Forest Restoration Ecology

- Objectives:
  - Definitions, terminology & introductory material
  - Restoration Ecology within the Ecological Hierarchy
    - Succession & Disturbances
    - Invasive Species
  - Future of forest restoration in Hawaii?

  - **First:** questions, take-home points, things you learned, etc. from SER reading assignment

Forest Restoration Ecology

- Environmental Values of Restoration
  - “…*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 & climate change mitigation
7) Preservation of land-based cultural traditions

Forest Restoration Ecology

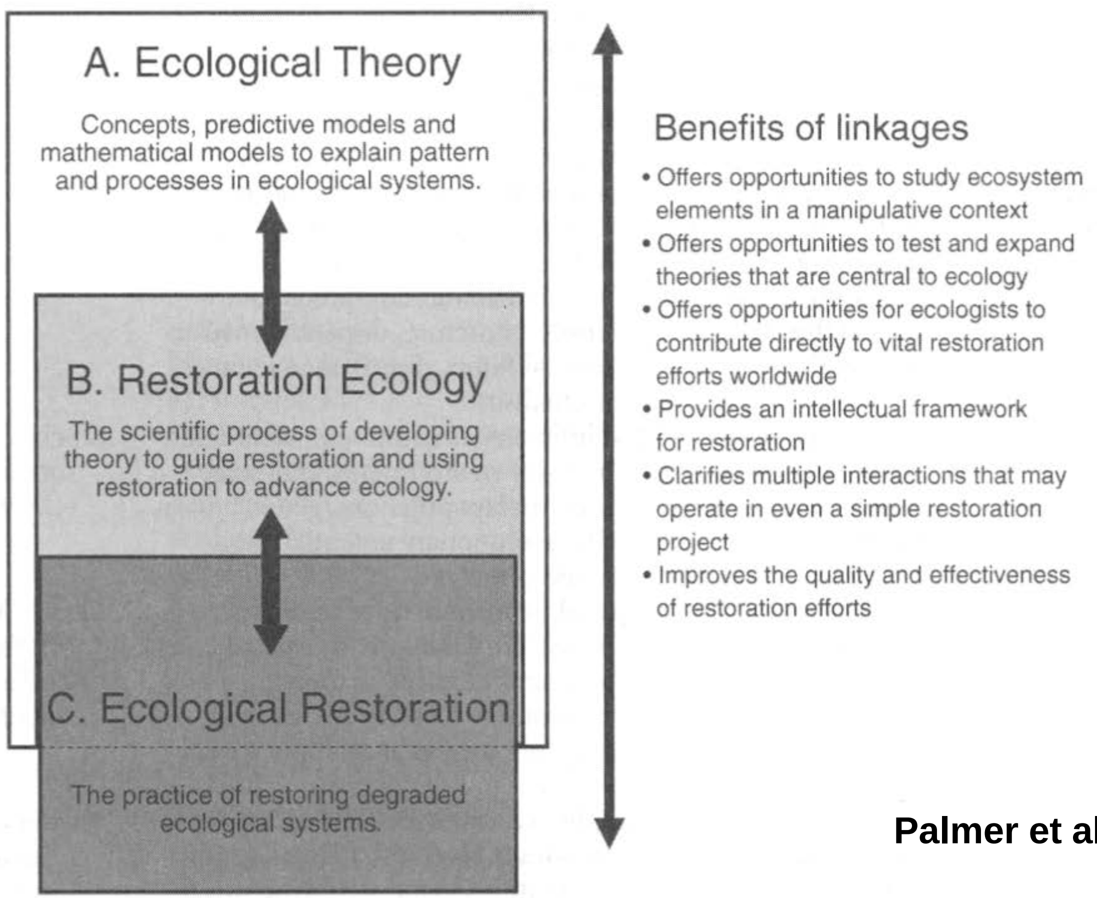
- Terminology
  - *Restoration ecology*
    - “Science of restoration”
      - Science = Creation & dissemination of new knowledge
    - Requires *a priori* knowledge of and a strong basis in ecological theory
    - Application of ecological theory to restore ecological systems
      - “Acid test for 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 system to historical/reference state
      - Intentional activity
    - Implication → system transformed from some desirable state <u>and</u> this transformation is not desirable
      - **Value judgment**
    - *Ecological restoration* assists or initiates recovery
      - Often requires continued management over time
      - *Adaptive ecosystem management* helps guarantee the continued well-being of the restored system thereafter

