Foundations of Restoration Ecology

- Objectives:
  - Ecological Foundations (Overview of Ecology of populations, communities, ecosystems, & landscapes)
  - Definitions (restoration ecology, ecological restoration, reference systems, etc.)
  - Foundations of Restoration Ecology and overview of Ecological Restoration (Ch. 1 in text; SER Primer and SER Guidelines)

Foundations of Restoration Ecology

- Environmental Values of Restoration (SER 2004)
  - "…*ecological restoration*…*offers the hope of recovery from much of the environmental damage inflicted by misuse or mismanagement of Earth's natural resources*" (Palmer *et al*. 2006)

  1) Diversification and/or augmentation of habitat, which harbors the genetic diversity required for future adaptability
  2) Retention and enhancement of biodiversity
  3) Preservation of land-based cultural traditions for indigenous peoples
  4) Storage of C and, thus, the removal of CO_2 from the atmosphere
  5) Retention of precipitation to maintain integrity of the H_2O cycle
  6) Stabilization of substrate to prevent erosion & promote formation of topsoil
  7) Etc.

  - **That is a lot of things restoration is supposed to do!**

Foundations of Restoration Ecology

- Ecological Foundations
  - "*Restoration ecology ideally provides clear concepts, models, methodologies, & tools for practitioners*…"
    - What is ecology?
      - Study of the distribution (where) and abundance (how many) of living organisms, and their interactions with each other and their physical environment
      - Typically focused on distribution (where) and abundance (how many) at lower levels, and interactions and processes at higher levels of the ecological hierarchy
    - What are the levels (hierarchy) of ecology?

Ecosystems Biosphere

Organisms (Individuals)

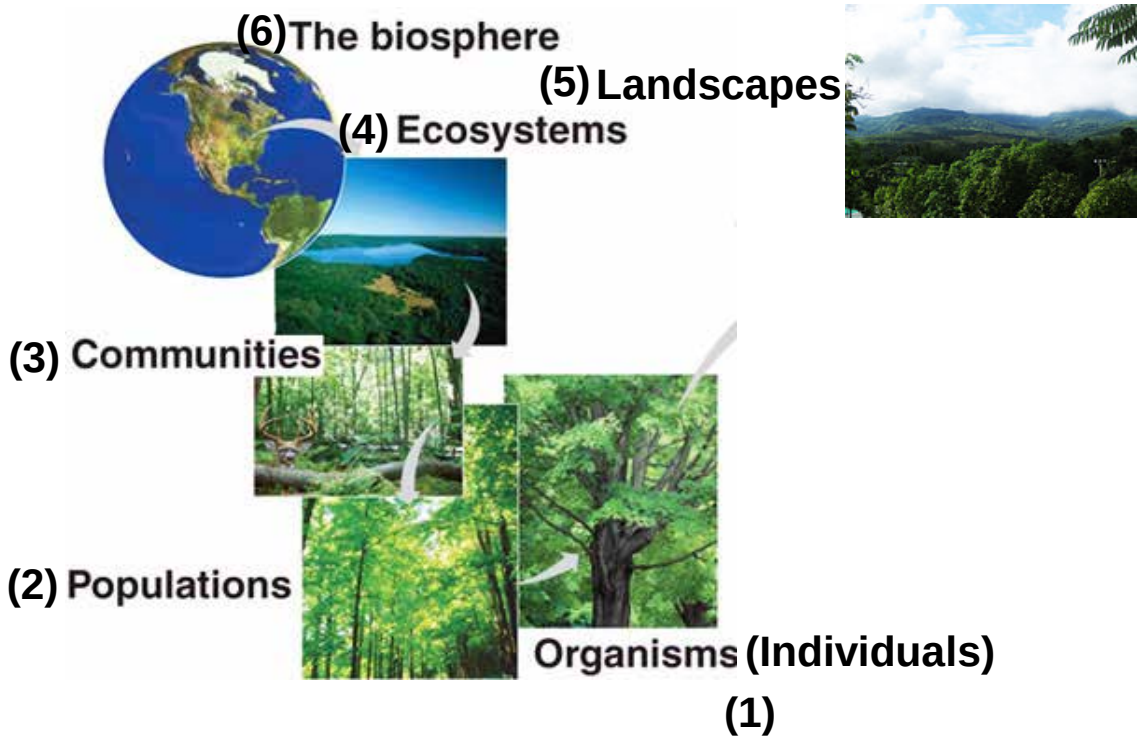
Landscapes

Communities

Populations

Foundations of Restoration Ecology

- Ecological Foundations
  - Ecological Levels/Hierarchy



Foundations of Restoration Ecology

- Individuals (Organisms)
  - Individual of a given species (as an example)
  - Study of the life history of an individual (i.e., species) and its response to its environment
    - Species: all individuals that can potentially breed with one another and produce viable offspring → Populations

