversity, more focus now on ecosystem processes
    - Still have poor understanding of ecological impacts
  - Elimination of invaders and restoration of pristine species assemblages likely impossible
    - Need better understanding of ecological impacts of invasion
    - Need better understanding of how to deal with invasion in a restoration context
Restoration Ecology: Invasive Species

• **Restoration** = sustainable ecosystems
  – Natural disturbance events
  – Abiotic and biotic processes leading to stability
    • **Resilient** – return to pre-disturbance conditions following a disturbance (w/o human intervention)
    • **Resistant** to change following arrival of propagules of invasive species
Restoration Ecology: Invasive Species

- Management and prevention approaches
  - Prevention $\rightarrow$ relatively pristine state
  - Management (removal) $\rightarrow$ degraded state

(D’Antonio & Chambers 2006)
Restoration Ecology: Invasive Species

- Management and prevention approaches
  - Prevention management
    - Ecosystems currently providing valuable services and/or intact structure and processes
    - Maintain or increase ecosystem resistance prior to invasion
    - Maintain ecosystem resilience following a disturbance
Management and prevention approaches

– Active management
  • Following establishment of invaders and changes in ecosystem properties and processes
  • *Top-down control*: removal/elimination of invader
    – Manual removal, herbicides, biological control
  • *Bottom-up control*: restoration of properties or processes that contribute to stability
    – Manipulation of disturbance regimes
    – Manipulation of soil conditions
    – Direct seeding of desirable species
Restoration Ecology: Invasive Species

• Are invasive species always bad?
  – Not all invaders are necessarily “bad” in restoration
    • Many “fade out” naturally over time
      – Management would be a poor expenditure of resources
    • Can be used to facilitate desirable species
      – “Benevolent” invaders
  • Should nonnative species be used in restoration?
    – Provision of ecosystem goods and services
    – Highly degraded systems where desirable species not likely