Forest Restoration Ecology

- *Restoration ecology* vs. *Ecological restoration*



Palmer et al. 2006

Forest Restoration Ecology

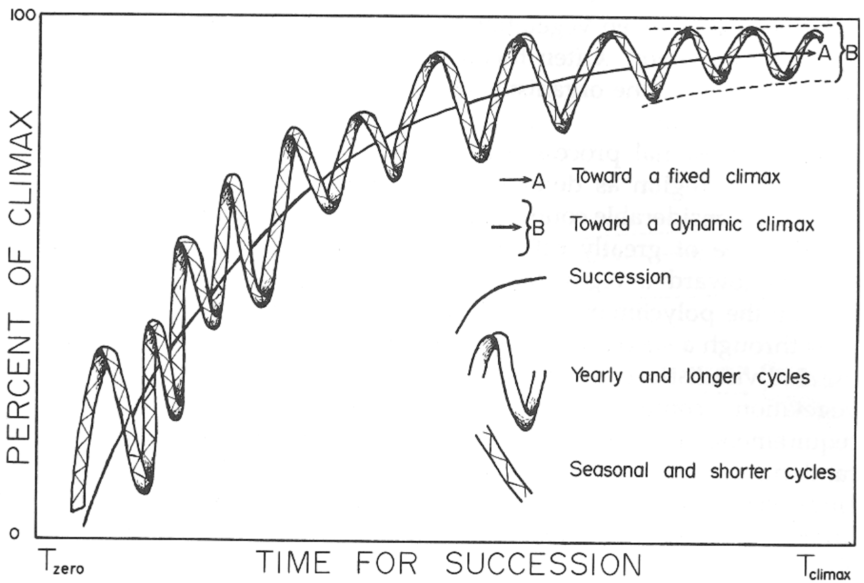
- Ecological restoration
  - Continuum of effort needed to restore a system
    - As simple as removing an unnatural disturbance **or** reinstating a natural disturbance
    - In many cases, ecosystems have been pushed beyond the point of spontaneous recovery
      - Necessitates anything from active outplanting to removal of invasive species to major topographic work
      - Typically involves more than a single treatment or activity in time → long-term commitment of resources
    - Active vs. Passive Restoration

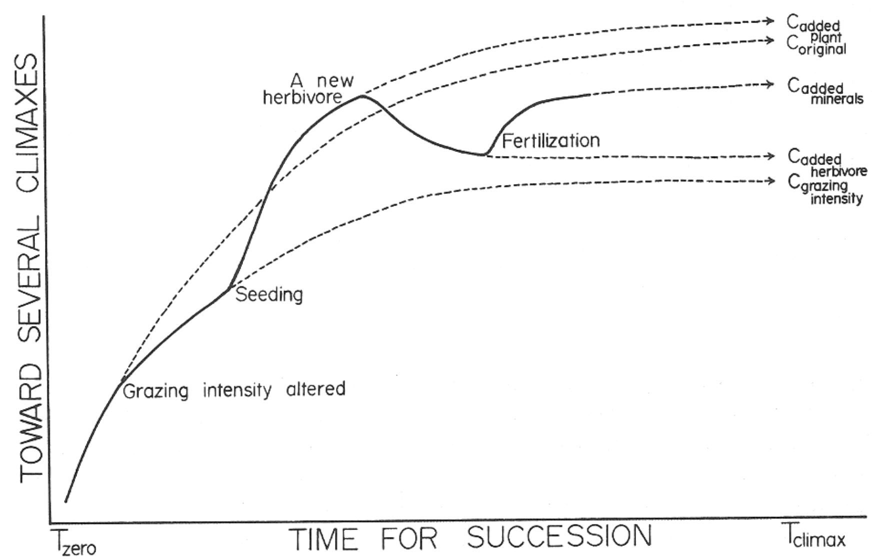
Forest Restoration Ecology

- 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

Forest Restoration Ecology

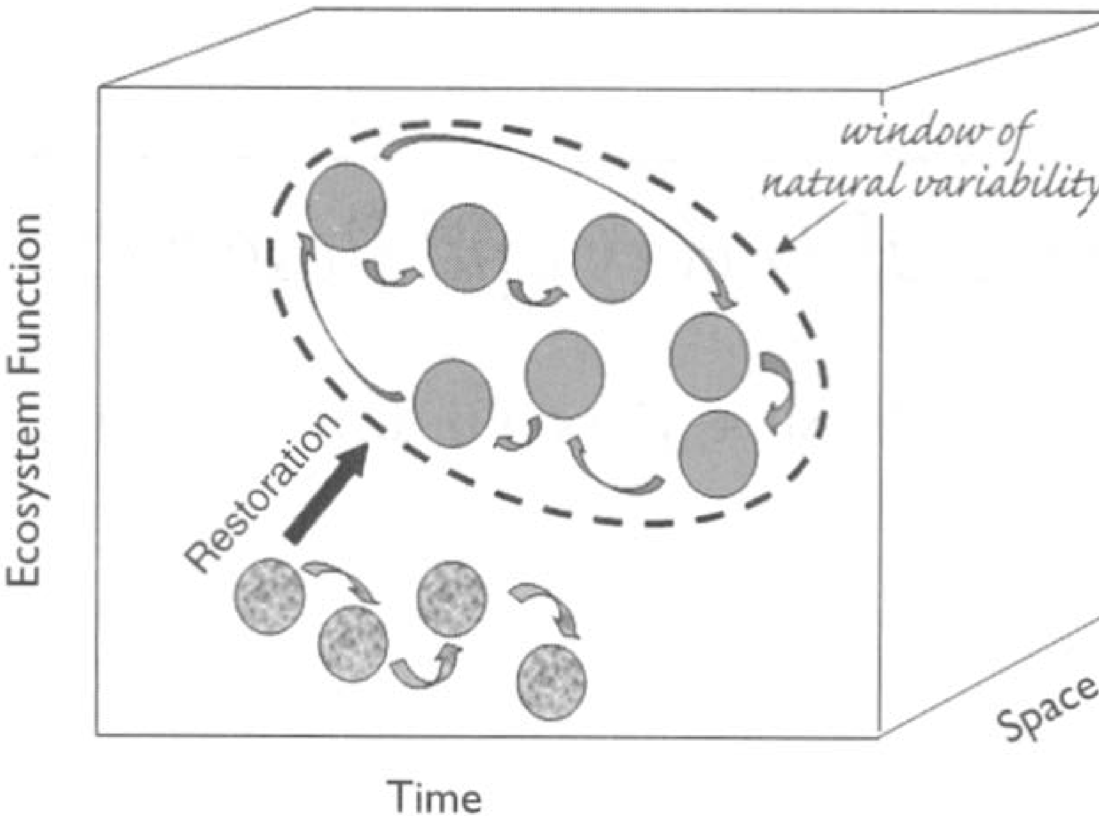
- *Reference ecosystem*: Alternative stable states