Acacia koa **individual**

Foundations of Restoration Ecology

- Populations
  - Group of potentially interbreeding & interacting individuals of the same species living in the same place & time
  - Study of the abundance, distribution, & dynamics of a group of individuals of the same species

Acacia koa **population**

Foundations of Restoration Ecology

- Population characteristics
  - Age structure, density and distribution
  - Birth, death, immigration, and emigration
    - Growth rates
  - Reproduction → transfers genetic characteristics from one generation to the next (fitness)
  - Characterized by high variability (spatial & temporal)
  - Interaction with other populations via competition, predation, mutualisms, etc. → Communities

Foundations of Restoration Ecology

- Community
  - Collection of species/populations interacting directly and indirectly in the same place & time
  - Description & quantification of natural assemblages of different populations/species

***Acacia koa*-**
"dominated" community

Foundations of Restoration Ecology

- Community characteristics
  - Biological structure = the mix of species (number and relative abundance)
    - Species diversity (richness and evenness)
      - Typically, few species are abundant and most are rare
  - Biological structure is largely controlled by biotic interactions, but is constrained by abiotic factors (e.g., climate, substrate, topography, etc.)
    - Vertical layering and horizontal patterns
  - Characterized by high variability (spatial & temporal)
    - Temporal ≈ **Succession**
      - **Disturbances**

Foundations of Restoration Ecology

- Community characteristics (cont'd)
  - Fundamental niche constrains community structure
    - Because fundamental niches overlap for many species, actual distribution is typically smaller (realized niche)
  - Organisms alter the environment for other species
    - Can be beneficial or not
  - Communities are shaped by interactions between 2 or more populations of organisms
    - Competition, predation, commensalism, mutualism, etc.

Foundations of Restoration Ecology

- Ecosystem
  - Bounded ecological system consisting of all of the organisms in a given area and the physical environment within which they interact
    - Biotic & abiotic components are a single interactive system
  - Study of interactions among organisms and their physical environment as an integrated system
    - Particular emphasis on the flow of energy and materials

Tropical Rainforest Ecosystem

Foundations of Restoration Ecology

- Ecosystem characteristics
  - 3 basic components:
    - Autotrophs (plants)
    - Heterotrophs (consumers and decomposers)
    - Abiotic elements (water, atmosphere, soil)
  - Solar energy is the driving force of ecosystems
    - Carbon is the energy currency
  - Pools (quantities) and fluxes (flows) of materials and energy
  - Bounded spatially, but scale varies widely
  - Biomes are widespread terrestrial ecosystems
    - Tundra, boreal forest (taiga), deserts, temperate broadleaf forest, tropical rainforest, etc.

Foundations of Restoration Ecology

- Ecosystem characteristics (cont'd)
  - Characterized by high variability (spatial & temporal)
  - Structure and function governed by 5 state factors
    - Climate
    - Parent material
    - Topography
    - Time
    - Biota
  - Ecosystem processes governed by interactive controls
    - Biotic community
    - Resource supply
    - Disturbances
    - Human activity

Foundations of Restoration Ecology

- Landscape
  - Heterogeneous region consisting of 2 or more interacting ecosystems that exchange organisms, energy, water, nutrients, etc.
  - Study of the spatial arrangement of ecosystems and how this affects biotic and abiotic components

