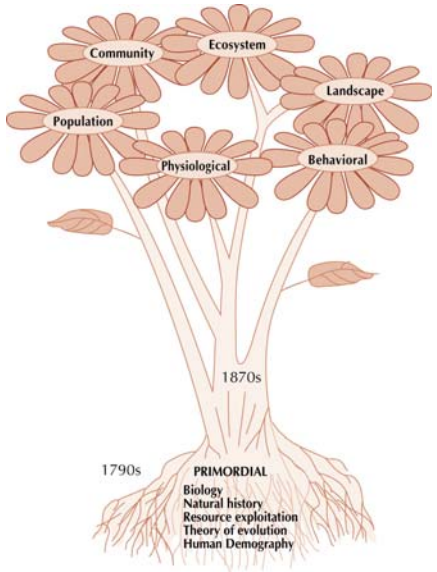
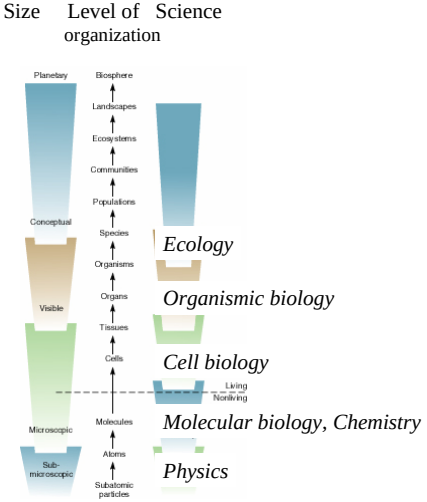
Large-scale ecology

- Landscape Ecology
  - ✓The study of landscape structures and processes
- Geographical Ecology
  - ✓Large-scale patterns of distribution and diversity of organisms
- Global Ecology
  - ✓Global processes and phenomena, e.g., global climate changes

Chapter 21
LANDSCAPE ECOLOGY





Chapter Concepts

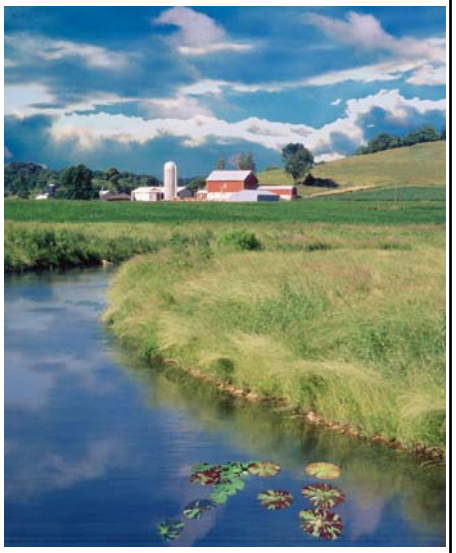
- Landscape structure includes size, shape, composition,number, and position of ecosystems within the landscape
- Landscape structure influences processes such as the flow of energy, materials, and species between the ecosystems within a landscape
- Landscapes are structured and change in response to geological processes, climate, organisms activities, and fire

Definitions

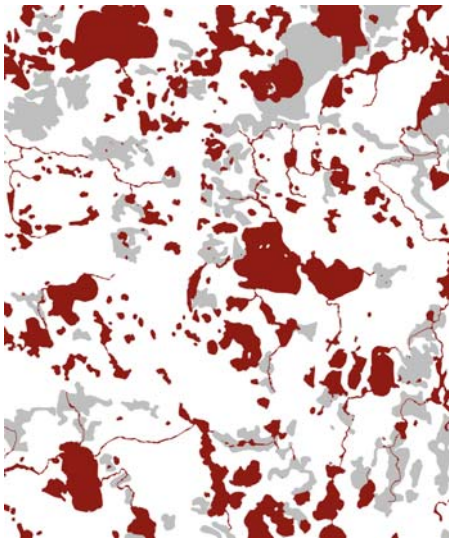
- *Landscape:* Heterogeneous area composed of several ecosystems
- *Landscape Elements:* Visually distinctive patches in an ecosystem
- *Landscape Ecology:* Study of landscape structure and processes (structure, function and changes)

Landscape Ecology

- What is Landscape Ecology?
- Questions?
- Role of model
- Techniques
- Examples and applications



- ✓ Land cover
- ✓ Patch
- ✓ Fragmentation
- ✓ Landscape element
- ✓ Shape, size, composition, number, position, connection



In a landscape view, ecosystems are more or less discrete elements called patches, which, together, form a mosaic pattern. In this photograph, patches of a deciduous forest ecosystem are separated by patches of pastureland. Besides their composition, patches can be described by number, size, shape, and position. Here, six to eight different forest patches range in size from a few trees to hundreds of trees, they have irregular to elongated shapes, and are concentrated in the right-hand portion of the scene

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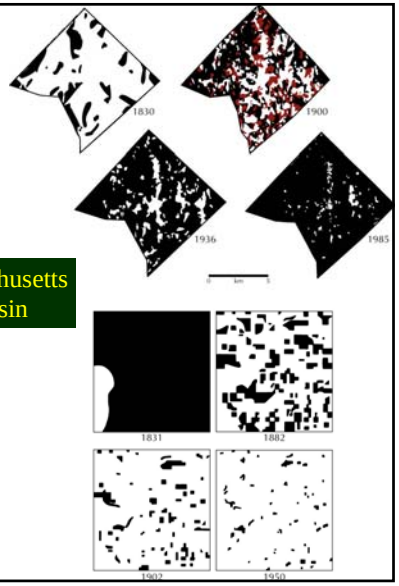
Examples:

New England's deforestation
Rapid recovery

Disturbance
- Event
- Regime

Massachusetts
Wisconsin



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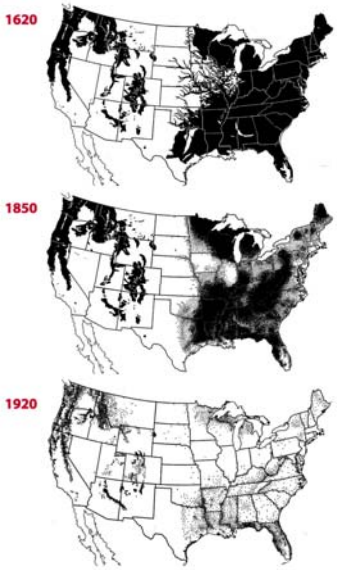
Forest cover changed over time



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Fire
Disturbance
Recovery

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Fire in Yellowstone National Park

- Create a spatial mosaic of vegetation patch

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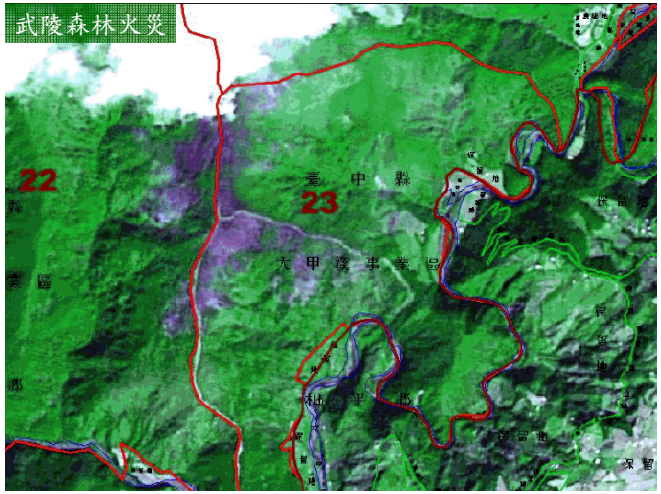

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What is Landscape Ecology?

- Study the causes and ecological consequences of *spatial patterns* in the environment, often over very large areas
- Examine the interaction between spatial pattern and configuration and ecological processes, i.e., the causes and consequences of *spatial heterogeneity* across a range of scales

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Landscape Ecology

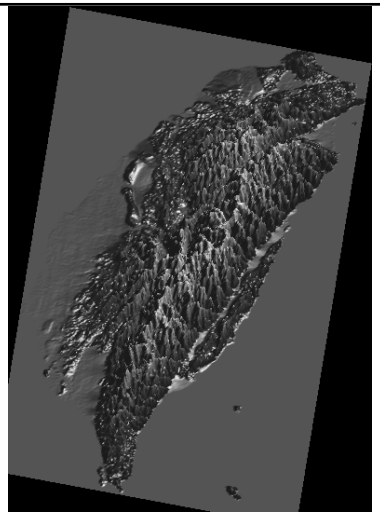
- Is the study of reciprocal effects of spatial pattern on ecological processes
- Promotes the development of models and theories of spatial relationships, the collection of new types of data on spatial pattern and dynamics, and the examination of spatial scales rarely addressed elsewhere in ecology

Spatial pattern

- The amount and configuration of *something* within an area (mosaic)

Heterogeneity

- Spatial
- Temporal
- Homogeneity



Development & History

- A long history in Europe – provides the foundation for most land use planning
- Rapidly expanding applications in North America - emerges from ecosystem ecology
- Human factors

Three major aspects

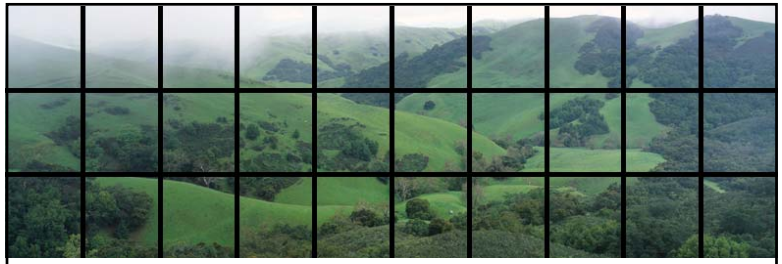
- Structure – the spatial pattern
- Function – interactions among the spatial element
- Change – dynamic change over long time periods