Forest Restoration Ecology

- Ecological restoration: Restoration targets a “*shifting baseline*”



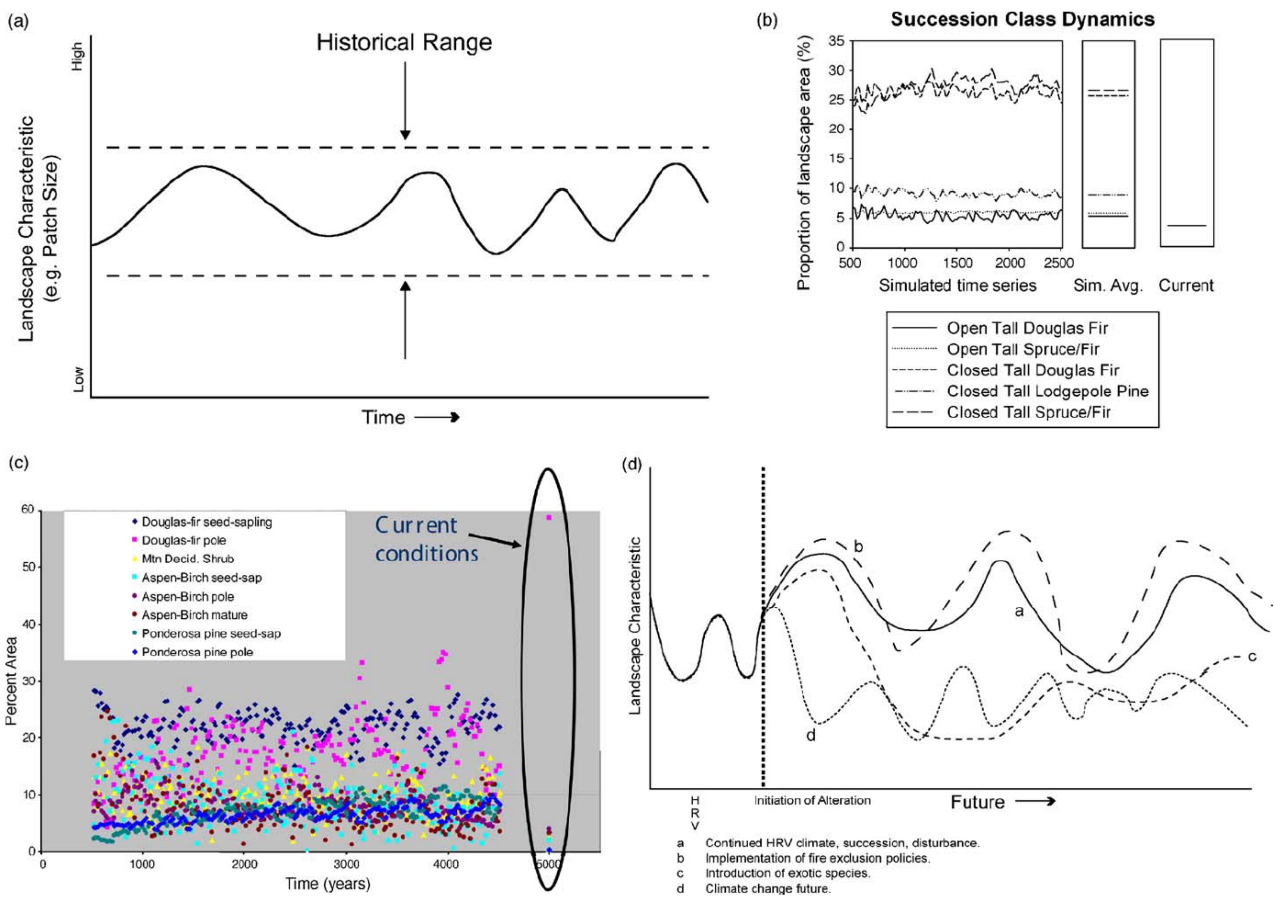
Palmer et al. 2006

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
  - Historic Range of Variability (HRV)

Forest Restoration Ecology

- *Reference ecosystem*: Historic Range of Var.



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

(Keane *et al*. 2009)

Forest Restoration Ecology

- Terminology
  - *Conservation biology*
    - Save it <u>before</u> it becomes damaged, degraded, or destroyed
    - As with restoration ecology, based on fundamental ecological and evolutionary principles
    - *Conservation biology* is the scientific discipline that informs *biological conservation* (the act of conserving)