Windward Mauna Kea Landscape

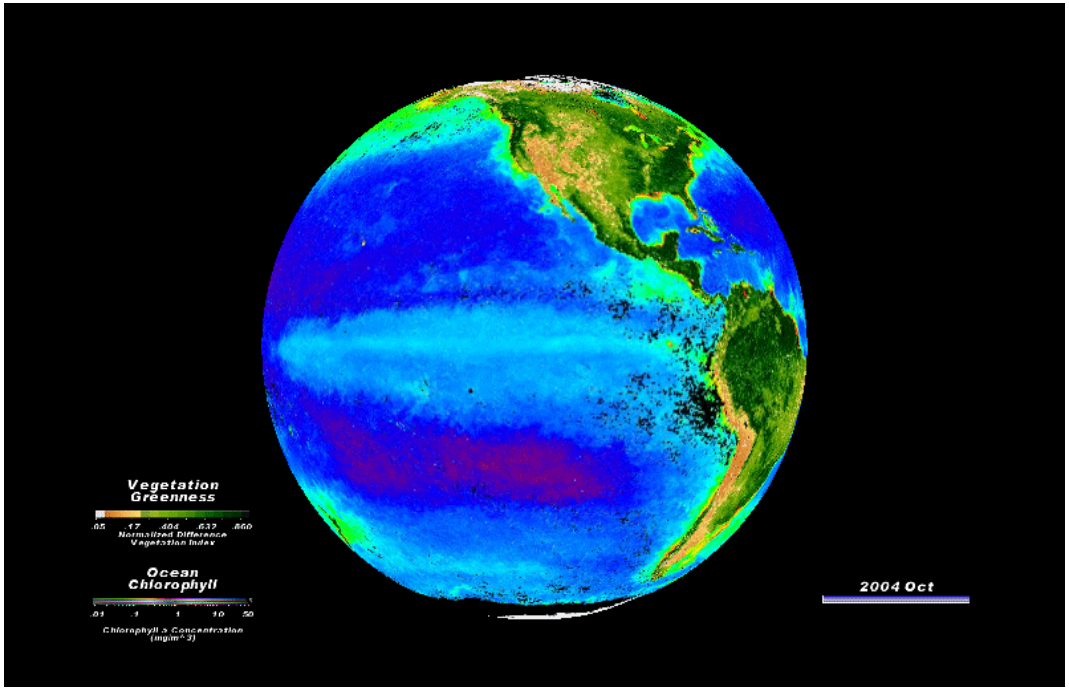
Foundations of Restoration Ecology

- Landscape characteristics
  - Patches (size and shape)
  - Corridors
  - Connectivity
  - Boundaries
  - Configuration
  - Interactions

Foundations of Restoration Ecology

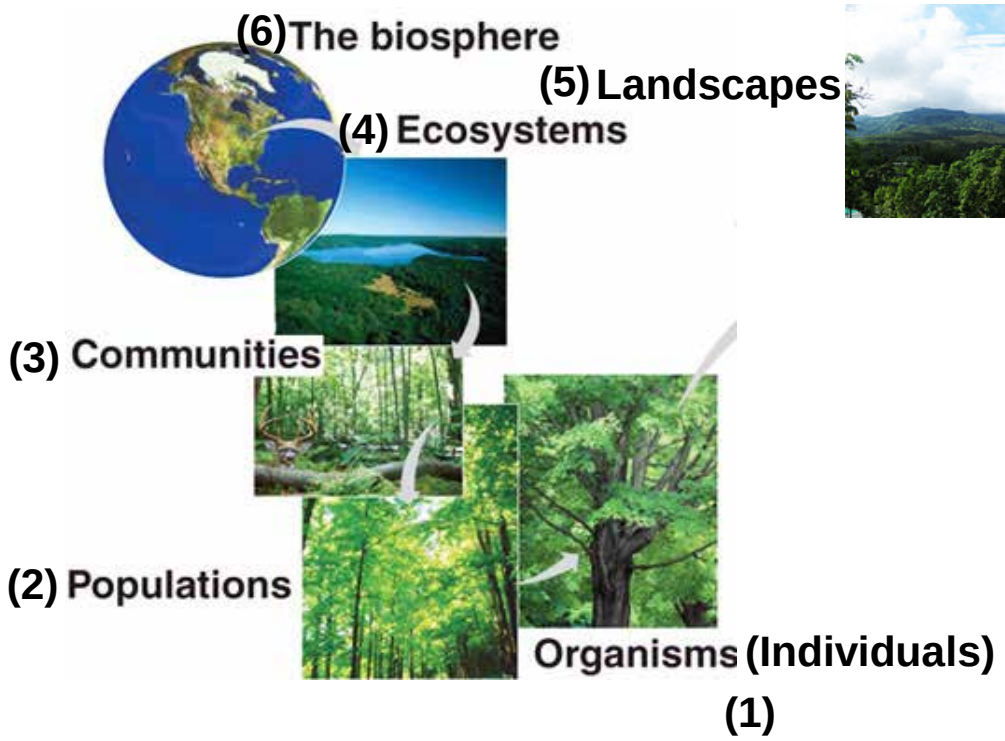
- Biosphere
  - Global sum of all ecosystems (biotic and abiotic) as an integrated system
    - Earth as an ecological system

The Earth Biosphere



Foundations of Restoration Ecology

- At what level of the ecological hierarchy should ecological restoration focus? Why?