Landscape Structure

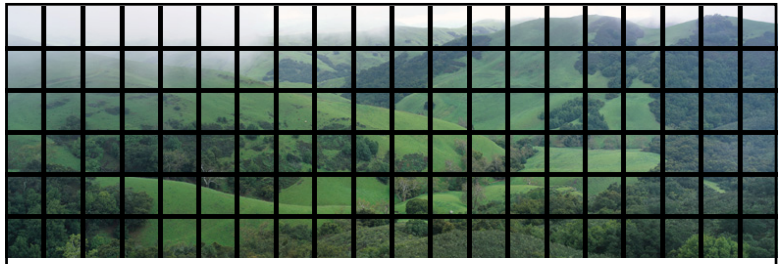
- *Bowen and Burgess* published quantitative analysis of several Ohio landscapes
  - ✓Quantified patch shape by ratio of patch perimeter to perimeter of a circle with an area equal to that of the patch

$$s = \frac{P}{2\sqrt{\pi A}}$$

S = Patch shape - Increasing value indicates less circular shape
P = Patch perimeter
A = Patch area

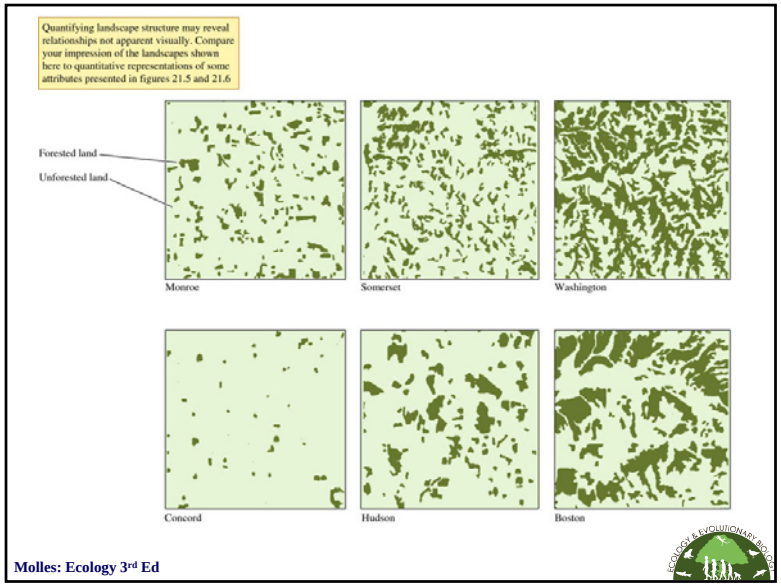


One common way to quantify a landscape is to identify land cover types and calculate their relative abundance. The fraction of an image or scene covered by a patch is called percent cover. You can make a rough estimate of percent cover by dividing a landscape into squares and counting them, then dividing by the total number of squares. Notice that you have to make decisions about squares that are not completely forested.



In practice, percent cover of a landscape is calculated from a map view, not an oblique view like this image, but the procedure is the same.

The size of the squares you use can affect the precision of the estimate. Using a grid with smaller squares would allow you to be more precise.



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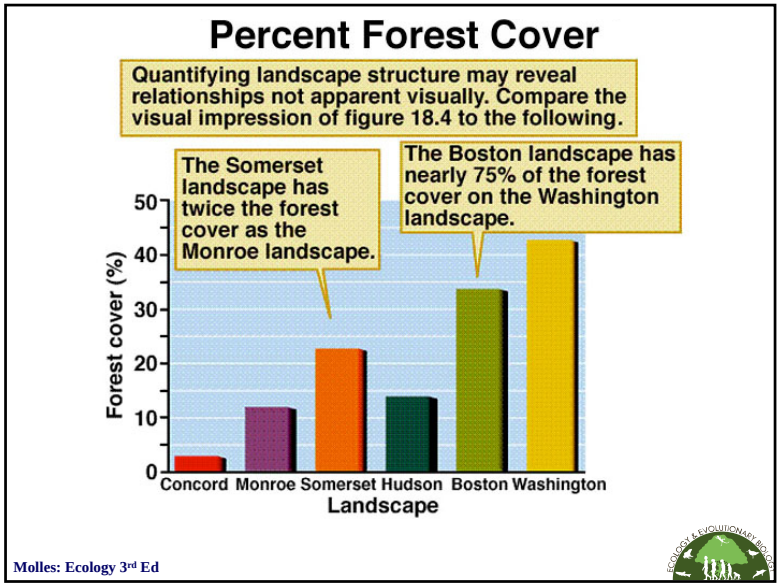

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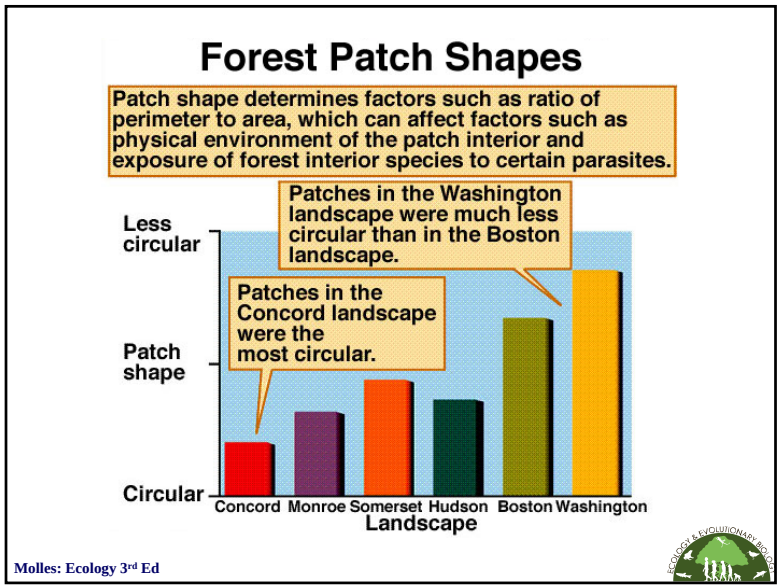

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Fractal Geometry of Landscapes

- Perimeter estimates of a complex shape depend on size of measuring device
  - ✓Smaller features may only show up with smaller measuring devices

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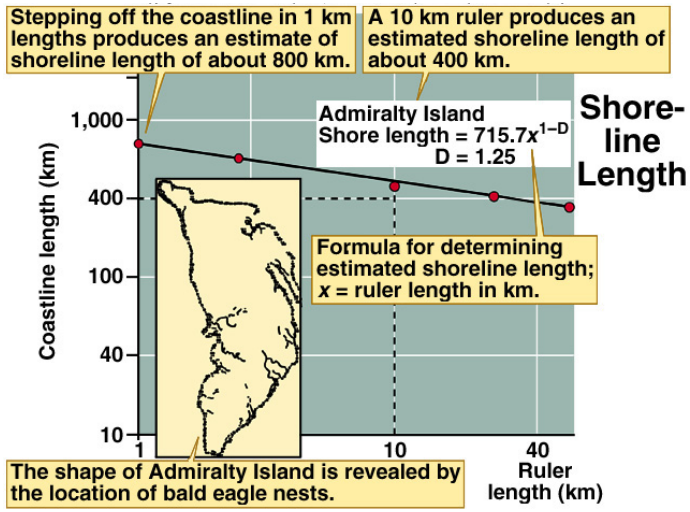
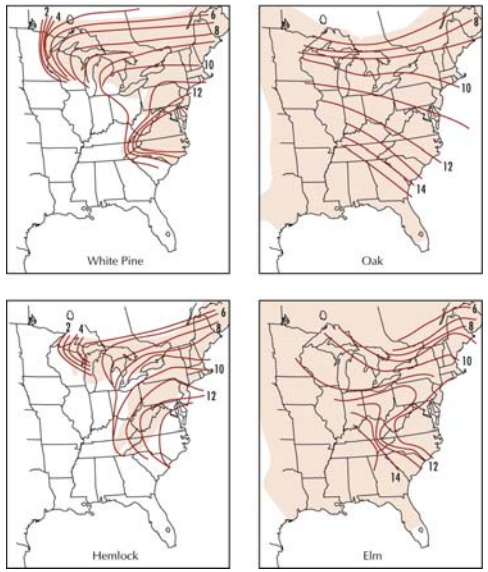
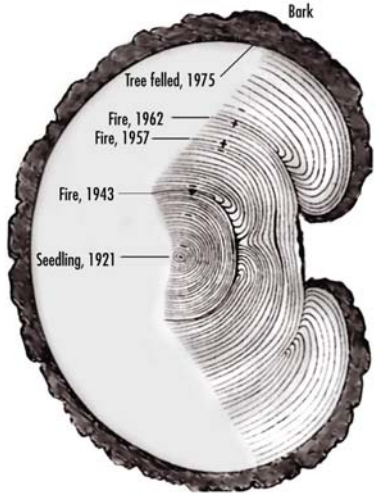


Causes of landscape patterns

- All landscapes have a history
- Climates
- Human activities
- Wildlife influence





Importance of scale

- Spatial scale
  - Grain – spatial resolution
  - Extent – the size of the study area
- Temporal scale

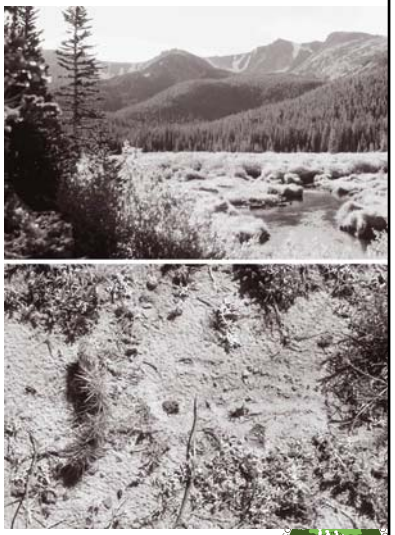
- What is the “right” scale?

