# Introduction to Landscape Ecology

# Introduction

**Examples of courses offered by the Ecology Department**

- **BIOL 532 Physiological Plant Ecology**
- **BIOL 506 Population Dynamics**
- **BIOL 542 Community Ecology**
- **BIOL 515 Landscape Ecology and Management**

- **BIOL 513Z Terrestrial Ecology of Plains and Prairies**
- **F&WL 510 Fisheries Science**
- **BIOL 521 Conservation Biology**

## Introduction

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**Why do we break ecology into subdivisions to learn it? What are the pros and cons of doing this by levels of organization vs system, place, or goal?**

## Today’s Lecture

**Development of Landscape ecology:**

- **State of Ecology in the 1970’s**
- **Emergence of landscape ecology in the 1980’s**
- **Current understanding of landscape ecology**

**Discussion question:**

**Is landscape ecology a distinct subdiscipline within ecology or simply mainstream ecology?**

# State of Ecology in the 1970s

- Largely based on levels of biotic organization
  - Cell
  - Organ
  - Individual
  - Population
  - Community
  - Ecosystem
  - Biome
  - Biosphere

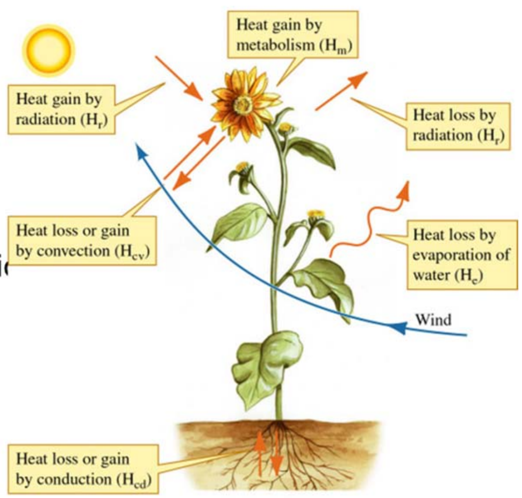
# State of Ecology in the 1970s

- **Largely based on levels of biotic organization**
  - **Cell**
  - **Organ**
  - **Individual (e.g. Physiological ecology)**
  - **Population**
  - **Community**
  - **Ecosystem**
  - **Biome**
  - **biosphere**

## Regulating Body Temperature

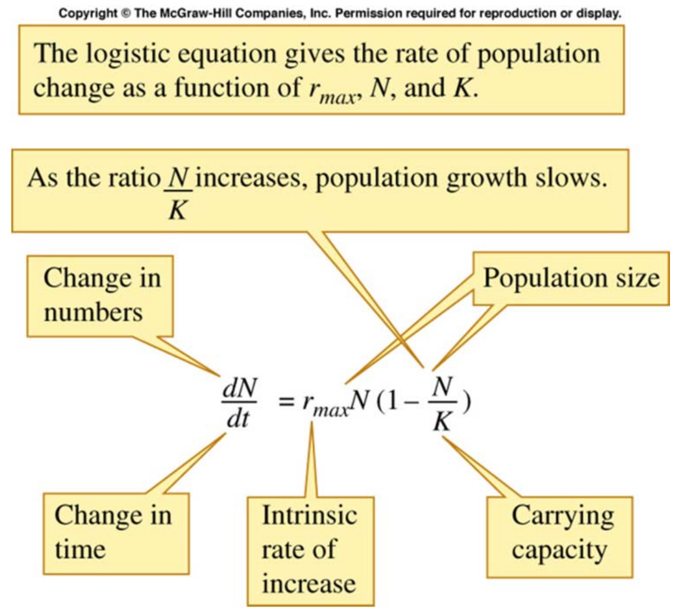
$$HS = Hm \pm Hcd \pm Hcv \pm Hr - Hc$$

- HS = Total heat stored in an organism
- Hm = gained via metabolism
- Hcd = gained / lost via conduction
- Hcv = gained / lost via convection
- Hr = gained / lost via electromag. radiati
- Hc = lost via evaporation



# State of Ecology in the 1970s

- Largely based on levels of biotic organization
  - Cell
  - Organ
  - Individual
  - Population (e.g., population growth)
  - Community
  - Ecosystem
  - Biome
  - biosphere




**ASSUMPTIONS OF EXPONENTIAL GROWTH EQ.**

(dN/dt = rmaxN)

**No immigration or emigration**

**Constant birth and death rates, thus resources are not limiting**

**No genetic structure (all ind have same birth and death rates)**

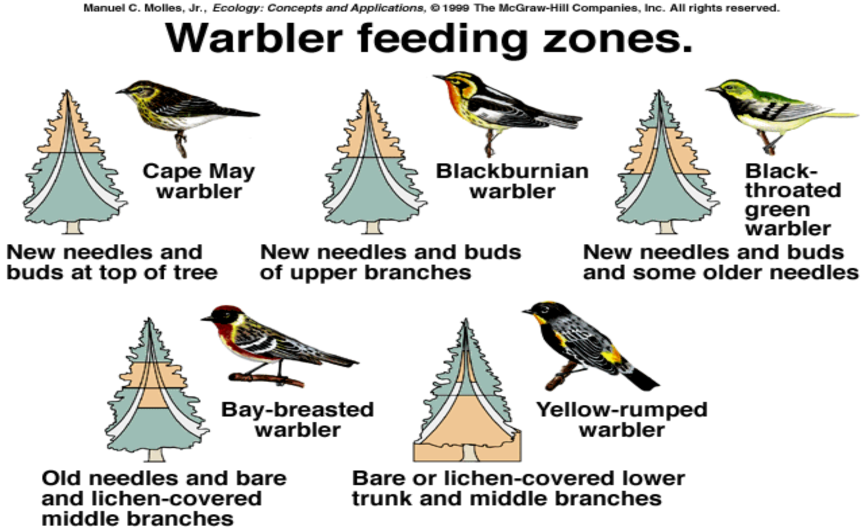
**No age or size structure (all ind have same birth and death rates).**

**Continuous growth with not time lags.**

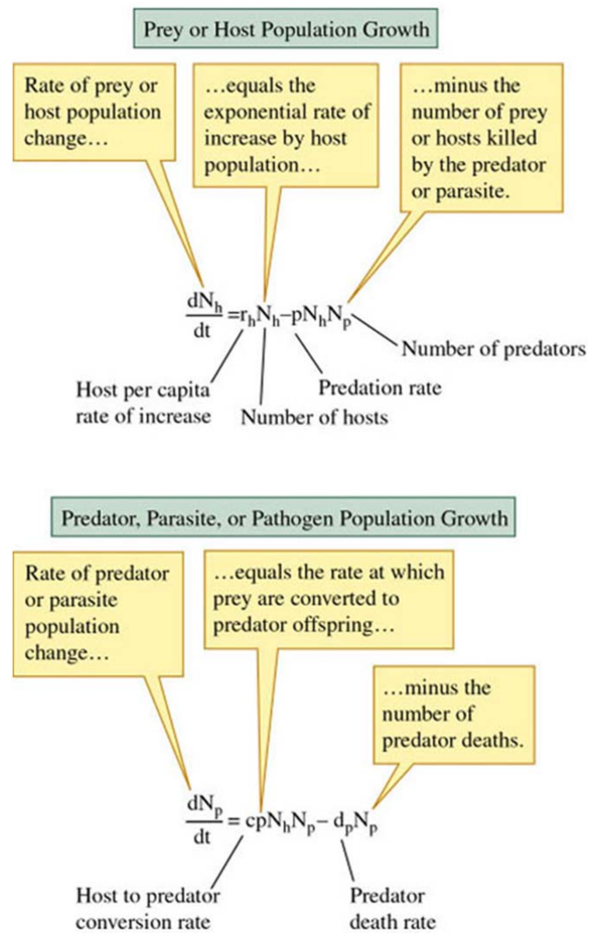
# State of Ecology in the 1970s

- Largely based on levels of biotic organization
  - Cell
  - Organ
  - Individual
  - Population
  - Community (e.g., competition, predation)
  - Ecosystem
  - Biome
  - biosphere