Foundations of Restoration Ecology

- Ecosystem approach as a bridge between *Biological conservation & Ecological restoration*
  - Millennium Ecosystem Assessment (MEA 2005)
    - Ecosystems provide a suite of goods and services
    - Emphasizes structure, function, and process
      - » Provision and regulation of goods and services provided by biologically diverse systems

Foundations of Restoration Ecology

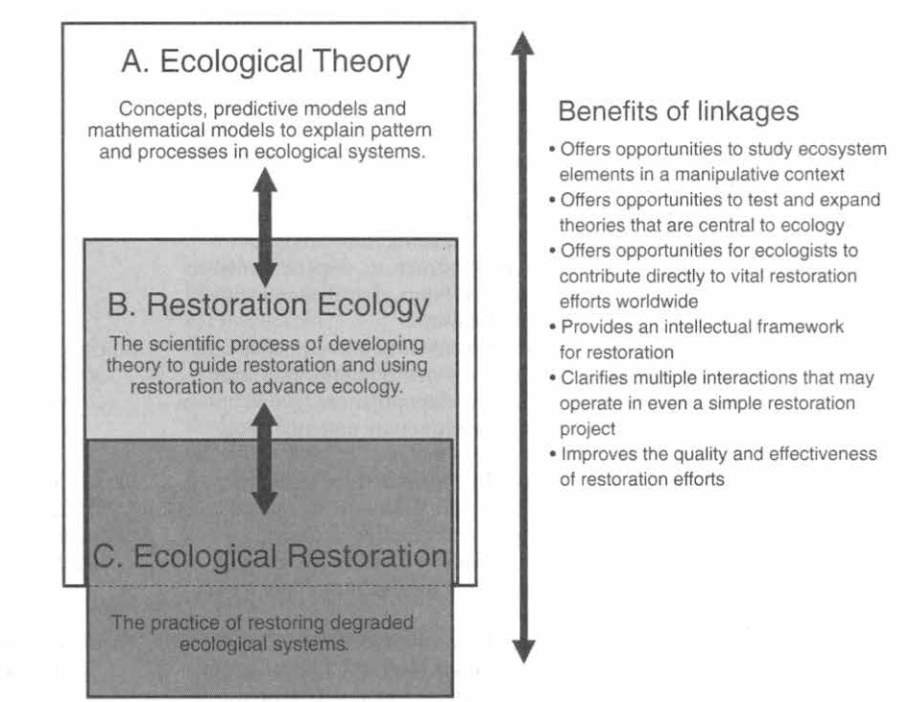
- Terminology: *Restoration ecology*
  - the scientific discipline of developing and/or applying theory to guide restoration activities
    - Science based (creation & dissemination of new knowledge)
    - Requires *a priori* knowledge of ecological theory
    - Largely consists of the application of this ecological theory to restore ecological systems
      - Restoration is an “acid test for ecological theory”
        - » Restoration can potentially guide ecological theory as much as ecological theory can guide restoration
      - Ecological theory is the basis for ecological restoration (the practice of restoration)

Foundations of Restoration Ecology

- Terminology: *Ecological restoration*
  - the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed
    - Intentional activity
    - Attempt to return a system to a historical / reference state
    - Implies that the system has been transformed from some desirable state, and that retransformation is now desirable
    - *Ecological restoration* assists or initiates recovery
      - Often requires continued management
    - *Ecosystem management* can provide for the continued well-being of the restored system into the future