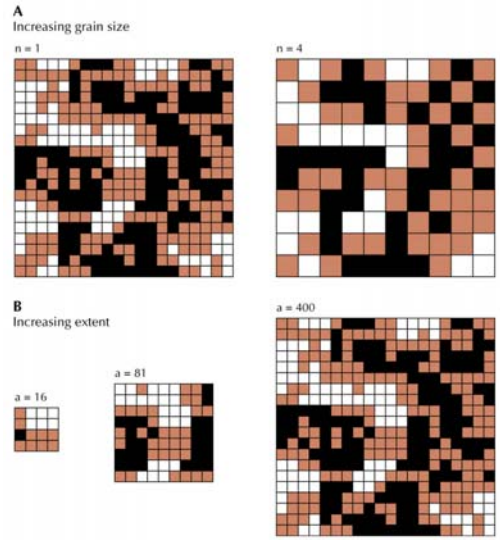
Compare

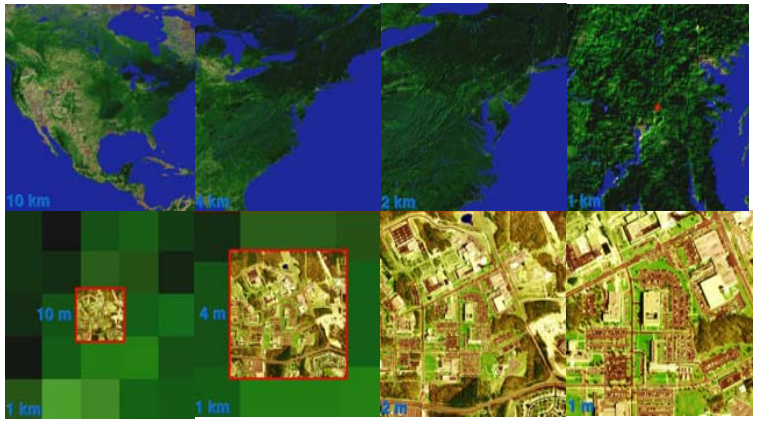
the scale of an eagle

and

the scale of an ant



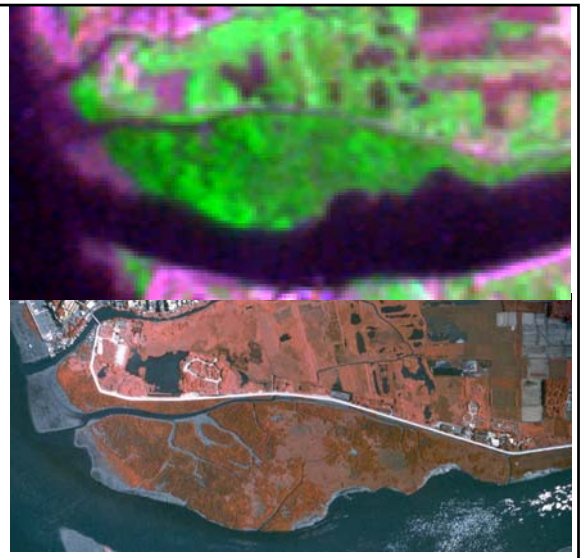


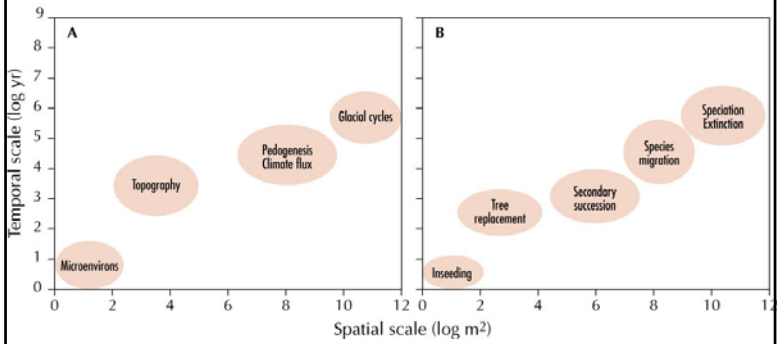


Spatial resolution

SPOT satellite image (12.5 m x 12.5 m)

Aerial photo (0.5 m x 0.5 m)





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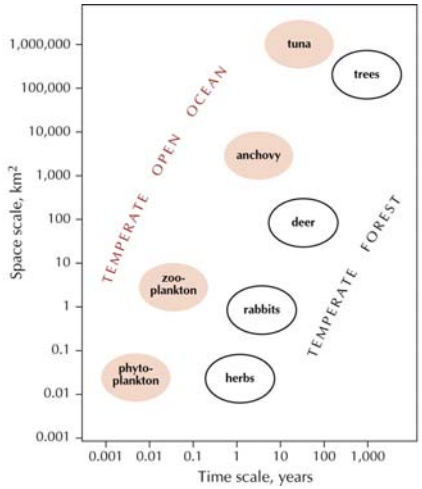

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How are patterns measured on landscapes?

- GIS (地理資訊系統)
- Data types – aerial photography, digital remote sensing, and airborne imaging scanner, published data and censuses
- Ground survey of vegetation and animal distribution

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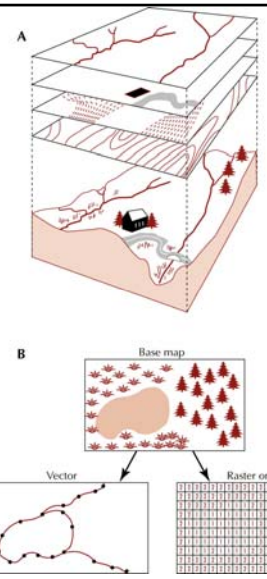
GIS

Vector vs raster data structure



Questions asked by landscape ecologists – some examples

- How does the spatial arrangement of habitat influence the presence and abundance of species?
- Does the surrounding landscape influence local populations?
- Do landscape patterns affect the transport of materials from land to water?
- How do ecosystem processes vary spatially?
- How are disturbances an integral part of landscapes?

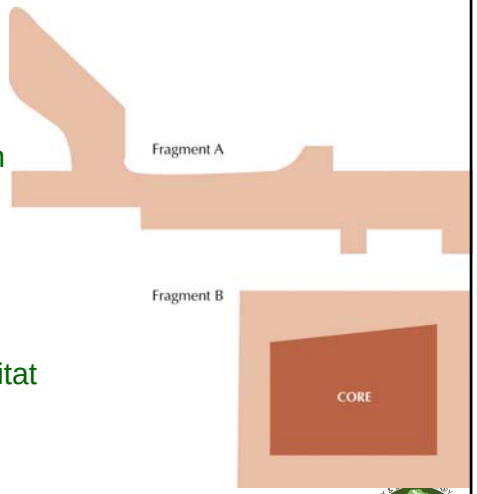
How does the spatial arrangement of habitat influence the presence and abundance of species?

- Patch size
- Habitat arrangement
- Suitable habitat
- Connectivity

Effect of patch size

Large vs. small patch variability
- Microclimate
- Habitat diversity
- Heterogeneity

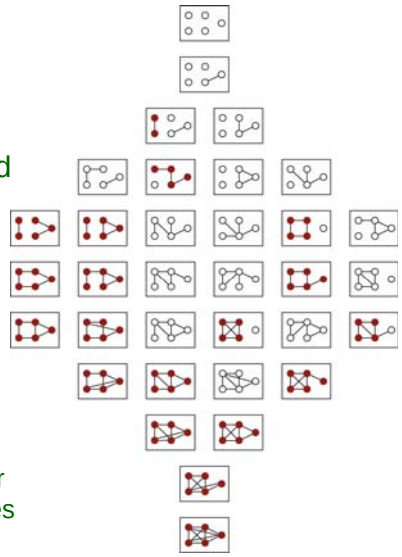
Edge vs. interior habitat
- Shape



Effect of habitat arrangement

- Corridor, e.g., fencerows of trees and shrubs
- Locally extinct
- Rate of recolonization

Simulation study:
Isolated patch – died out easier
Population size in Square/pentagonal > line/triangle (offered fewer opportunities of exchanges of organisms)



Effect of habitat arrangement

- Source and sink patches
- Sources (local birth rate > mortality rate)
- Sink patch (local birth rate < mortality rate)
- Maintain equilibrium (constant population size)
- Key source patches

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Identifying suitable habitat

- The suitable habitats for a particular species depend on a variety of factors
- Example – Eastern timber wolf

  vegetation type, deer density (prey), land ownership class, road density, human population density