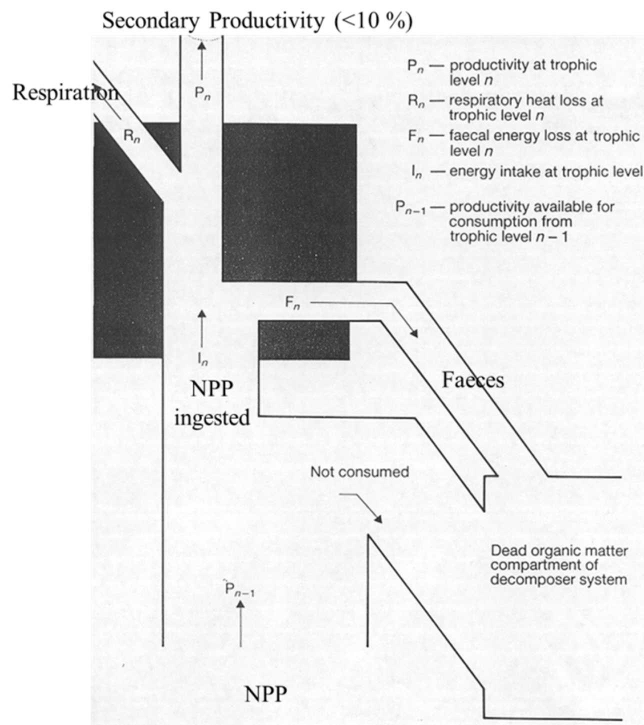


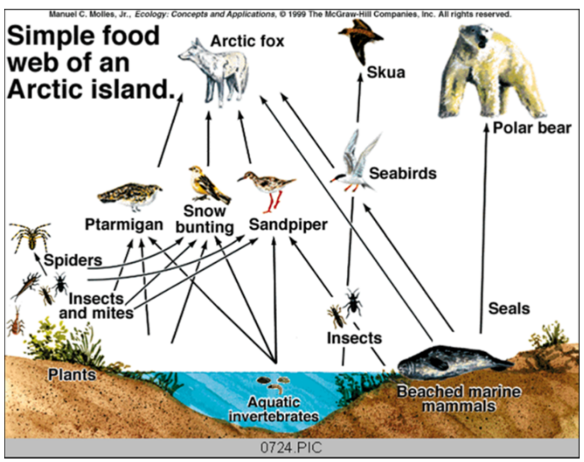


# State of Ecology in the 1970s

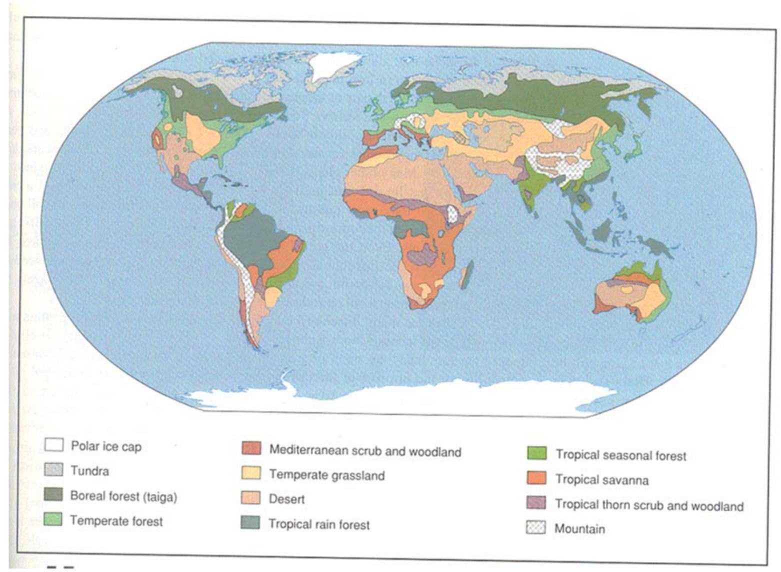
- Largely based on levels of biotic organization
  - Cell
  - Organ
  - Individual
  - Population
  - Community
  - Ecosystem (e.g. energy flow)
  - Biome
  - biosphere

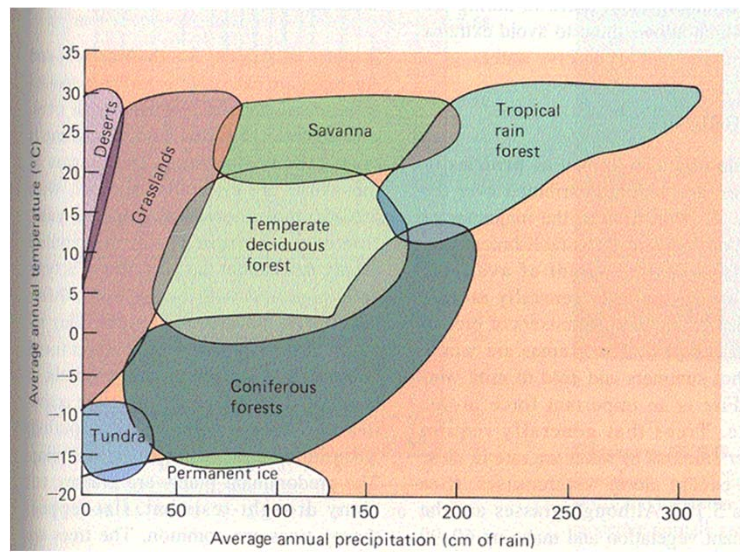


# State of Ecology in the 1970s

- **Largely based on levels of biotic organization**
  - **Cell**
  - **Organ**
  - **Individual**
  - **Population**
  - **Community**
  - **Ecosystem**
  - **Biome (distribution, climate controls)**
  - **biosphere**



# State of Ecology in the 1970s

- **Environmental awareness and applications**
  - **Minimum viable population size**
  - **Controlling disturbances (e.g., fire, flooding)**
  - **Forage and wood production**
  - **Effects of air and water pollution**

# State of Ecology in the 1970s

- **Key assumption - ecosystems were in equilibrium ("perfectly balanced")**
  - **Environment was rather constant**
  - **Evolution was gradual and organisms were well adapted to local environment**
  - **Species distributions were determined by broad climate and by competition**
  - **Vegetation across biomes was rather homogeneous except where upset by irregular disturbance**

# State of Ecology in the 1970s

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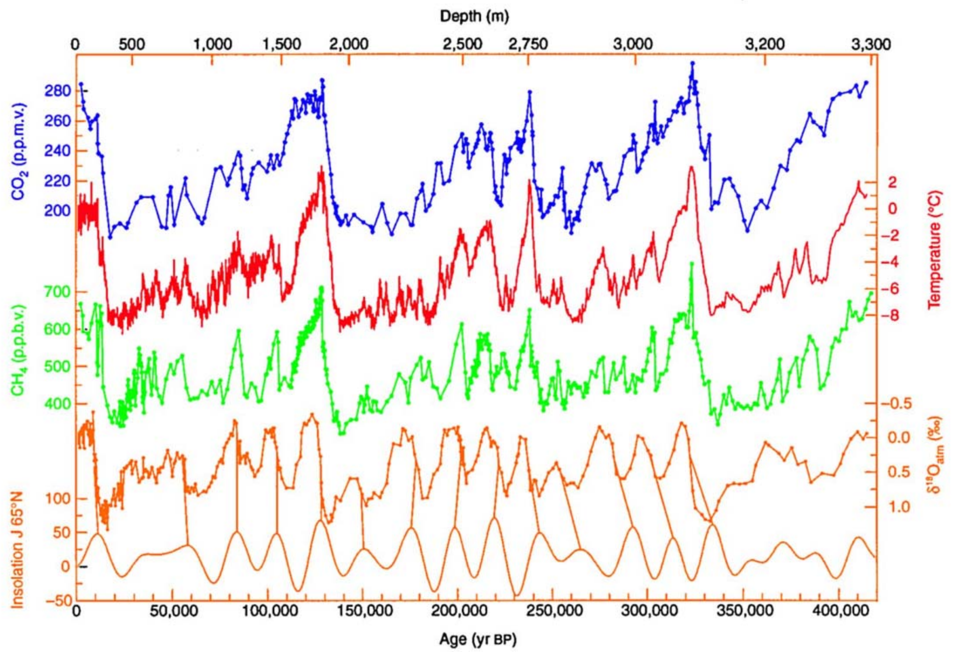
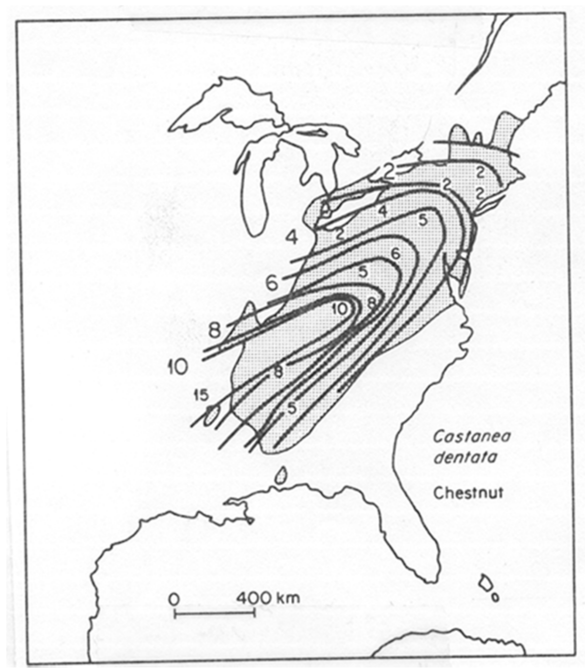
- **Spinoffs of equilibrium view**
  - **vegetation patterns seen by first European settlers had "always been there"**
  - **communities were stable in composition and patterned by climate, env gradients, competition.**
  - **humans were exogenous and cast the natural system out of balance.**
  - **conservation could best be done by setting nature reserves and leaving them alone**

# State of Ecology in the 1970s

- **Puzzling problems**
  - **Climate flux and vegetation response**




**Fluctuation in temperature, atmospheric gasses, and radiation over the past 400,000 years**




**Change in distribution of American chestnut over the 15,000 years since deglaciation.**

# State of Ecology in the 1970s

- Puzzling problems
  - Climate flux and vegetation response
  - Loss of species from small forest patches

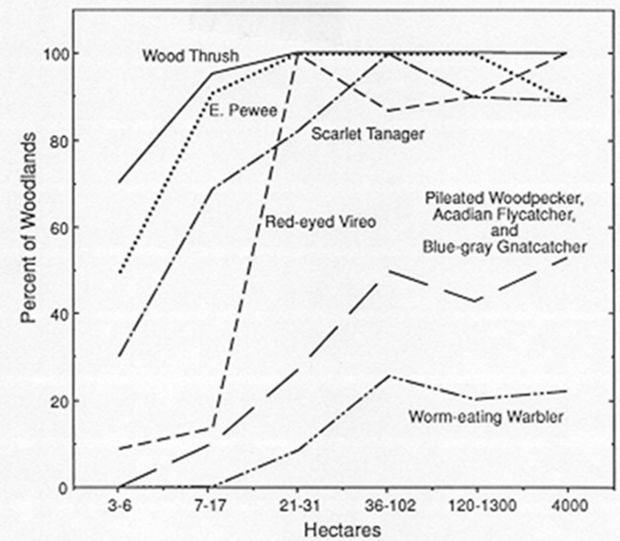




FIG. 5.1 Proportion of woodlots of each size class in which the species indicated were found (Robbins 1980).