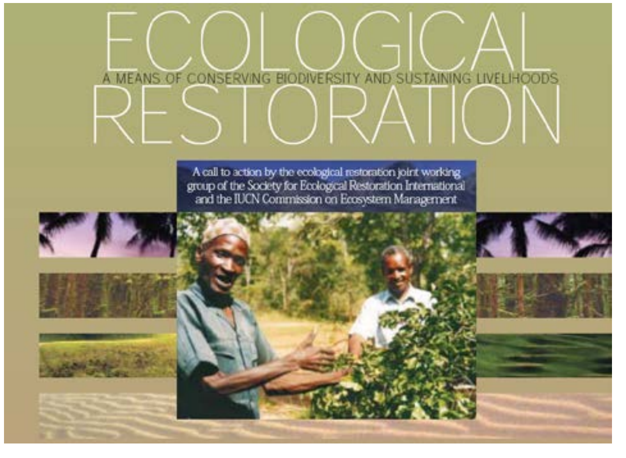
    - *<u>Restoration</u> <u>ecology</u> is to <u>ecological</u> <u>restoration</u> what <u>conservation</u> <u>biology</u> is to <u>biological</u> <u>conservation</u>*

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 & description *vs*. Replicable practice
    - In reality, they are quite complementary & overlap
      - Widespread habitat loss has made conservation difficult or impossible in many cases → Restoration is necessary

Forest Restoration Ecology

- Human and cultural elements are crucial to viability of restoration projects globally
  - 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

- Restoration planning steps (SER)

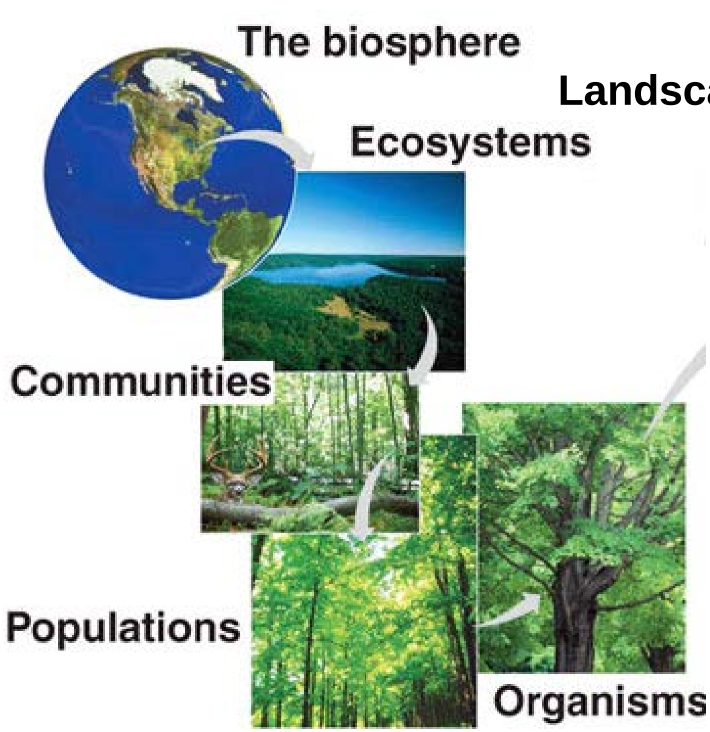
1) Clear rationale as to why restoration is needed
2) Ecological description of the site to be restored
3) Statement of goals & objectives of the restoration project
4) Designation & description of the reference system
5) Explanation of how the proposed restoration will integrate with the landscape & surrounding ecosystems
6) Plans, schedules & budgets for site prep., installation & post-installation activities; should include 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 & maintenance

Forest Restoration Ecology

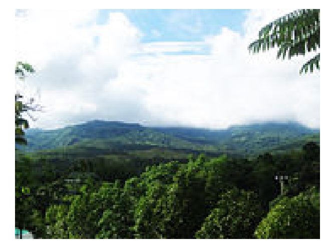
- Attributes of restored ecosystems (SER)
  1) Contains a characteristic assemblage of the species that occur in the reference ecosystem
  2) Consists of native species to greatest practicable extent
  3) All functional groups necessary for the continued development and/or stability are represented
  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)



Landscapes



(Individuals)

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?

Forest Restoration Ecology

- 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:
    - Biotic interactions
    - Habitat and resource dynamics
    - Disturbance regimes
    - Ecological 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 for ecological restoration
    - Forces 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
    - “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
    - 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