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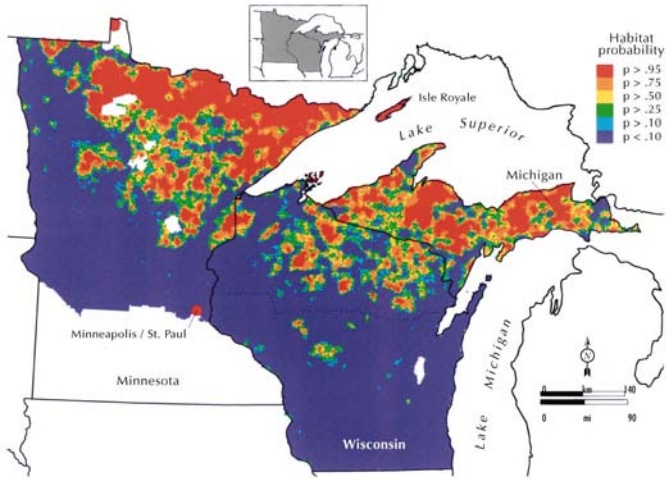

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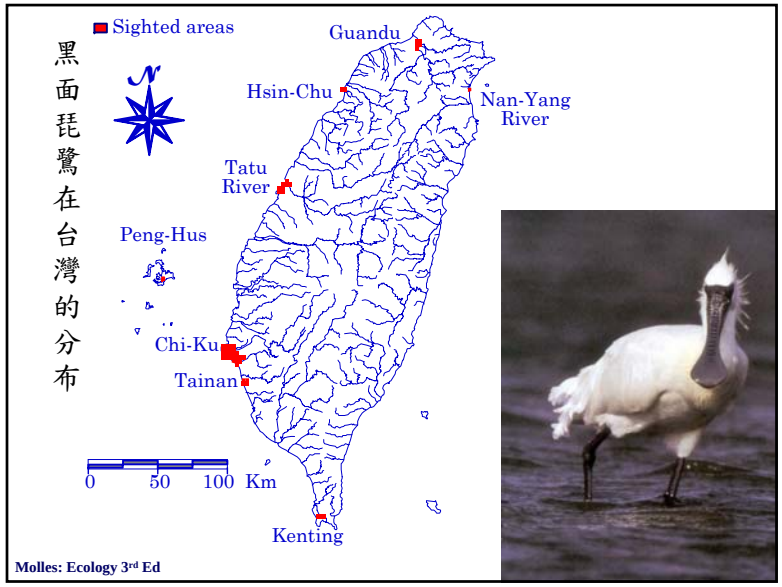
黑面琵鷺在台灣的分布
Sighted areas
Guandu
Hsin-Chu
Nan-Yang River
Tatu River
Peng-Hus
Chi-Ku
Tainan
0 50 100 Km
Kenting
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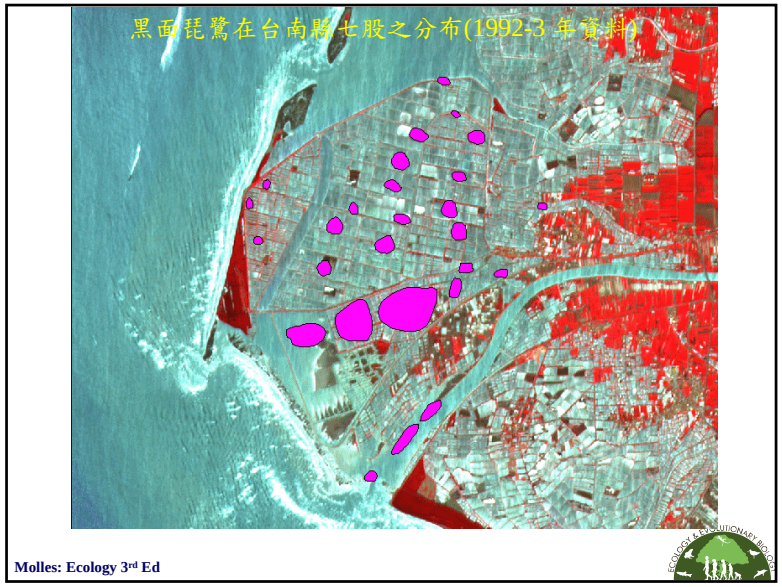
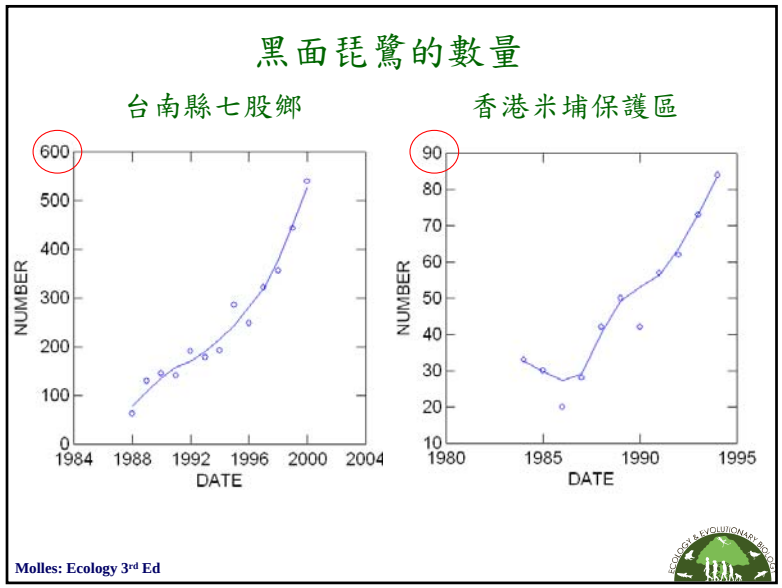

黑面琵鷺在台南縣七股之分布(1992-3 年資料)
Molles: Ecology 3rd Ed


黑面琵鷺的數量
台南縣七股鄉
香港米埔保護區
NUMBER
DATE
600
500
400
300
200
100
0
1984 1988 1992 1996 2000 2004
90
80
70
60
50
40
30
20
10
1980 1985 1990 1995
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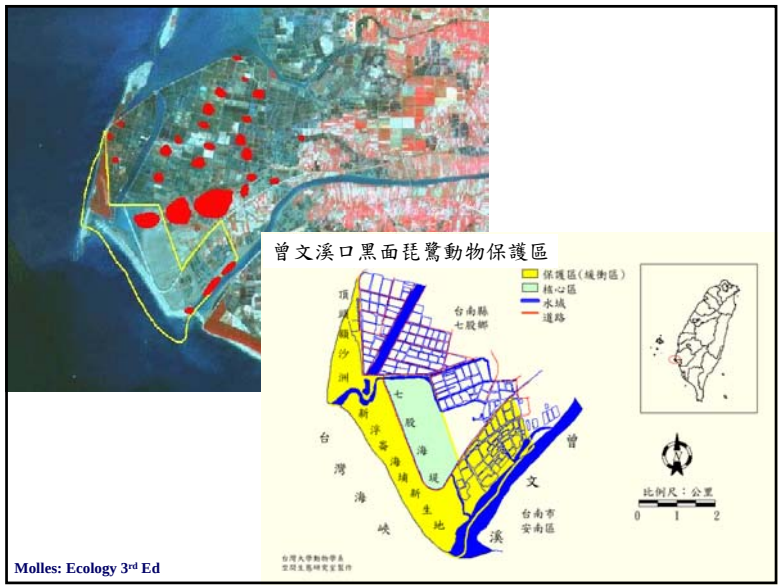
曾文溪口黑面琵鷺動物保護區
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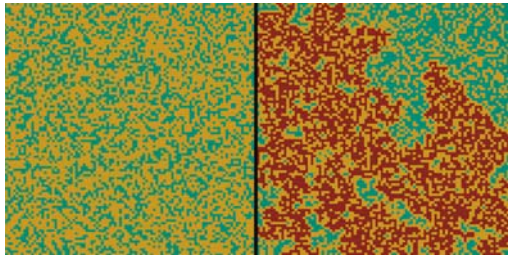
Habitat connectivity

- Threshold dynamic – abundance and spatial arrangement of habitat & dispersal capabilities of organism



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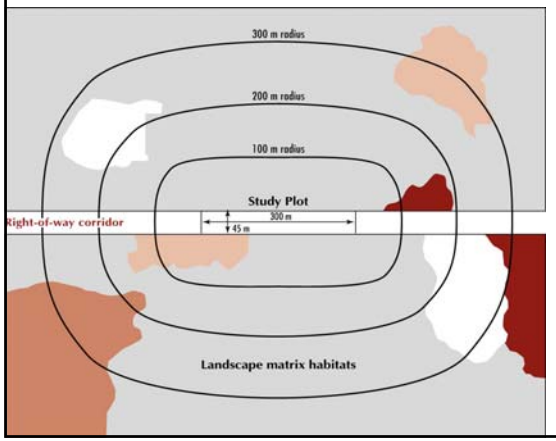
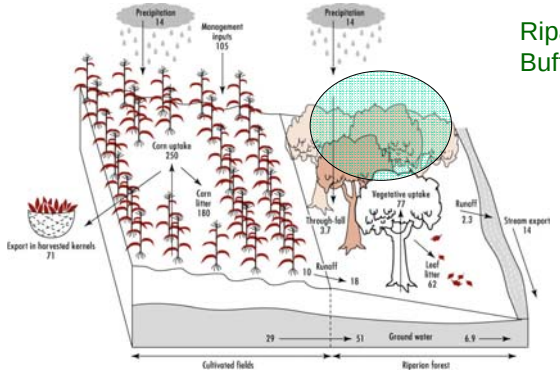
Does the surrounding landscape influence local populations? – landscape context



What happens in small areas may be influenced considerably by the surrounding landscape

Do landscape patterns affect the transport of materials from land to water?