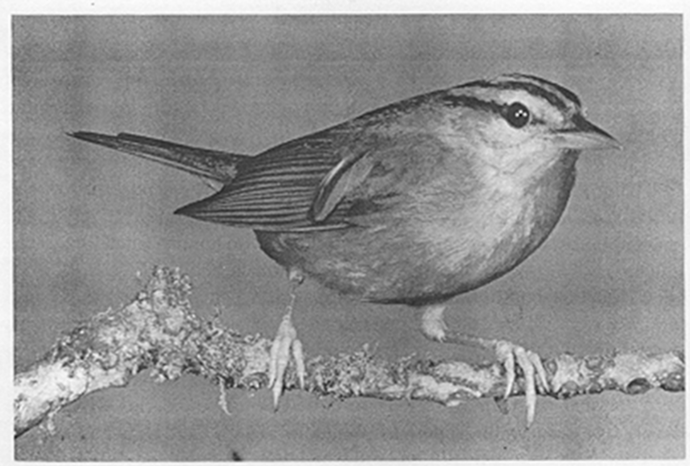
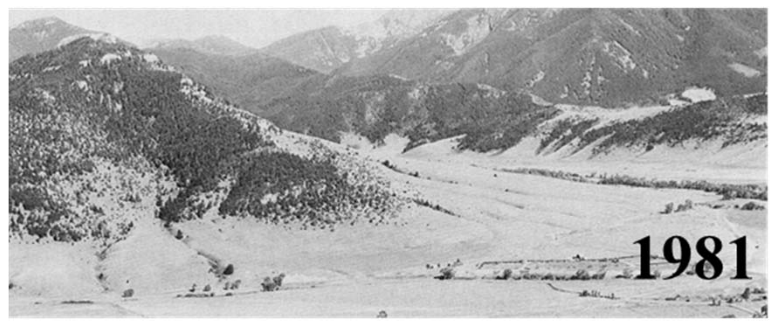


FIG. 5.2 Worm-eating warbler.

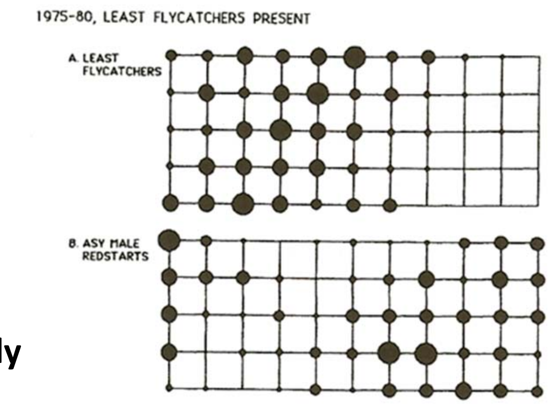
# State of Ecology in the 1970s

- **Puzzling problems**
  - **Climate flux and vegetation response**
  - **Loss of species from small forest patches**
  - **Natural disturbance – agent of death or balance?**

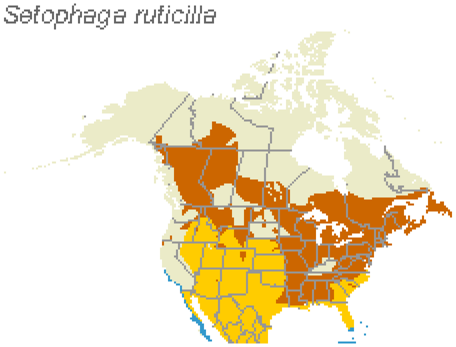



# State of Ecology in the 1970s

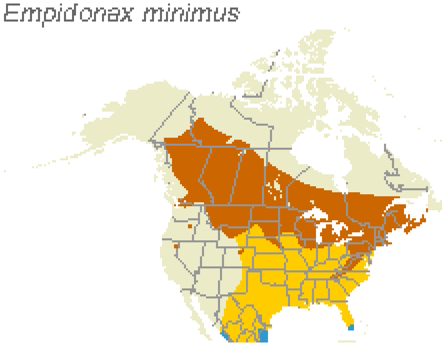
- **Puzzling problems**
  - Climate flux and vegetation response
  - Loss of species from small forest patches
  - Natural disturbance – agent of death or balance?
  - Biotic interactions such as competition differing locally vs regionally




American Redstart
*Setophaga ruticilla*



Least Flycatcher
*Empidonax minimus*



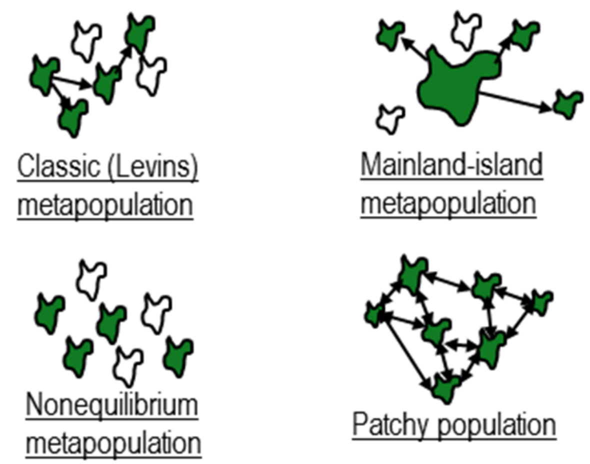
American Redstart (Sherry and Holmes 1988)

- Territory location negatively influenced by presence of least flycatcher territories.
- Across new England, these two species are found in the same places?

# Emergence of Elements of Landscape Ecology in the 1980s

- **Interactions across space**
  - **Populations do have immigration and emigration (e.g., Levins metapopulation model)**

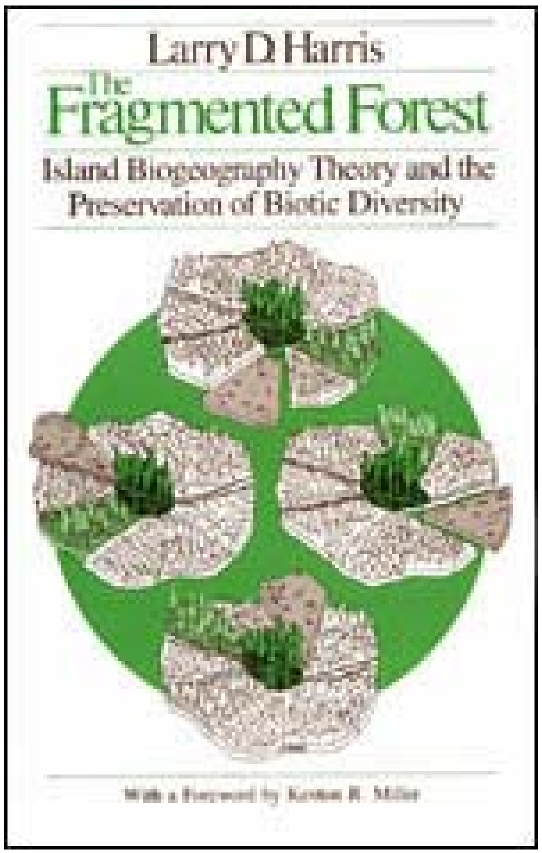
Figure 1. Types of spatially structured populations. Shaded patches are occupied; white patches are vacant. *(figure adapted from Harrison and Taylor 1997)*




**Levins (1969, 1970) model. Suitable habitat is disjunct. Occupancy of a patch is a function of extinction rates in the patch relative to colonization rates. Population stability increased with dispersal among patches.**

# Emergence of Elements of Landscape Ecology in the 1980s

- **Interactions across space**
  - **Populations do have immigration and emigration (e.g., Levins metapopulation model)**
  - **Adjacent patches interact (e.g., Harris's The fragmented Forest)**