Restoration Ecology: Succession & Disturbances

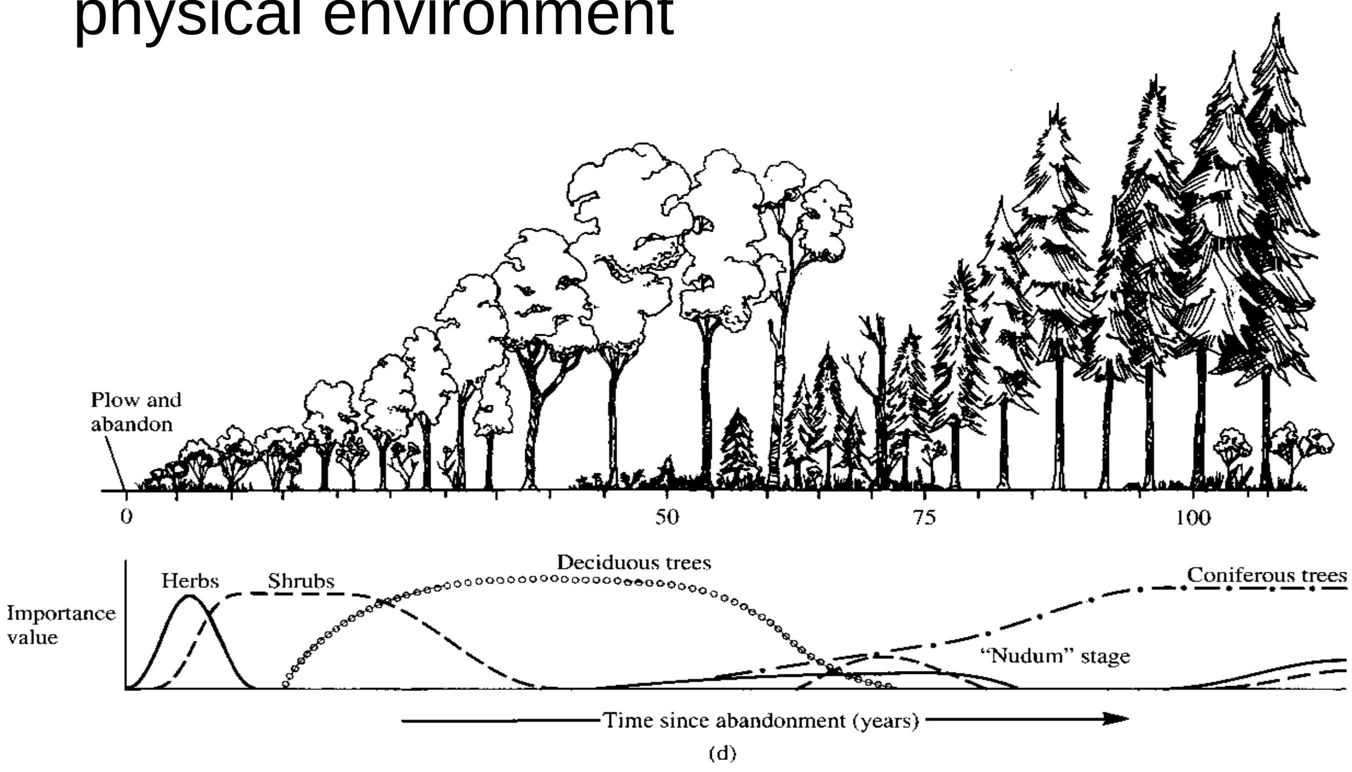
- What is a (natural) disturbance?
  - Relatively discrete event in time that disrupts ecosystem, community and/or population structure, and changes substrate and resource availability, and the physical environment

Restoration Ecology: Succession & Disturbances

- 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

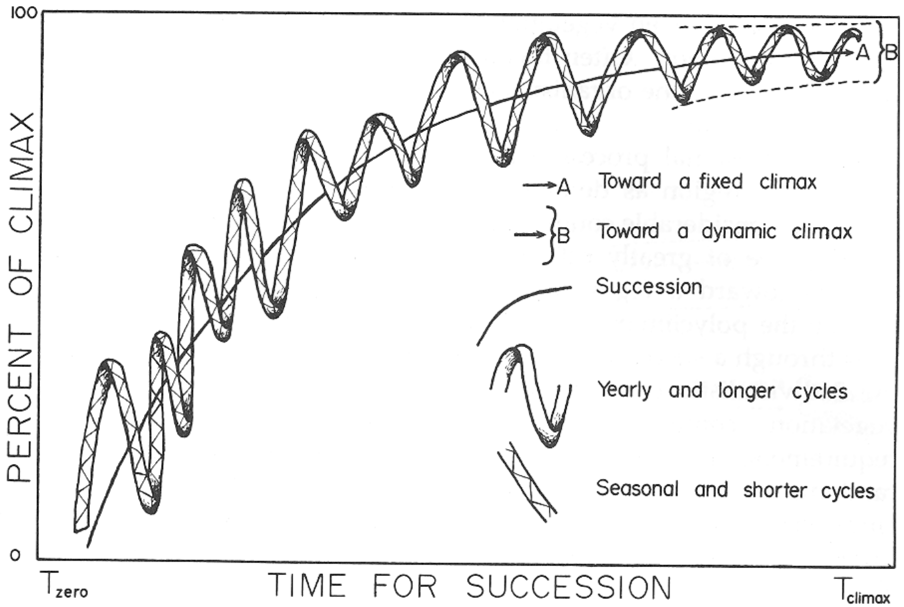
Restoration Ecology: Succession & Disturbances