Riparian trees
Buffer zone

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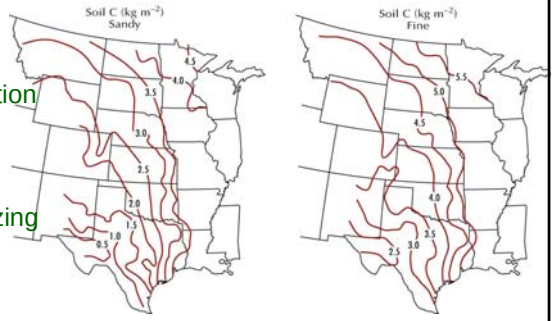
How and why do ecosystem processes vary spatially?

- Climate
- Natural gradient
- Landscape position
- Agricultural management
- Animal activities (e.g., beaver, grazing animals)



Pattern of soil C levels in the top soil in sandy (left) and fine-textured (right) soils in the mid-West

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How are disturbances an integral part of landscapes?

- Disturbance is a major agent of pattern formation and the source for the maintenance of ecosystem function (e.g., fire, hurricane and typhoon)
- Natural disturbance both create and respond to landscape pattern
- Intentional or unintentional shifts in the disturbance regime may dramatically alter the landscape
- Example: the management of Gandau Nature Park and Nature Reserve

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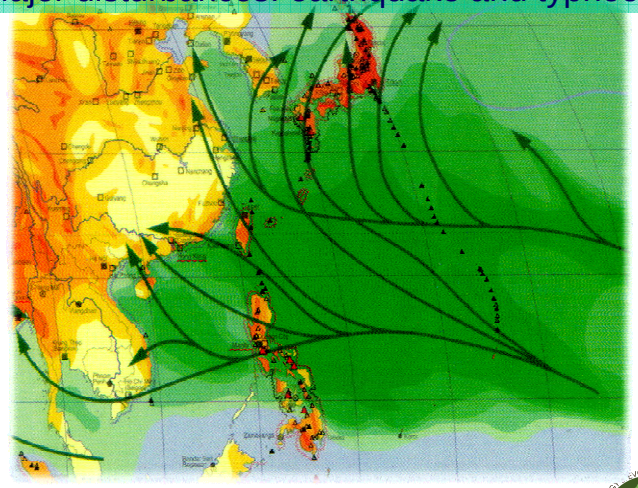
Major disturbances: earthquake and typhoon



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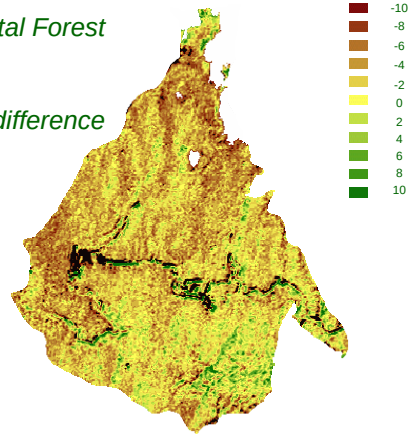
Typhoon Fred - August 19~21, 1994

Fushan Experimental Forest

Two SPOT images
NDVI (normalized difference vegetation index



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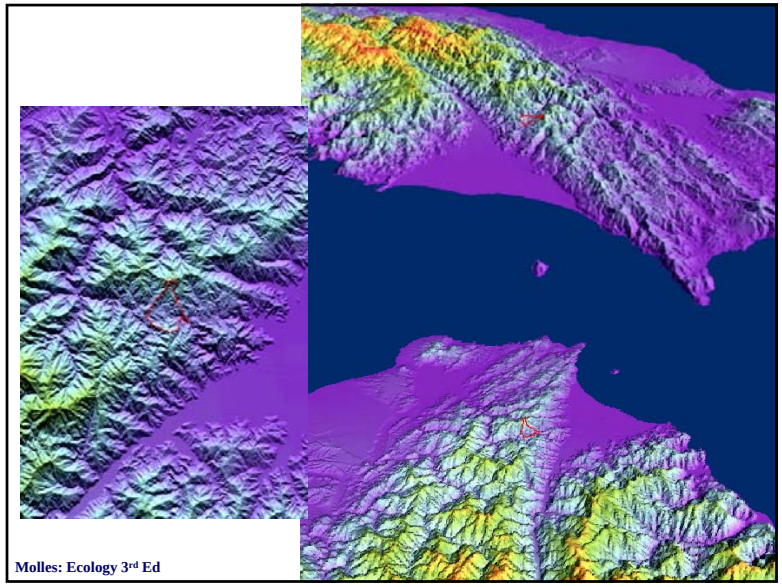

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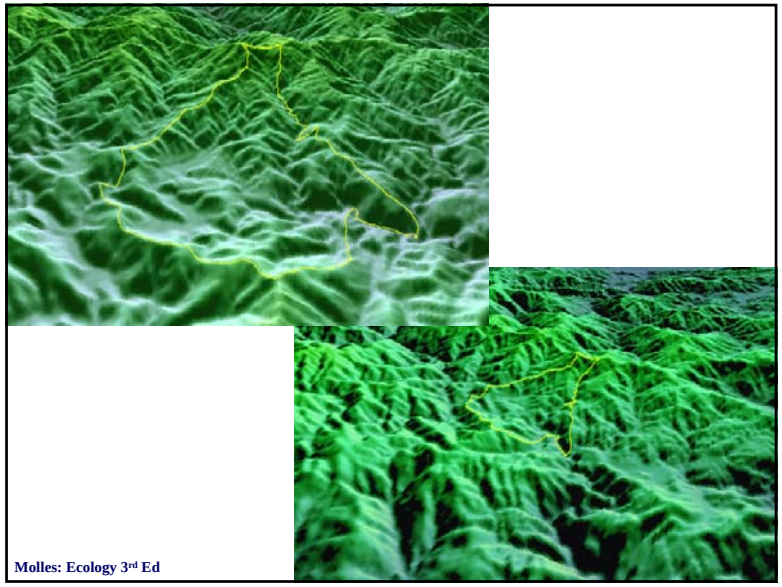

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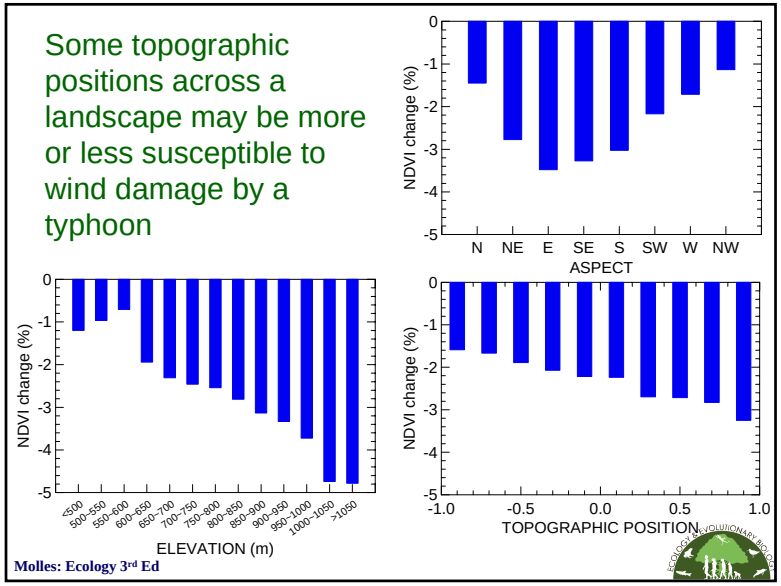
Some topographic positions across a landscape may be more or less susceptible to wind damage by a typhoon



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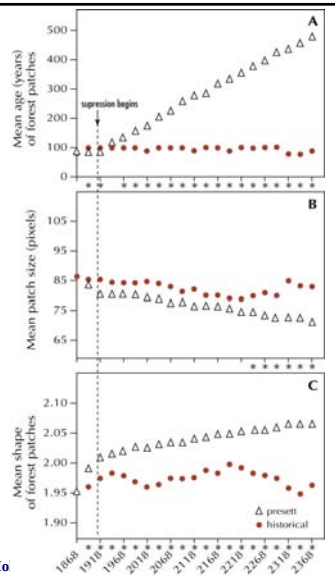
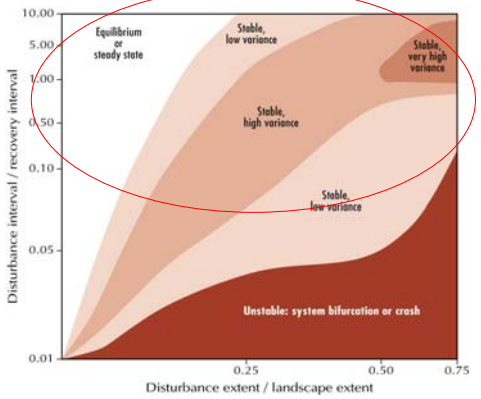


Simulation study

Time lag
Fire suppression effect on landscape

Mo

- Gap formation and generation
- "Shifting mosaic"