Foundations of Restoration Ecology

- *Restoration ecology* vs. *Ecological restoration*



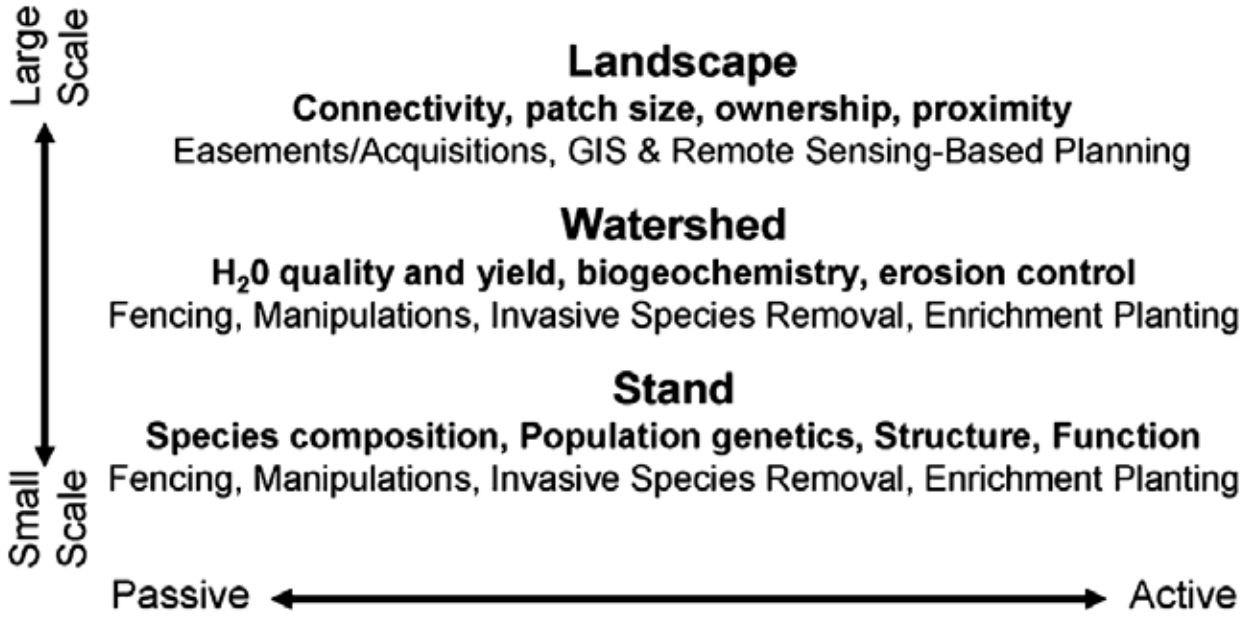
(Palmer *et al*. 2006)

Foundations of Restoration Ecology

- Ecological restoration is typically not a one-time activity or intervention
  - Long-term commitment of land and resources
  - 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 cases, however, ecological systems have been pushed beyond the point of spontaneous recovery
      - Necessitates anything from active outplanting to major topographic work (e.g. reclaimed mines, wetlands)

Foundations of Restoration Ecology

- Ecological restoration spans a range of spatial scales and intervention intensities



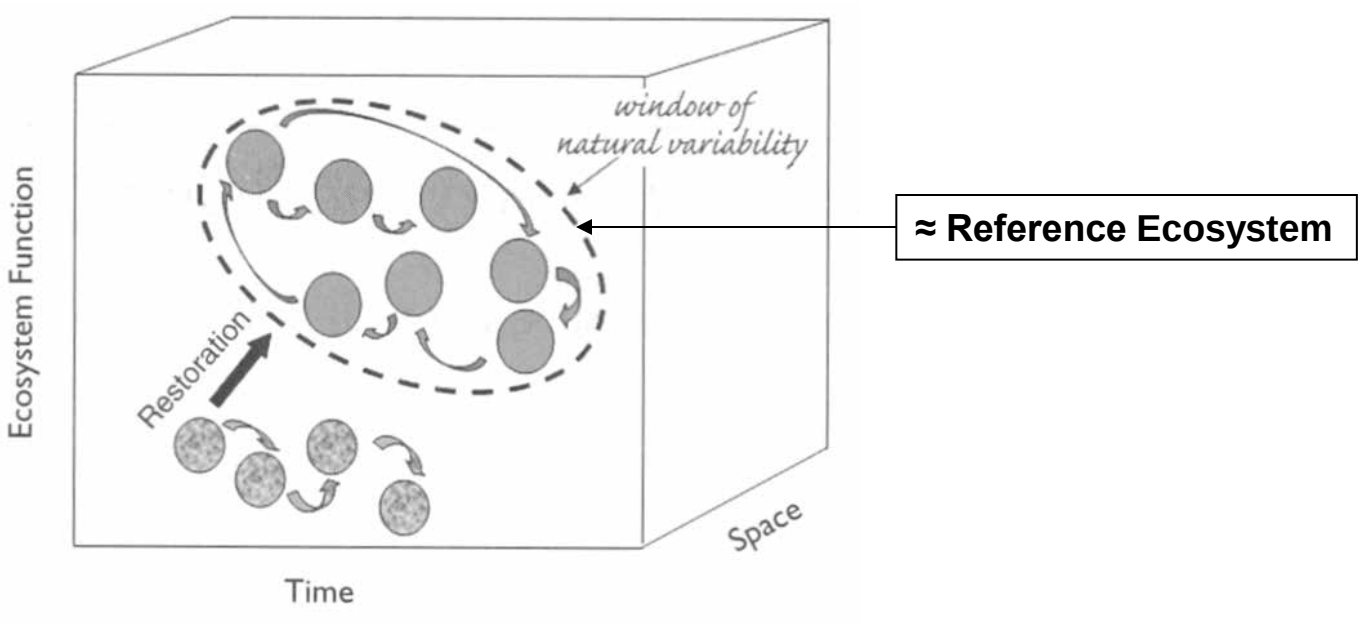
(Giardina *et al*. 2007)