- 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

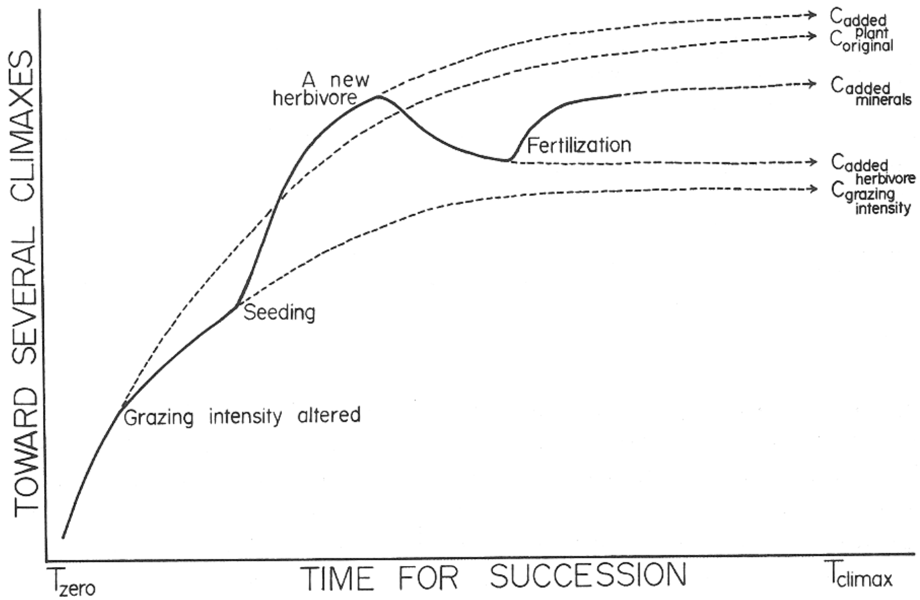


Restoration Ecology: Succession & Disturbances

Single Steady State



Multiple/Alternative Steady States



Restoration Ecology: Succession & Disturbances

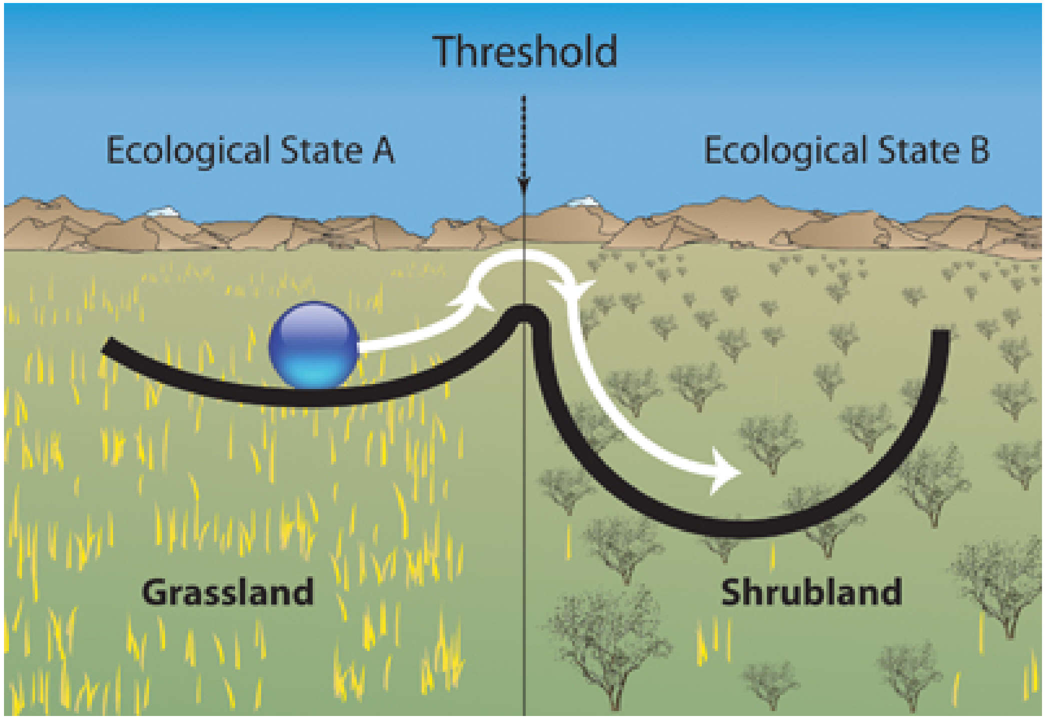
- Single Equilibrium Endpoint
  - Return to a pre-disturbance state following disturbance
    - Steady directional change to a single endpoint
    - Predictable consequence of species interactions
    - Strong internal regulation via negative feedback mechanisms
  - Restoration can accelerate succession by skipping some points along the continuum
    - e.g., Restoring fire and flood regimes
    - Depends upon level of degradation

Restoration Ecology: Succession & Disturbances

- 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

Restoration Ecology: Succession & Disturbances

- 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

Restoration Ecology: Succession & Disturbances

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

Restoration Ecology: Succession & Disturbances

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

Restoration Ecology: Succession & Disturbances

Example 3: Nonnative Tropical Grassland (Hawaii) – Nonnative grass invasion and increased fire frequency

Problem: Invasion, increased fire, ecological threshold crossed

Solution: Remove fire
- Remove ignitions
- 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*