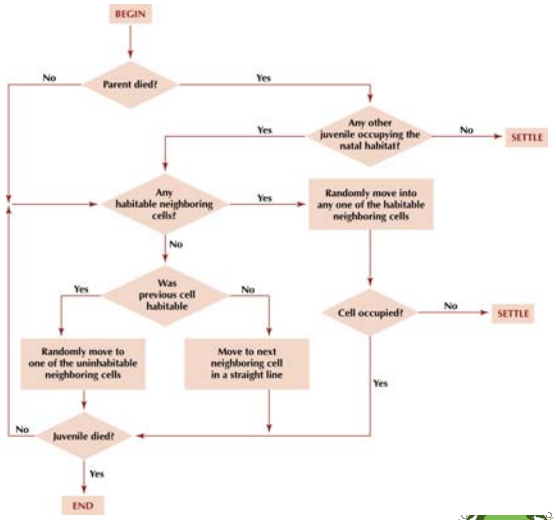


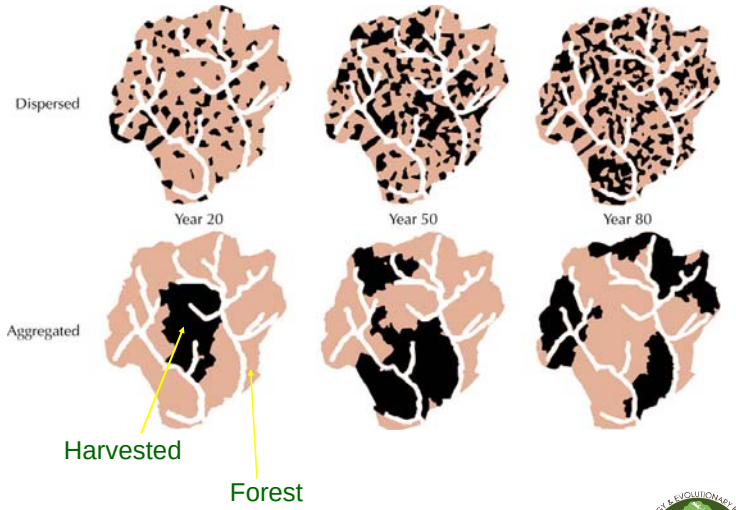
Role of models

- Summarize and integrate previous results
- Generate and test new hypothesis
- Suggest insights into the relationships between landscape patterns and ecological processes
- Experimental approach, Comparative data, Studies of large scale effect - Provide new insight for empirical study
- *Spatially explicit*

Flow diagram:

Dispersal of Bachman's sparrow





Techniques specific to Landscape Ecology

- Computer
- GIS and large database
- Broad-scale field studies
- Spatial data
- Model
- Simulation

Applications

- Ecosystem management and land-use planning (ecological systems as functional units & long term sustainability & alternative scenarios)
- Habitat fragmentation and the conservation of biodiversity (island biogeography, reserve design guidelines)
- Global climate change

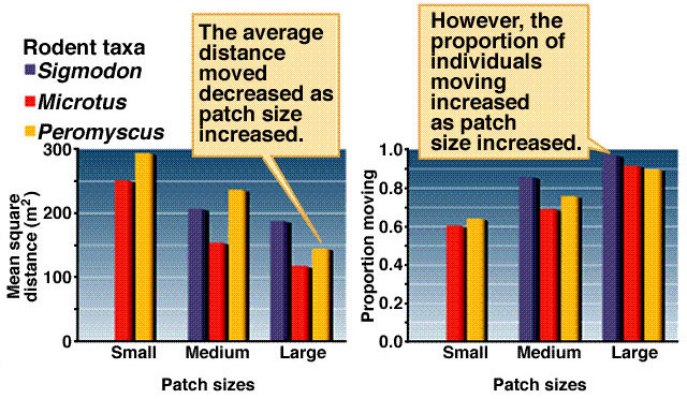
Landscape Structure and Dispersal of Small Mammals

- Ecologists have proposed landscape structure can influence movement of organisms between potentially suitable habitats
  - ✓Metapopulations: pops. of many species occur in spatially isolated patches, with significant exchange of individuals
    - Rate of movement of individuals between subpopulations can affect species persistence in a landscape

Landscape Structure and Dispersal of Small Mammals

- *Diffendorfer et. al.* studied how patch size affects movement of three small mammal species
  - ✓Predicted animals would move farther in more fragmented landscapes
    - Must move farther to obtain resources
  - ✓Predicted animals would stay longer in more isolated patches

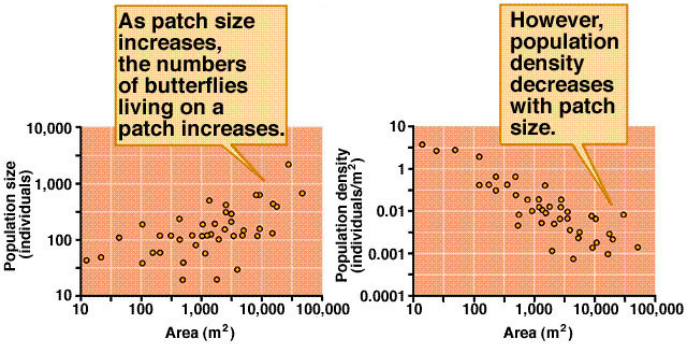
Patch Size and Mammal Movement



Habitat Patch Size and Isolation and Density of Butterfly Populations

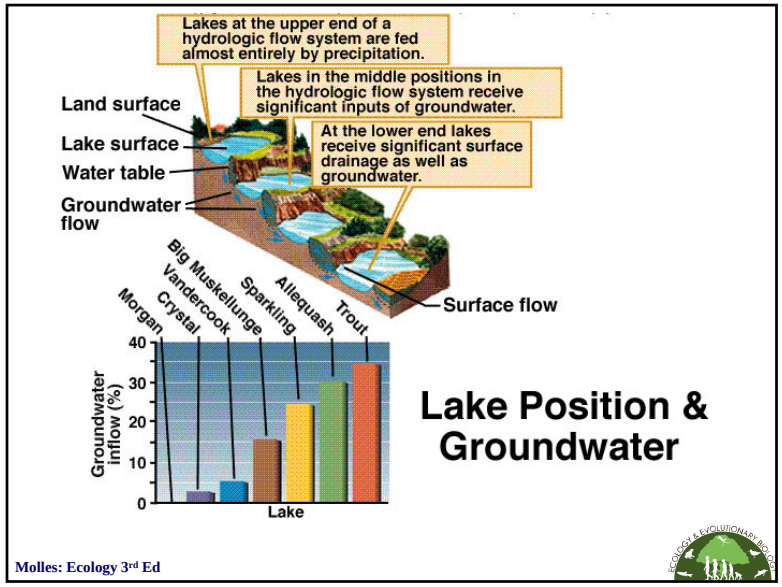
- *Hanski et al*. found butterfly density significantly affected by size and isolation of habitat patches
  - ✓Population size within patch increased with patch area
  - ✓Population density decreased as patch area increased
  - ✓Isolated patches had lower butterfly densities
    - Pop. partially maintained by immigration

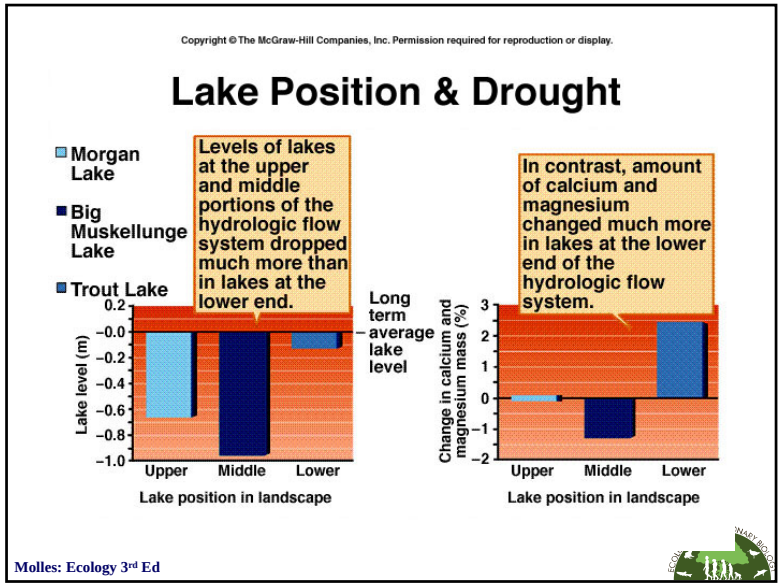
Habitat & Population



Landscape Position and Lake Chemistry

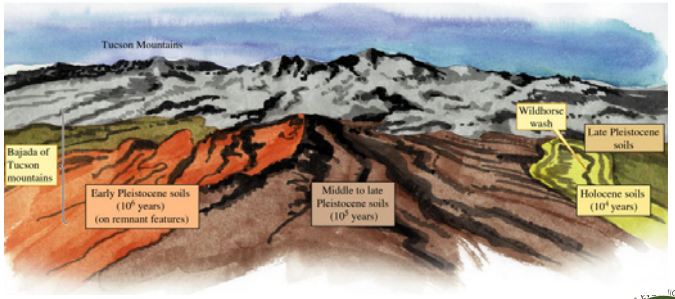
- *Webster* explored how lake position in a landscape affected chemical responses to drought
- Lake position in landscape determined portion of water received as groundwater
  - ✓Upper lakes dropped more than lower lakes
    - Concentration of dissolved ions increased most at upper and lower ends





Origins of Landscape Structure and Change

- Geological processes such as volcanism, sedimentation, and erosion are primary source of landscape structure.