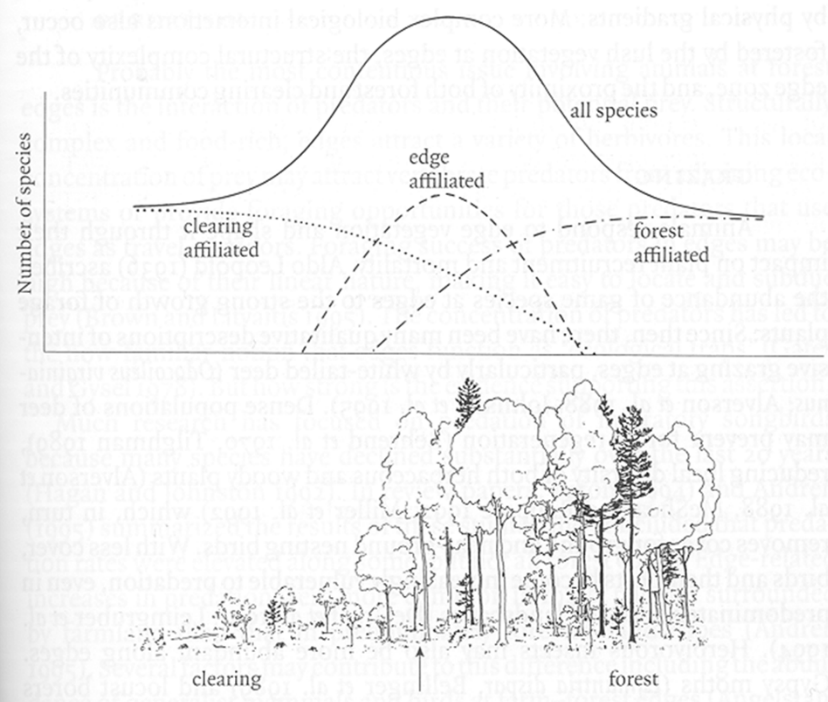
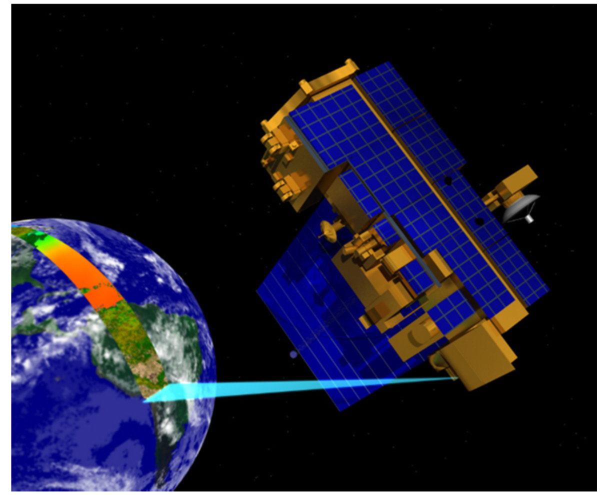



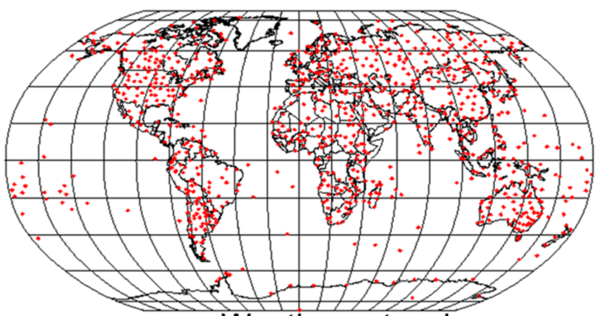

Fig. 6.4. A typical distribution of animal species at a closed forest edge. The arrow indicates the boundary of the gap-forming disturbance.

**Patches interact such that along a gradient from patch edge to interior several ecological properties vary predictably including: microclimate, disturbance rates, decomposition rates, vegetation structure, vegetation composition, and animal distributions. Thus, patch size matters as does neighborhood.**

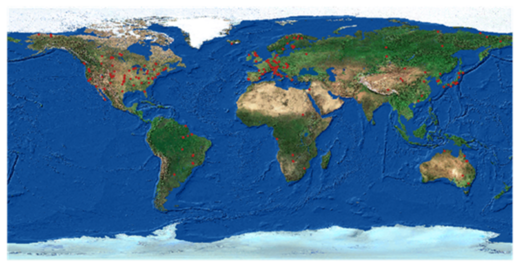
# Emergence of Elements of Landscape Ecology in the 1980s

- **Interactions across space**
- **Larger areas**
  - **New tools (air photos, satellite images, radio telemetry, networks of field measurements high-speed computers and GIS) allowed study of larger areas.**

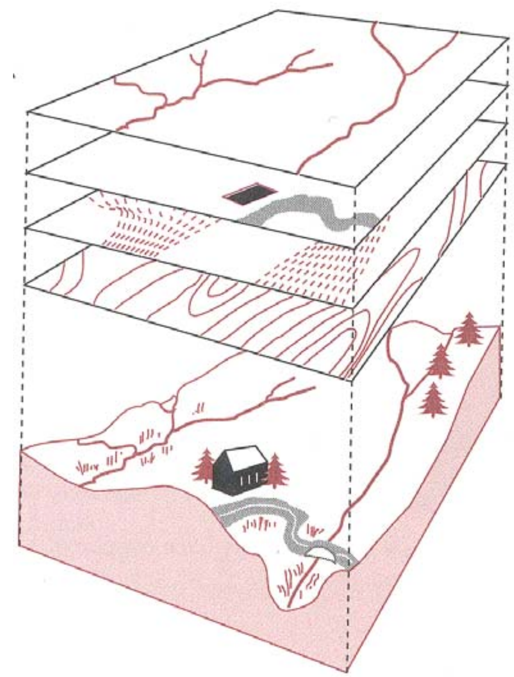


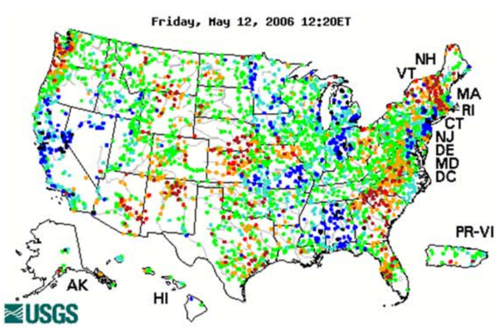


Weather network

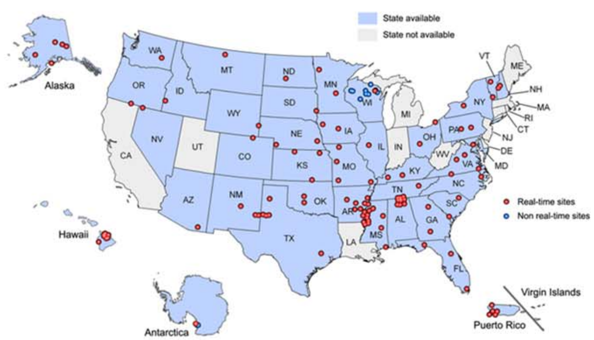


Carbon & Energy Fluxnet





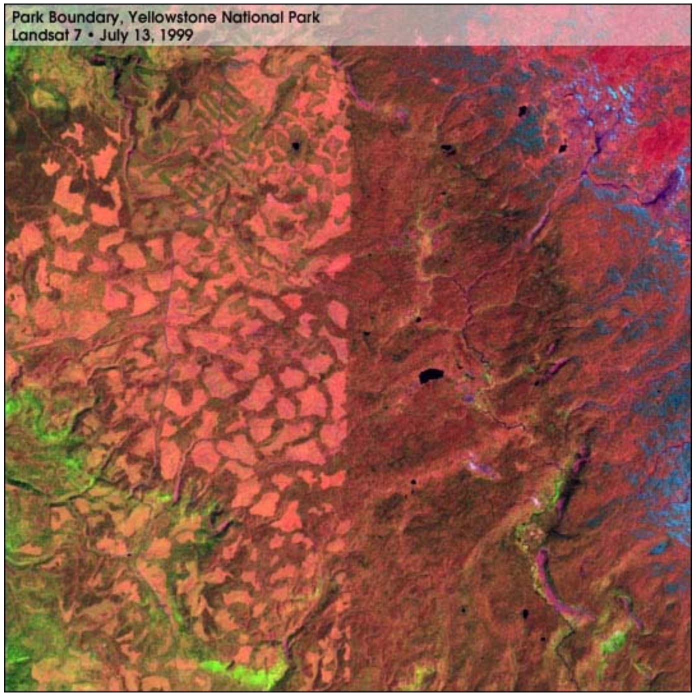

Streamflow network

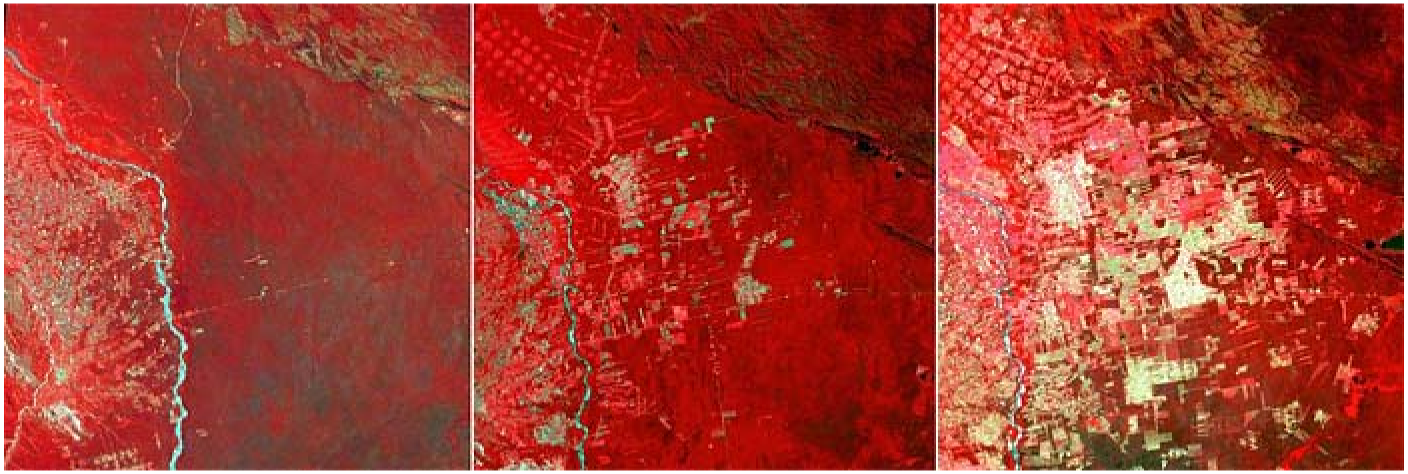



Soil moisture network

# Emergence of Elements of Landscape Ecology in the 1980s

- **Interactions across space**
- **Larger areas**
  - **New tools (air photos, satellite images, radio telemetry, networks of field measurements) allowed study of larger areas.**
  - **Quantification of large-scale human impacts**
  - **Watershed, regional , continental, global area issues: protected areas in a human matrix; Chesapeake Bay eutrophication, global $CO_2$**