Restoration Ecology: Invasive Species

– '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

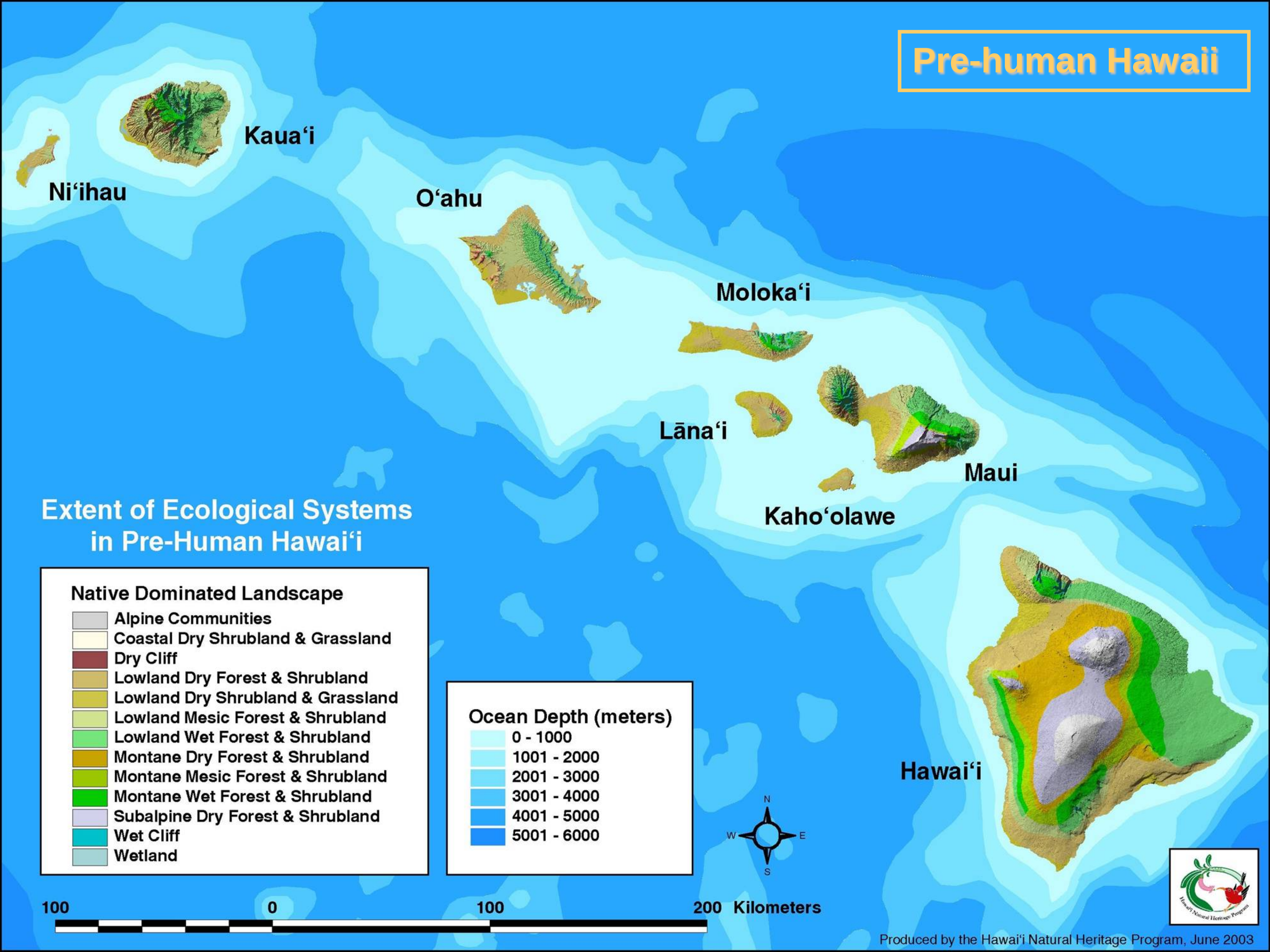
- ‘Cost’ of Invasive Species
  - Biodiversity
    - 2nd most important cause of loss of biodiversity
    - In the U.S., >1/2 of the species listed as threatened or endangered are at risk due to competition with or predation by nonnative species




Restoration Ecology: Invasive Species

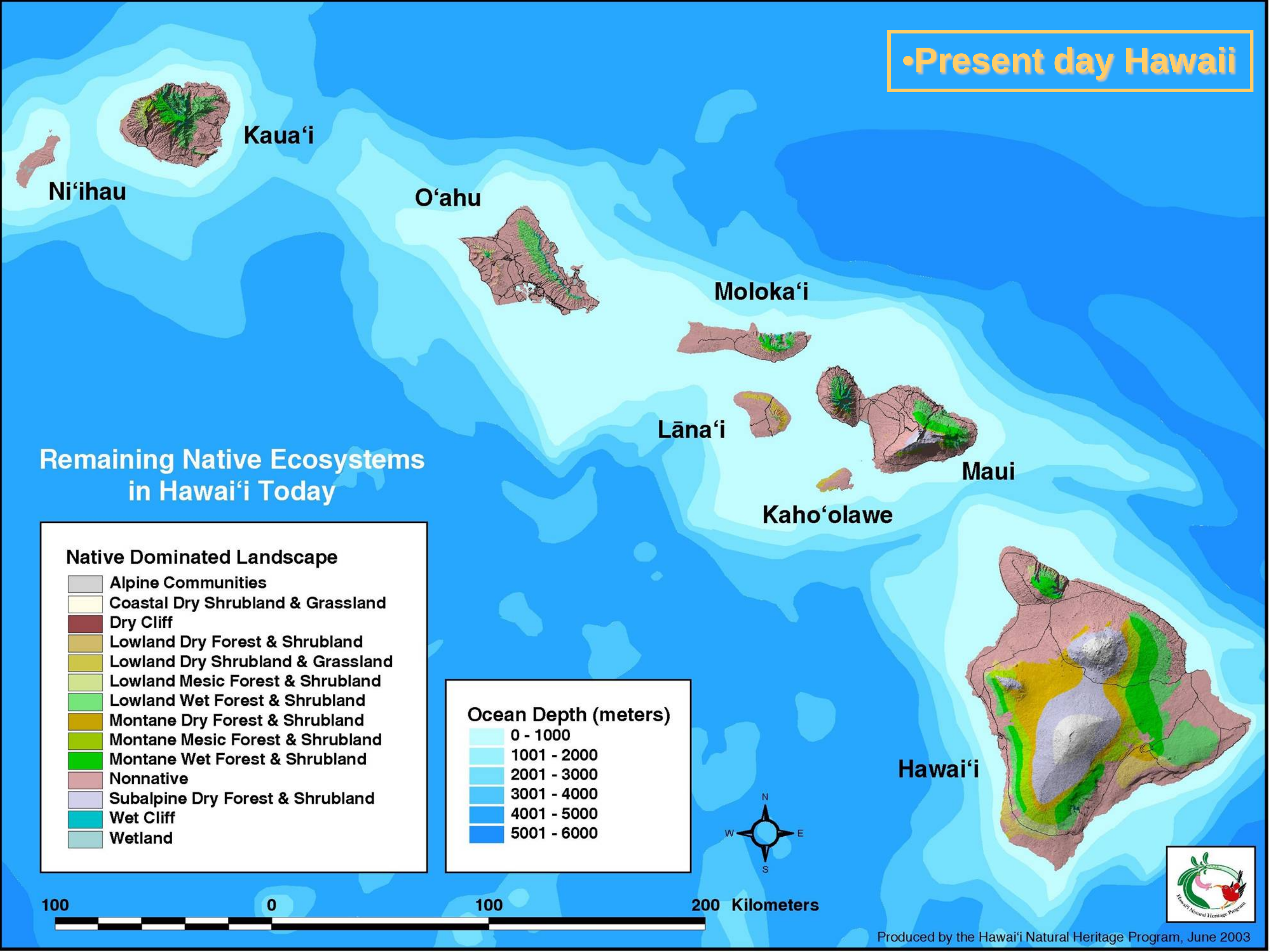
- ‘Cost’ of Invasive Species
  - Ecological systems, processes, goods and services
    - Changes in disturbance regimes
    - Alterations of biogeochemical cycles
      - » Nutrient cycling
      - » Hydrology
      - » Carbon cycling