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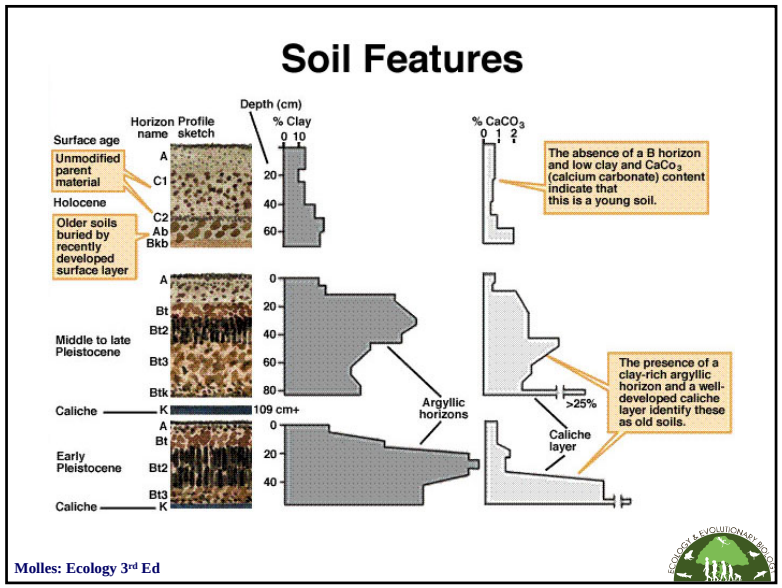
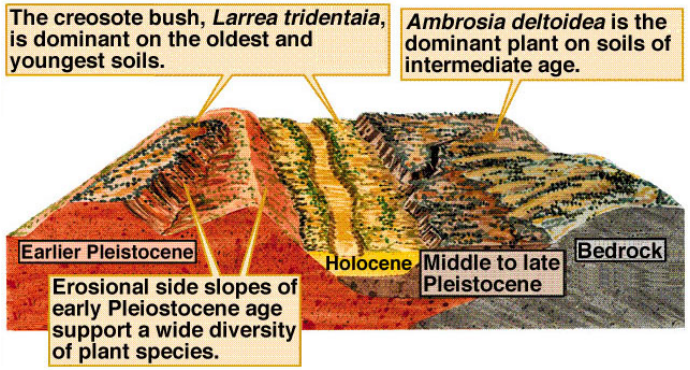


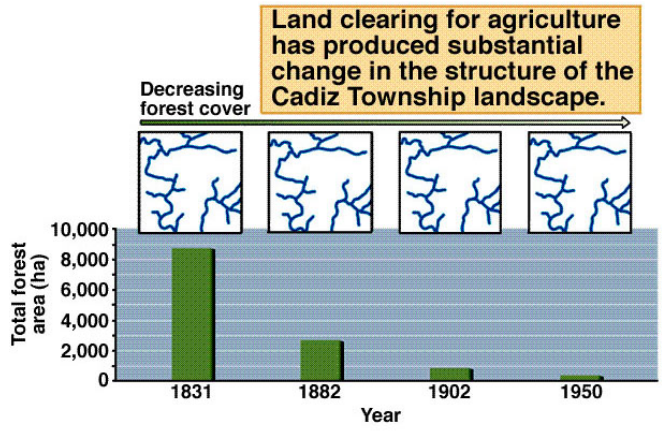
Soil and Vegetation Mosaics In Sonoran Desert

- *McAuliffe* showed bajadas in Sonoran Desert are complex mosaic of distinctive landforms
  - ✓ Found wide range of soil types and plant distributions that correspond closely to soil age and structure
    - Soil structure influences perennial plant distributions
      - Plant distributions map clearly onto soils of different ages

Vegetation & Soil Factors

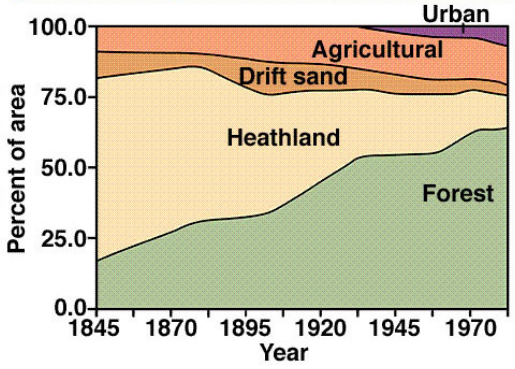


Forest Cover Change



Dutch Landscape Change

The most substantial change in this landscape in the Netherlands was a shift from predominantly heathland to predominantly forest.



Climate and Landscape Structure

- *McAuliffe*: soil mosaics consisted of patches of material deposited during floods originating in nearby mountains
  - ✓Materials eroded from mountain slopes and deposited as alluvium on surrounding bajadas
    - Alluvial deposits gradually changed; dependent upon climate
      - Different soils – plant types

Organisms and Landscape Structure

- Many studies have focused on conversion of forest to agricultural landscapes
  - ✓Eastern NA, many abandoned farms have reverted to forest, thus forest cover has increased
    - Similar patterns in parts of Europe

Organisms and Landscape Structure

- *Hulshoff* – Found forest and heathland coverage changed over time as well as number and average area of patches
  - ✓Cadiz Township - agricultural economy converted area from forest to farmland
    - Economy collapsed in response to introduction of synthetic fertilizers and inexpensive imported wool

Animal Modification on Landscape Structure (see figures)

- African Elephants knock down tress while feeding
  - ✓Change woodland to grassland
- Kangaroo Rats dig burrow systems that modify soil structure and plant distributions
- Beavers cut trees, build dams and flood surrounding landscape
  - ✓At one time, modified nearly all temperate stream valleys in Northern Hemisphere

Animal Modification of Landscape Structure

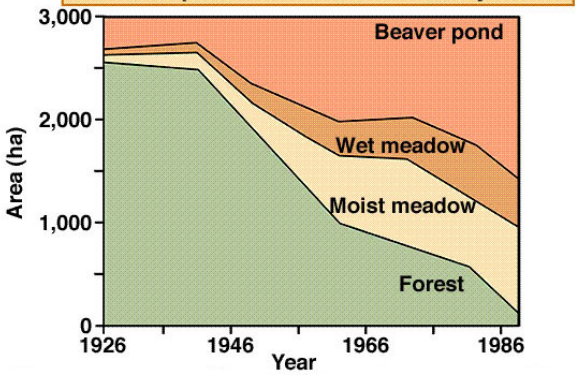
- *Johnston and Naiman* documented substantial effects of beavers on landscape structure
  - ✓Over 63 yr period, area of new ecosystems created by beavers increased from 200 ha to 2,661 ha
  - ✓Changed boreal forest landscape to complex mosaic

Animal Modification of Landscape Structure

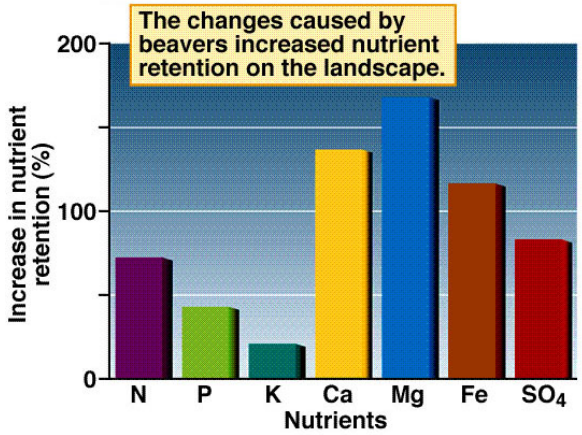
- Beaver activity between 1927-1988 increased quantity of most major ions and nutrients in impounded areas.
- Three possible explanations:
  - ✓Impounded areas may trap materials
  - ✓Rising waters captured nutrients formally held in vegetation
  - ✓Habitats created by beavers may promote nutrient retention by altering biogeochemical processes

Landscape Change by Beaver

From 1927–88, beavers transformed this landscape from one dominated by forest to a diverse patchwork of several ecosystems.



Nutrient Retention & Beavers



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Fire and Structure of a Mediterranean Landscape

- *Minnich* used satellite photos to reconstruct fire history of S. CA and N. Baja (1971-80)
  - ✓Landscape consisted of patchwork of old and new burns
  - ✓Similar climates with deviated fire histories:
    - Fire suppression in S. CA allowed more biomass accumulation and resultant large fires
      - Small burns more frequent in N Baja
        - Other factors ?