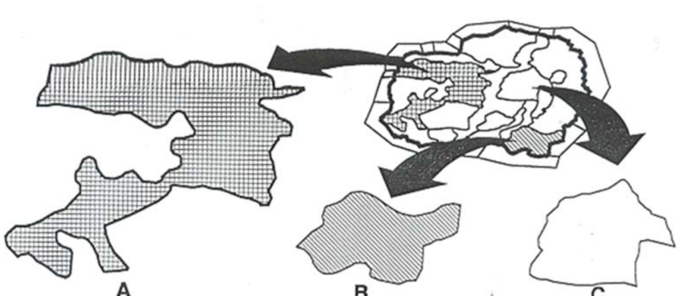


**LANDSAT » Deforestation in Bolivia from 1975 to 2000**

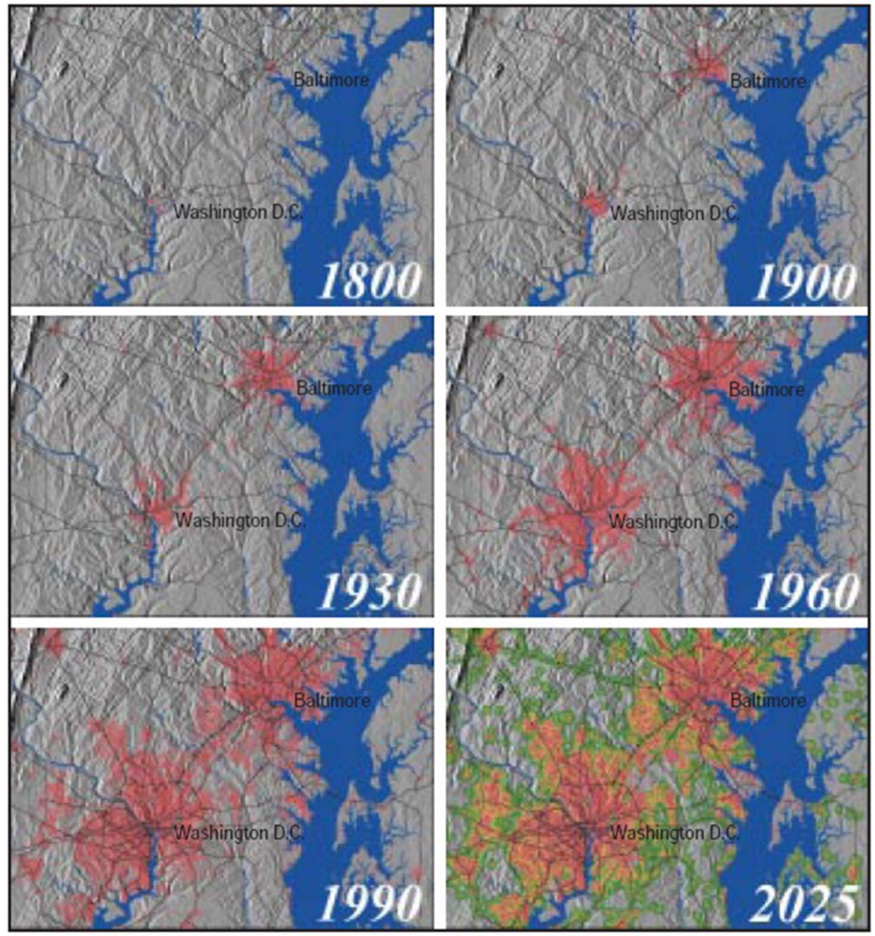
# Emergence of Elements of Landscape Ecology in the 1980s

- **Interactions across space**
- **Larger areas**
- **Quantitative methods**
  - **Metrics for quantifying spatial pattern: composition and configuration**
  - **Ways to measure movement**
    - Percolation theory
    - Circuit theory
    - And application to how to maintain connectivity among wildlands
  - **Spatial simulation models**
    - Protect alternative futures across large areas.




| | A | B | C |
|---|---|---|---|
| LID | NCVEG | NCVEG | NCVEG |
| PID | 104 | 400 | 200 |
| TYPE | MLS | COS | MGF |
| AREA | 51.33 | 16.83 | 18.59 |
| LSIM | 48.80 | 7.62 | 8.41 |
| PERIM | 6230 | 1922 | 1907 |
| EDGECON | 16.96 | 42.02 | 80.05 |
| SHAPE | 2.45 | 1.32 | 1.25 |
| FRACT | 1.33 | 1.26 | 1.25 |
| CORE | 6.46 | 2.35 | 4.62 |
| NCORE | 2 | 1 | 1 |
| CAI | 16.48 | 13.94 | 24.87 |
| NEAR* | 25.00 | 155.08 | 216.91 |
| PROXIM* | 200.34 | 2.38 | 0 |

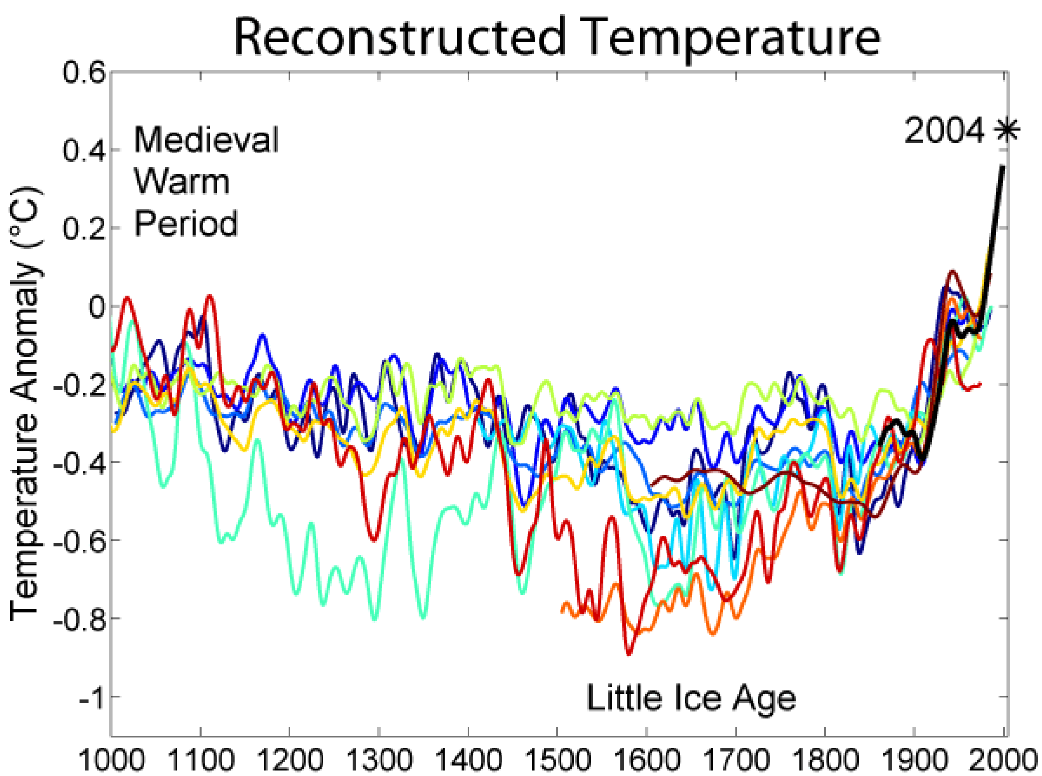
Figure 4. Example of FRAGSTATS patch indices for 3 sample patches drawn from a sample landscape. See text and Appendix for a description and definition of each metric. Indices with a '*' were computed using the raster version of FRAGSTATS.




This series of maps shows more than 200 years of urban growth in and around the Washington, D.C. area. The background in each map is a shaded-relief image. The red areas represent urban extent for each time period and the blue is Chesapeake Bay. Projections for 2025, made with a land use change model, show likely areas of new urban growth in yellow (high probability) and in greens (light green is moderate probability; dark green is low probability).