Pre-human Hawaii
Kaua'i
Ni'ihau
O'ahu
Moloka'i
Lāna'i
Maui
Kaho'olawe
Hawai'i
Extent of Ecological Systems
in Pre-Human Hawai'i
Native Dominated Landscape
Alpine Communities
Coastal Dry Shrubland & Grassland
Dry Cliff
Lowland Dry Forest & Shrubland
Lowland Dry Shrubland & Grassland
Lowland Mesic Forest & Shrubland
Lowland Wet Forest & Shrubland
Montane Dry Forest & Shrubland
Montane Mesic Forest & Shrubland
Montane Wet Forest & Shrubland
Subalpine Dry Forest & Shrubland
Wet Cliff
Wetland
Ocean Depth (meters)
0 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
N
W
E
S
100
0
100
200 Kilometers
Produced by the Hawai'i Natural Heritage Program, June 2003

•Present day Hawaii

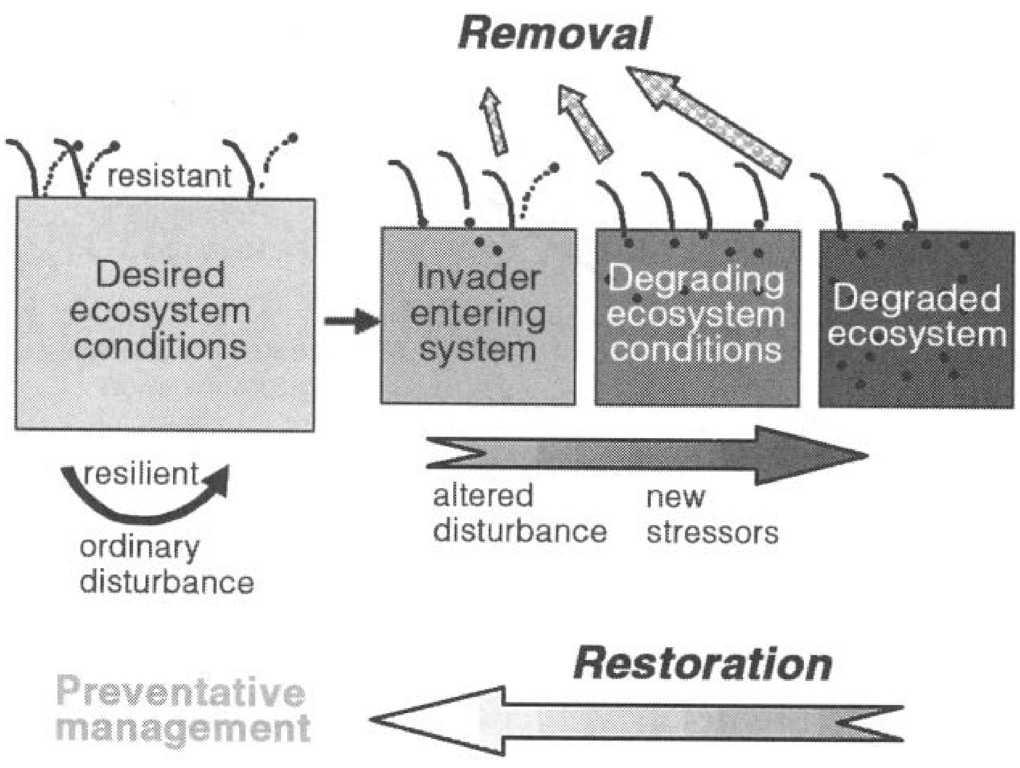


Restoration Ecology: Invasive Species

- 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

- Management and prevention approaches
  - Prevention → relatively pristine state
  - Management (removal) → 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 being invaded (e.g., occupying niche space)
    - Maintain ecosystem resilience following disturbances




Restoration Ecology: Invasive Species

- 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




Restoration Ecology: Future of Hawaii

- Future of forest restoration in HI (Friday et al. 2015)
  - – Use of non-native species
  - – Remote Sensing to increase efficacy
  - – Improved planting material
    - Direct seeding
  - – Improved site preparation/weed control
  - – Community involvement