Foundations of Restoration Ecology

- Terminology: *Reference ecosystem*
  - Historical ecosystem or trajectory
    - Model for planning restoration projects
      - "Desired outcome"
      - Can be an actual site, written description, etc.
      - Ideally is multiple sites and/or descriptions
    - Problematic because it often represents only one of many possible natural states
      - Ecological systems are characterized by high spatial & temporal variability
        - » Historic range of variability (HRV)
      - In turn, the restored ecosystem can return to any number of possible states
        - » Alternative stable states

Foundations of Restoration Ecology

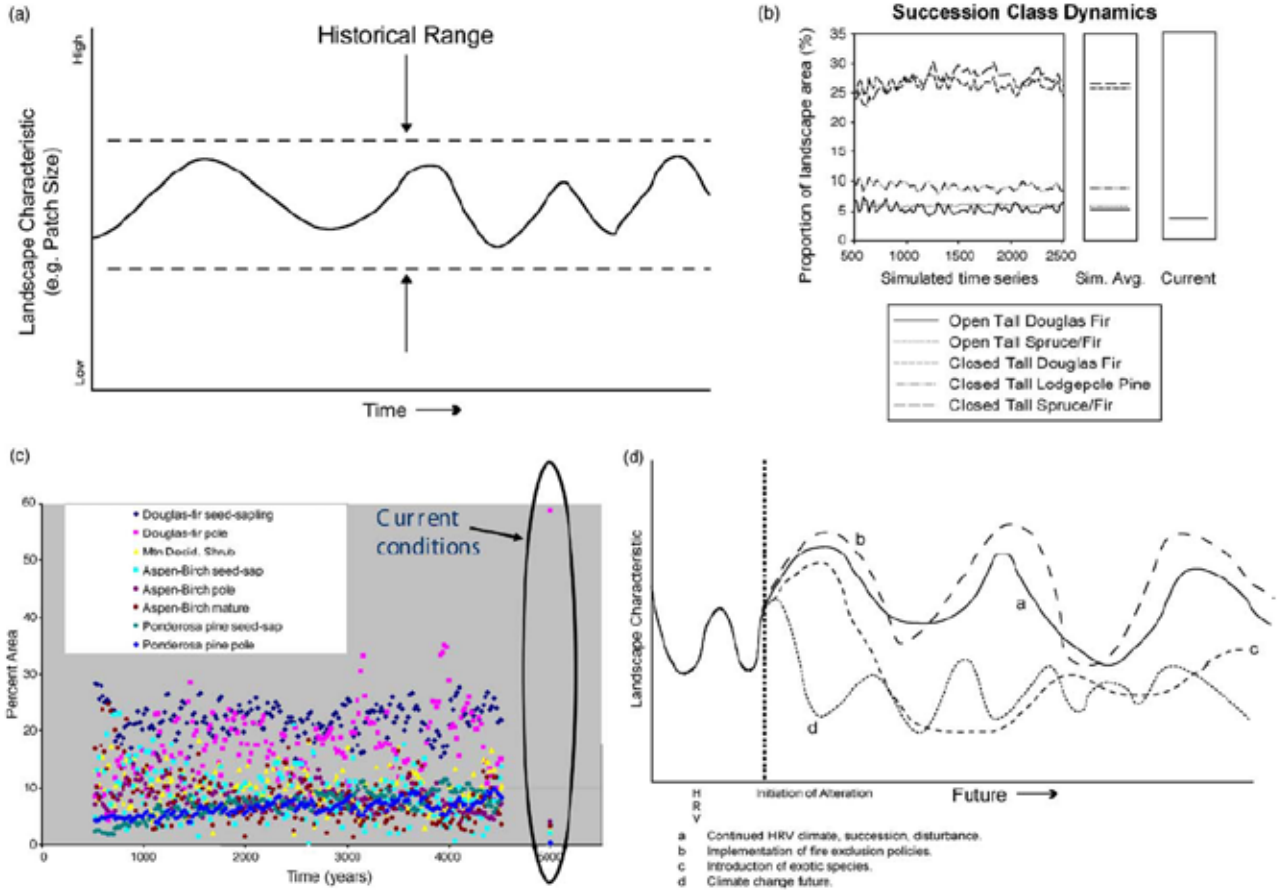
- Ecological restoration
  - Historic range of variability (HRV)