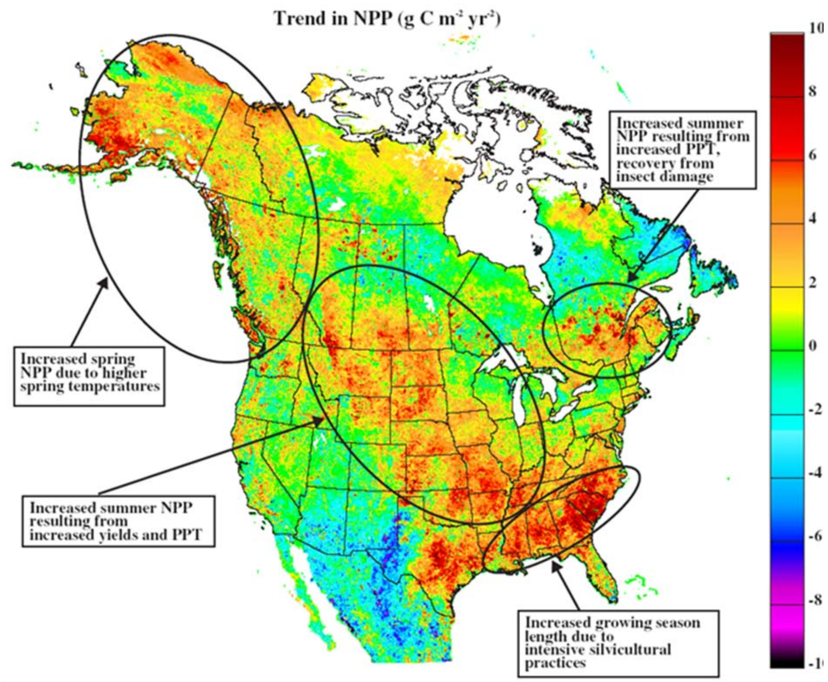
# Emergence of Elements of Landscape Ecology in the 1980s

- **Interactions across space**
- **Larger areas**
- **Quantitative methods**
- **Longer time periods**
  - **Paleoecology to go way back, long-term field measurements for past decades to century, simulation to project into the future**
  - **Application -how different are conditions now than at various times in the past? How much of the variation we see is natural vs human caused?**

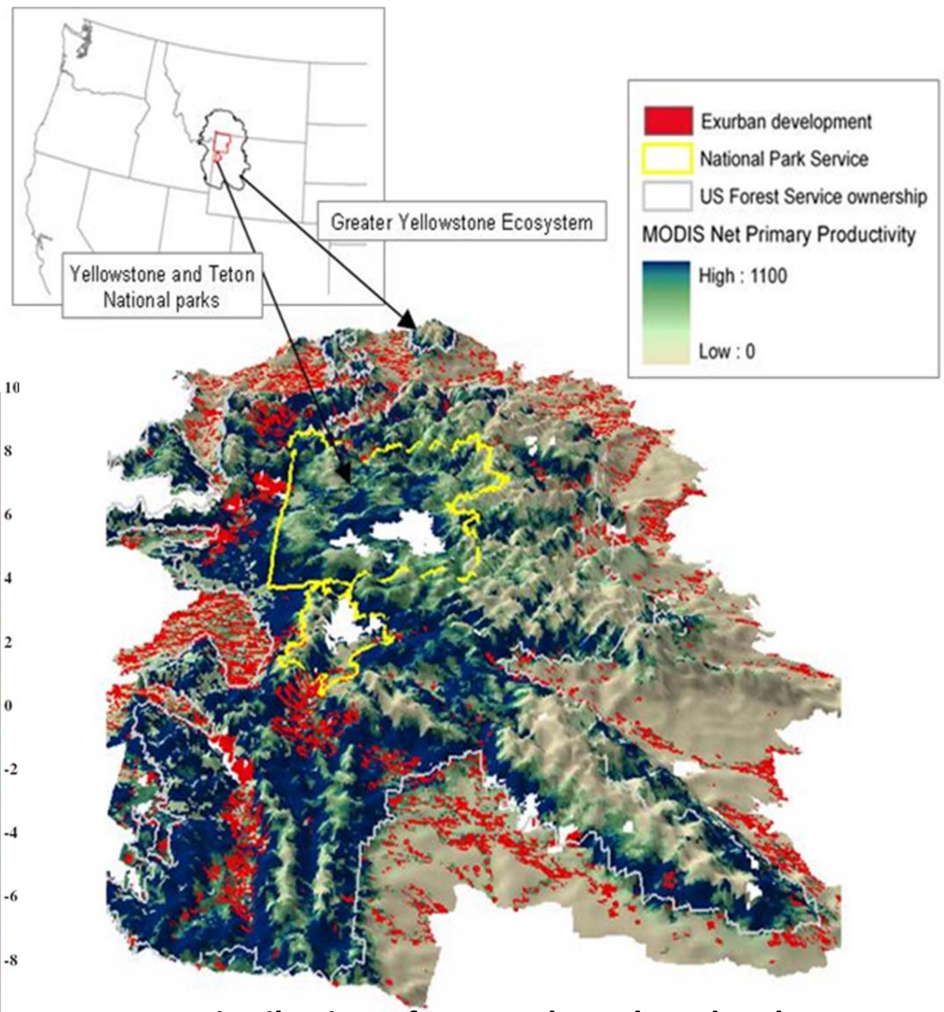


# Emergence of Elements of Landscape Ecology in the 1980s

- Interactions across space
- Larger areas
- Quantitative methods
- Longer time periods
- Place matters
  - Climate, soils, topography, biota differ from place to place.
  - Ecological processes and biodiversity vary accordingly.




Percentage increase in NPP (1982–1998)

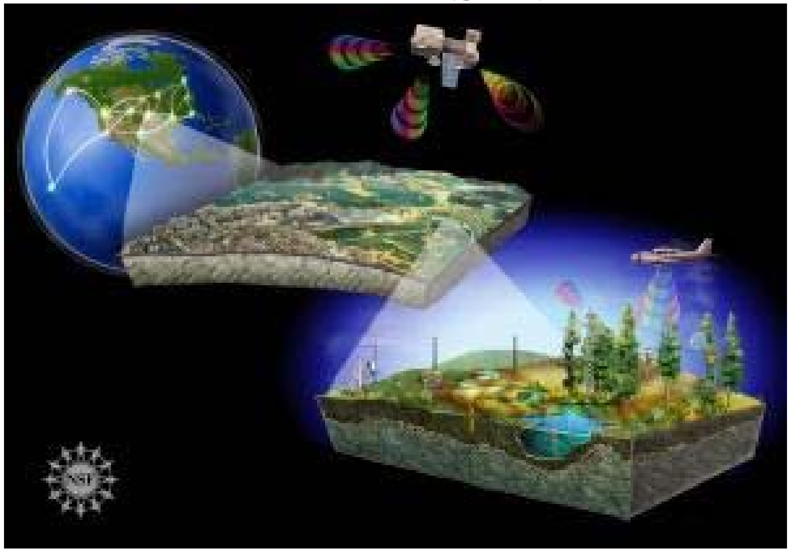



Distribution of NPP and exurban development across the Greater Yellowstone Ecosystem.

# Emergence of Elements of Landscape Ecology in the 1980s

- **Interactions across space**
- **Larger areas**
- **Quantitative methods**
- **Longer time periods**
- **Place matters**
- **Scale**
  - **Is “landscape” a scale as defined by grain and extent or a level of organization?**

**Scale – extent of are of interest and finest resolution of measurement (grain)**



**Levels of Organization**

**individual**

**population**

**community**

**ecosystem**

**landscape**

**biome**

**biosphere**

# Emergence of Elements of Landscape Ecology in the 1980s

- Interactions across space
- Larger areas
- Quantitative methods
- Longer time periods
- Place matters
- Scale
  - Is “landscape” a scale as defined by grain and extent or a level of organization?
  - What is the ‘right’ scale to address a particular ecological problem?

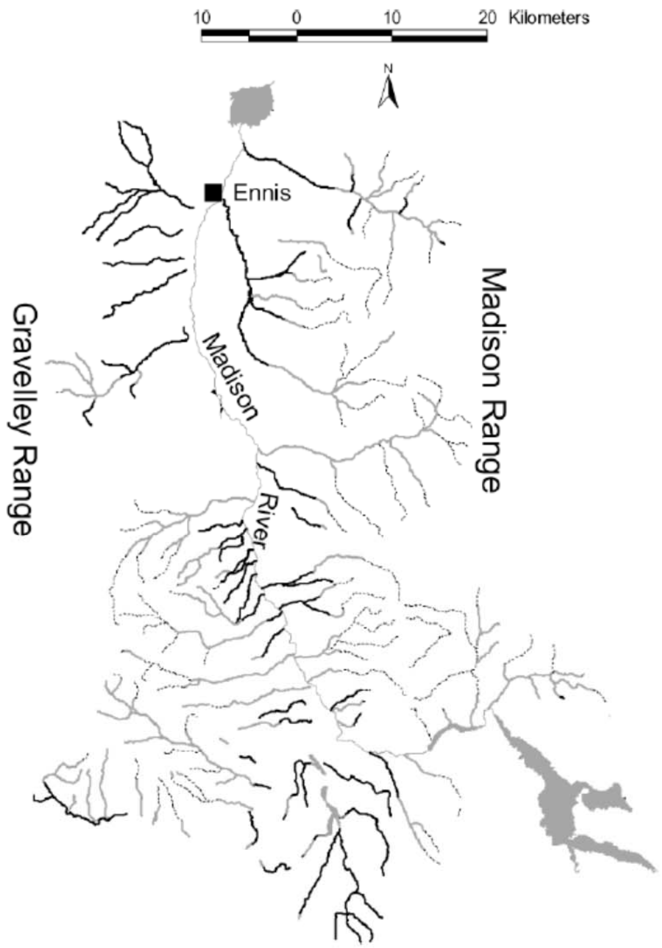
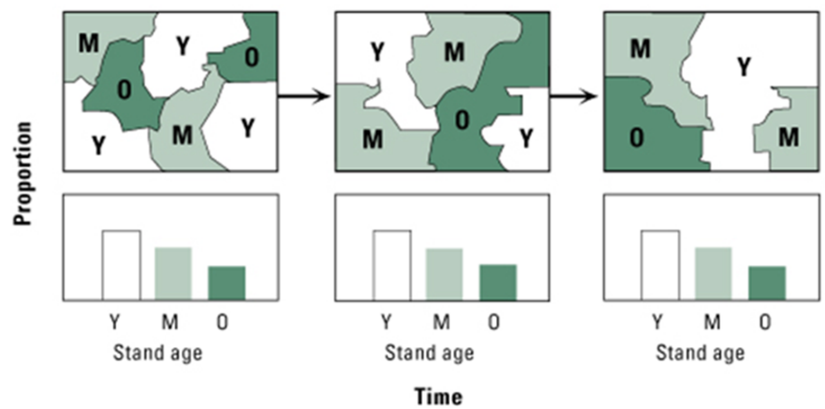



FIGURE 4.—Habitat suitability based on growth potential for age-0 westslope cutthroat trout in the Madison River basin (dark lines = highly suitable; broad gray lines = suitable; dotted black lines = unsuitable). Habitat suitability was not assessed for the Madison River itself (light gray line) or for the lower portions of major tributaries and spring creeks (not shown).

# Emergence of Elements of Landscape Ecology in the 1980s

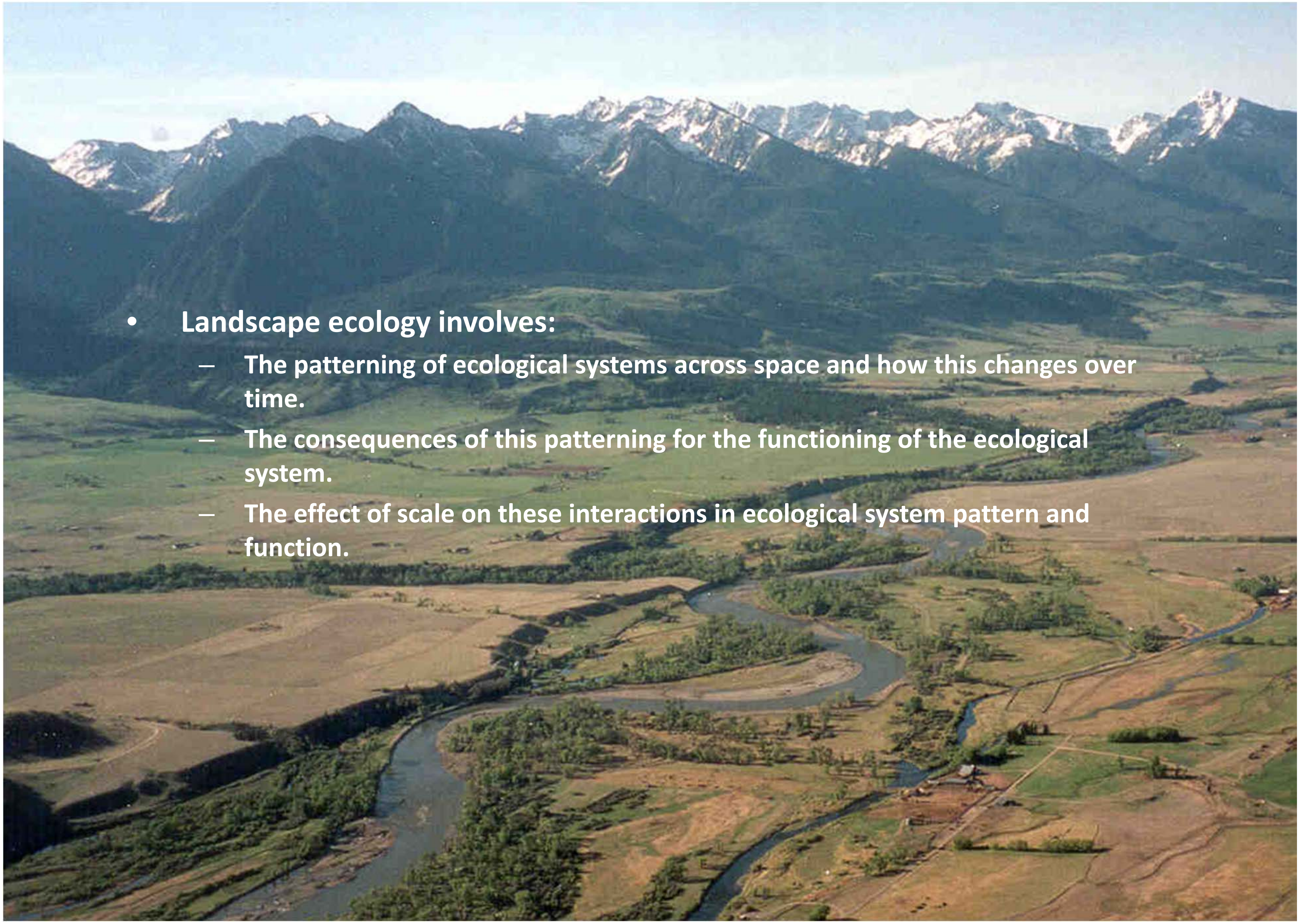
- Interactions across space
- Larger areas
- Quantitative methods
- Longer time periods
- Place matters
- Scale
- Equilibrium vs Disequilibrium
  - Perturbation at one scale may be equilibrium at a larger scale.
  - Notion of natural range of variation and application as a guide for management




Shifting Steady-State Mosaic - A landscape where the characteristics of individual patches are out of phase but the collective behavior of patches displays equilibrium.

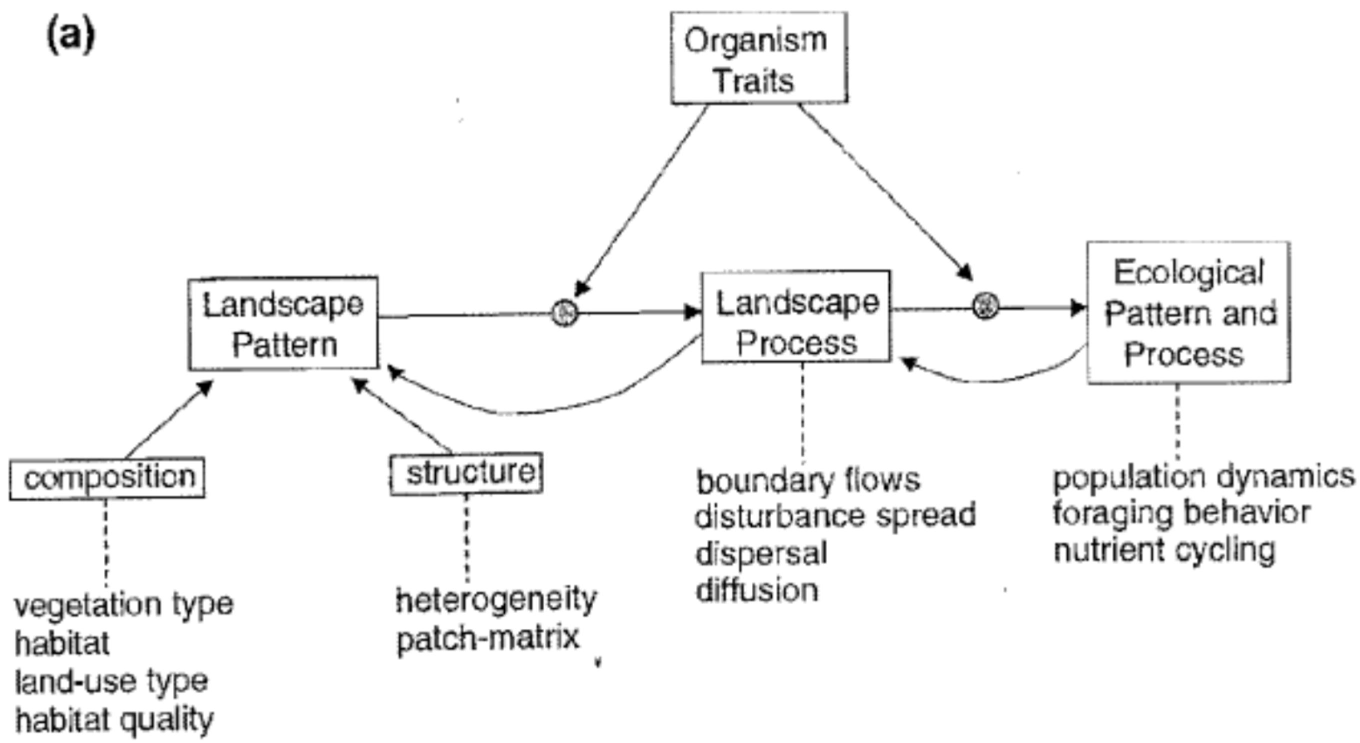
# Current Understanding of Landscape Ecology