(Palmer *et al*. 2006)

Foundations of Restoration Ecology

- Historic range of variability (HRV)
  - Restoration targets a “shifting baseline”

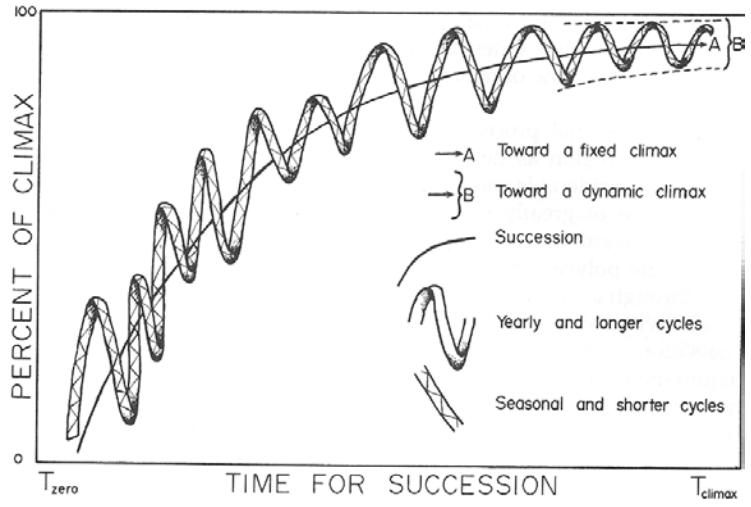


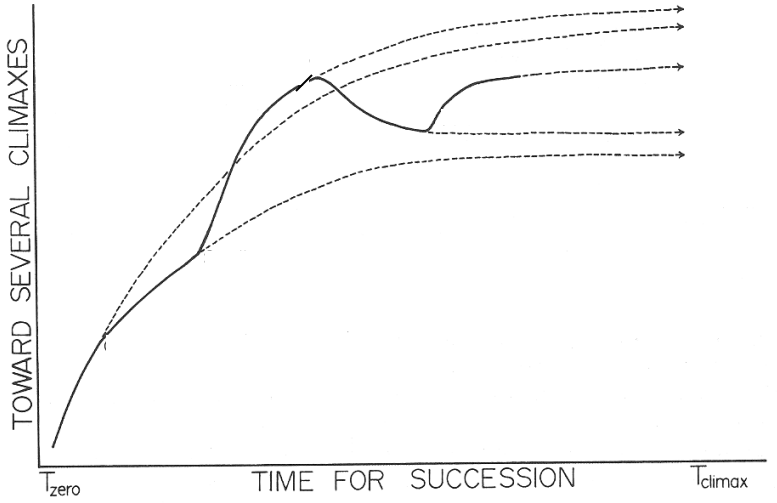
a) Business as usual
b) Fire Management
c) Invasive species
d) Climate Change

(Keane *et al*. 2009)

Foundations of Restoration Ecology

- *Reference ecosystems*
  - Shifting baselines & alternative stable states





Foundations of Restoration Ecology

- Source of information for reference ecosystems (SER 2004)
  - Remnants of the site to be restored
  - Ecological descriptions, species lists, etc. for the site to be restored prior to becoming degraded, damaged or destroyed
  - Ecological descriptions & species lists of similar ecosystems in other locales
  - Paleoecological evidence
  - Historical and/or recent photographs
  - Herbarium and museum specimens
  - Historical accounts and oral histories

Foundations of Restoration Ecology

- Restoration planning steps (SER 2004)
  - Restoration requires careful and systematic planning

1) A clear rationale as to why restoration is needed
2) An ecological description of the site designated for restoration
3) A statement of goals and objectives of the restoration project
4) A designation and description of the reference system
5) An explanation of how the proposed restoration will integrate with the landscape and its flows of organisms and materials
6) Explicit plans, schedules and budgets for site preparation, installation and post-installation activities, including a strategy for making mid-course corrections (adaptive management)
7) Well-developed and explicitly stated performance standards, with monitoring protocols for project evaluation
8) Strategies for long-term protection and maintenance