# Current Understanding of Landscape Ecology



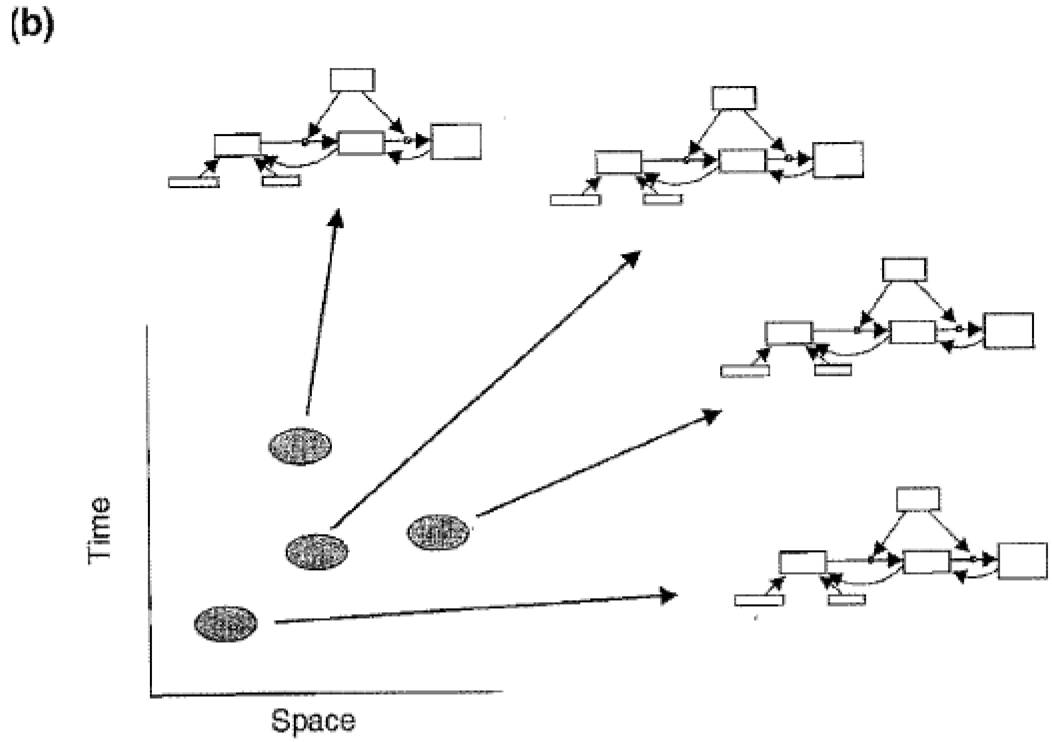
- Landscape ecology involves:
  - The patterning of ecological systems across space and how this changes over time.
  - The consequences of this patterning for the functioning of the ecological system.
  - The effect of scale on these interactions in ecological system pattern and function.

# Current Understanding of Landscape Ecology




**Elements of a framework for thinking about landscape effects on ecological systems (Wiens 2002).**

# Current Understanding of Landscape Ecology

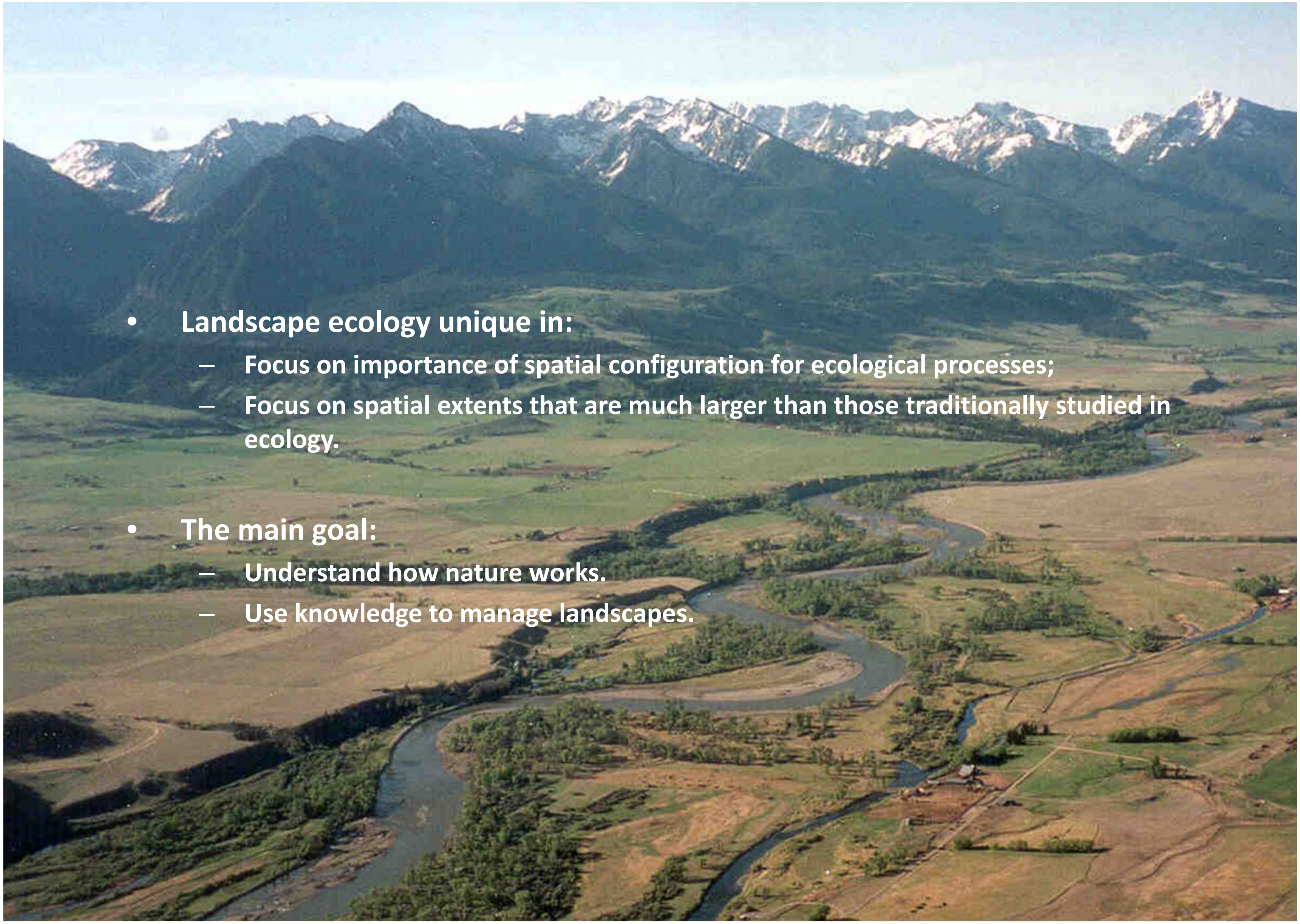



**Because all of the components of the web of spatial interactions shown in (a) may change with changes in scale, the resulting ecological patterns and processes that we study and attempt to manage will probably differ among different space-time scaling domains (shaded ellipses). (Wiens 2002).**

# Current Understanding of Landscape Ecology

- **Wiens 5 foundational concepts in landscape ecology**
  - **Landscape Elements Differ in Quality**
  - **Patch Boundaries Influence Ecological Dynamics Both Within and Among Patches**
  - **Patch Context Is Important**
  - **Connectivity Is a Key Feature of Landscape Structure**
  - **Spatial Patterns and Processes Are Scale-Dependent**

# Current Understanding of Landscape Ecology



- Landscape ecology unique in:
  - Focus on importance of spatial configuration for ecological processes;
  - Focus on spatial extents that are much larger than those traditionally studied in ecology.
- The main goal:
  - Understand how nature works.
  - Use knowledge to manage landscapes.

# Current Understanding of Landscape Ecology

- **Present Focus of Landscape Ecology (Turner 2005)**
  - **Conditions under which spatial pattern must be considered: when does space matter?**
  - **Understanding spatial dynamics: the linkage of space and time**
  - **Nonlinearities and thresholds: expecting the unexpected**
  - **Planning, managing, and restoring landscapes**

# Issues Now at the Forefront

- The continent or globe as a landscape.
  - NEON aimed at continental scale ecology
  - Global conservation strategy
  - Global carbon budgeting

- Accurate hindcasting and forecasting of spatial heterogeneous ecological systems

- Humans and ecosystems as coupled socio ecological systems
  - with feedbacks including human impacts on ecological systems, alteration of ecosystem services, effects on human well being

- Management of ecological and human systems under climate change

# Summary

## State of Ecology in the 1970s

- Largely based on levels of biotic organization
- Initial environmental awareness and applications
- Assumed "equilibrium" dynamics
- Puzzling problems arose that were inconsistent with traditional view.

# Summary

**Emergence of Elements of Landscape Ecology in the 1980s**

- Interactions across space
- Larger areas
- Quantitative methods
- Longer time periods
- Place matters
- Scale
- Equilibrium vs Disequilibrium

**Current Understanding of Landscape Ecology**

# Discussion

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**Is landscape ecology a distinct subdiscipline within ecology or simply mainstream ecology?**

**Levels of Organization**

**individual**

**population**

**community**

**ecosystem**

**landscape**

**biome**

**biosphere**