Foundations of Restoration Ecology

- Restoration planning steps

Species Targets

Ecosystem Targets

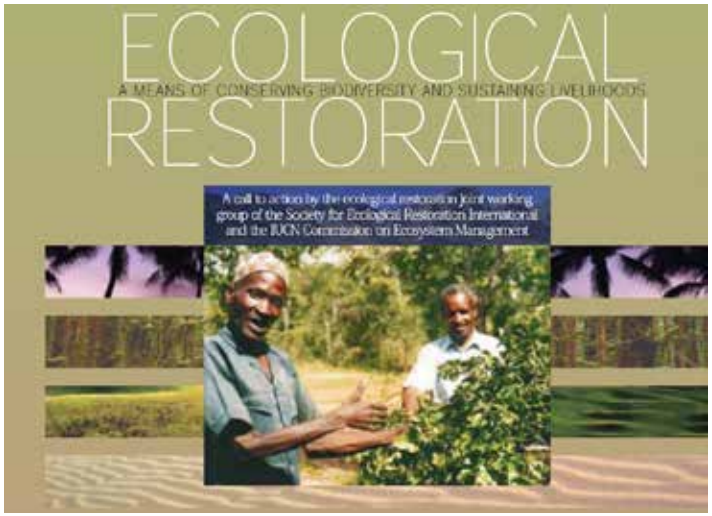
(Giardina *et al*. 2007)

Foundations of Restoration Ecology

- Attributes of restored ecosystems (SER 2004)
  1) Contains a characteristic assemblage of the species that occur in the reference ecosystem
  2) Consists of native species to the greatest practicable extent
  3) All functional groups necessary for the continued development and/or stability are represented or have the potential to colonize
  4) Capable of sustaining reproducing populations
  5) Functions normally for its ecological stage of development
  6) Suitably integrated into a larger ecological matrix or landscape
  7) Potential threats have been eliminated or reduced
  8) Sufficiently resilient to endure normal periodic stress events
  9) Self-sustaining to the same degree as the reference ecosystem and has the potential to persist indefinitely within the norms of ecosystem development

Foundations of Restoration Ecology

- Human & cultural elements of restoration crucial to viability of restoration projects worldwide
  - 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



Foundations of Restoration Ecology

- Terminology: *Conservation biology*
  - Science of analyzing and preserving existing biological diversity
    - 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*
      - Science & theory *vs*. practice

Foundations of Restoration Ecology

- *Conservation biology* vs. *Restoration Ecology*
  - "Conserving what is left" *vs*. "Restoring what once was"
  - Targeted or endangered species *vs*. Habitat structure and function
  - Zoological (fauna) *vs*. Botanical (flora)
  - Short *vs*. Long-term objectives
  - In reality, they are quite complementary
    - Widespread habitat loss has made conservation difficult or impossible in many cases → Restoration is necessary

Week 1 Readings/Lecture Slide Highlights

1. A reference ecosystem is the baseline used for designing ecological restoration projects, and monitoring their success over time. Because ecological systems are not static over time, a reference endpoint is seldom a single point in space or time, but rather should be considered as a range of desirable conditions or outcomes. One way to approach this is to establish a reference endpoint as a range of possible outcomes based on the concept of historic range of variability (HRV).

Week 1 Readings/Lecture Slide Highlights

2. Definitions are important, if nothing else than because they allow us to communicate more effectively. Restoration ecology is *"the scientific discipline of developing and/or applying theory to guide restoration activities*", while ecological restoration is *"the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed".*

Week 1 Readings/Lecture Slide Highlights

3. Restoration is seldom a one-time activity or intervention, but rather is typically a long-term commitment of resources (i.e., time and $$$). The actual amount of effort/resources required will vary from site to site depending on the degree of damage/degradation.

Week 1 Readings/Lecture Slide Highlights

4. To have any chance at success, a given restoration project should always start with *(i*) a clear rationale as to why restoration is needed and/or desired; and *(ii*) a clear statement of the goals and objectives of the restoration project.

Week 1 Readings/Lecture Slide Highlights

5. Ecological restoration is supposed to do a lot of things to save the Planet, and continue to provide the suite of goods and services that humankind depends on from natural and managed ecosystems. But restoration is not typically easy or straight-forward.