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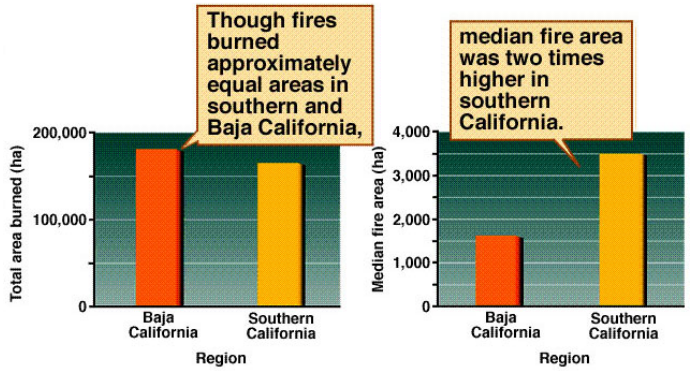
Baja Fire Characteristics



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南台灣銀合歡30年之變遷

- 從1976至2003年，約每10年，以遙測影像判釋銀合歡的覆蓋率
- 遙測影像
  - ✓1976、1986、1996年使用航空照片
  - ✓2002與2003年使用QuickBird與SPOT衛星影像
- 覆蓋率分成四個等級(<25%, 25-50%, 50-75%, >-75%)

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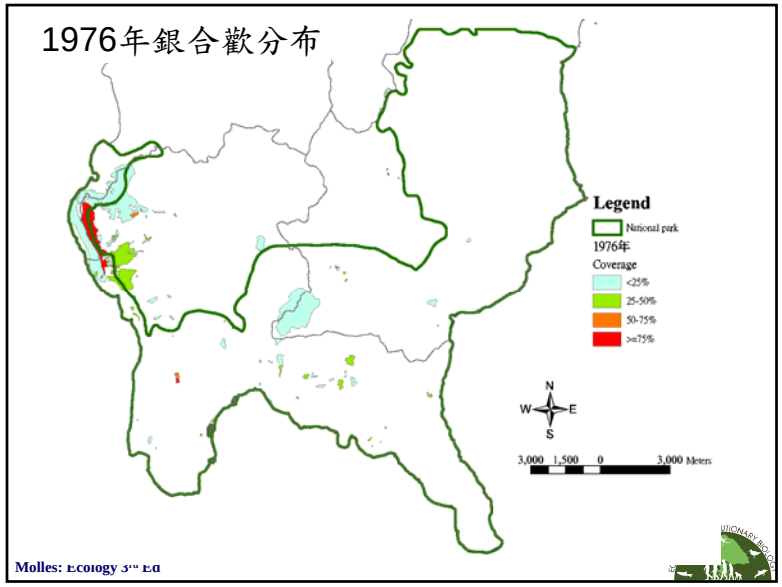
1976年銀合歡分布
Legend
National park
1976年
Coverage
<25%
25-50%
50-75%
>=75%
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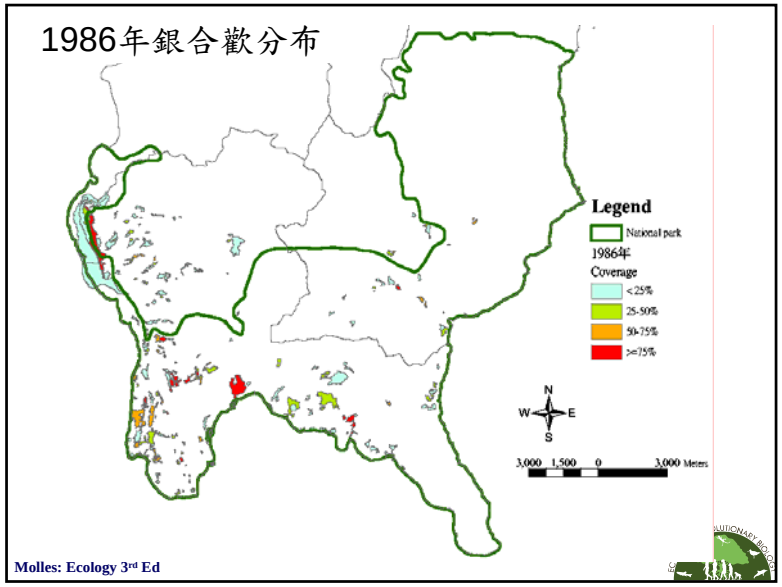
1986年銀合歡分布
Legend
National park
1986年
Coverage
<25%
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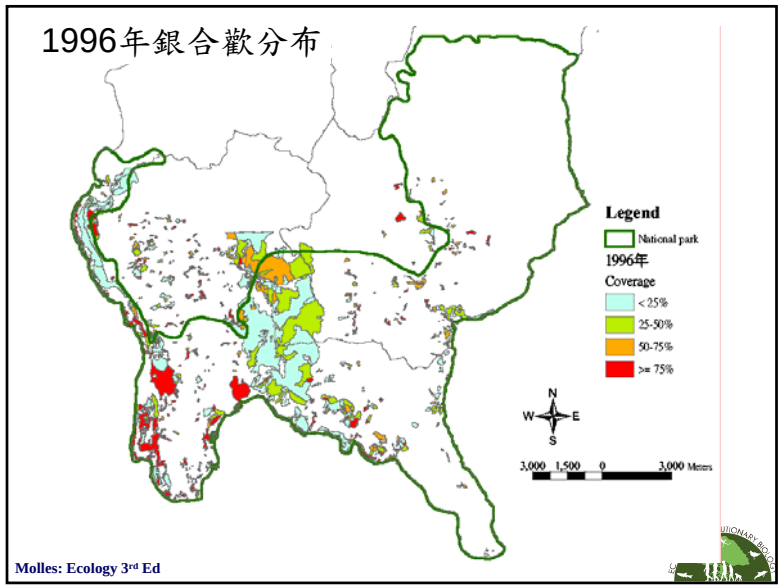
1996年銀合歡分布
Legend
National park
1996年
Coverage
< 25%
25-50%
50-75%
>= 75%
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2002年銀合歡分布 - QuickBird影像
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歡
核三廠
南灣
銀
合
歡


2003年銀合歡分布 - QuickBird影像
銀
合
歡
核三廠
南灣


2003年銀合歡分布 - QuickBird影像
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海洋生物
博物館
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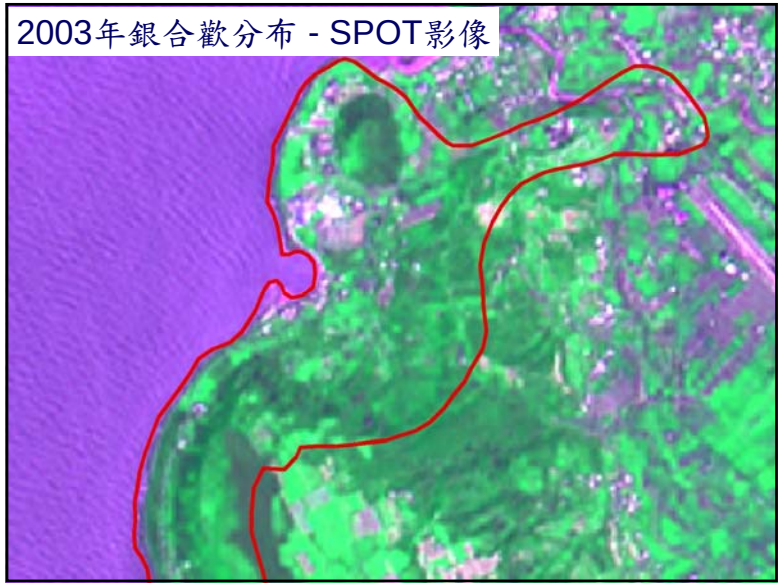
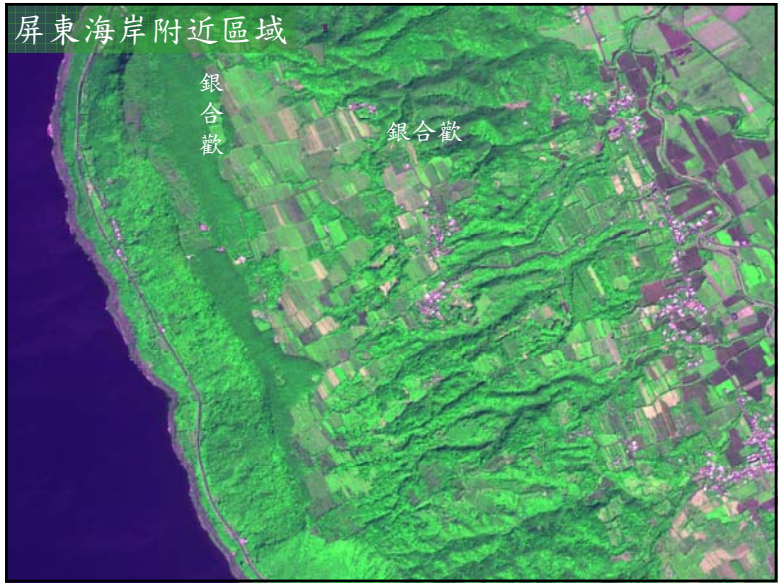

2003年銀合歡分布 - SPOT影像


屏東海岸附近區域
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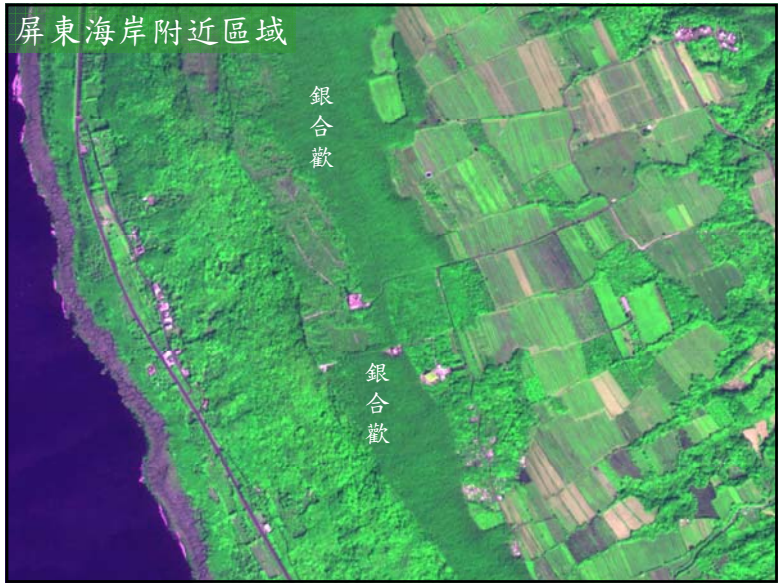
銀合歡



銀合歡變遷與生態衝擊

- 逐年增加其覆蓋範圍與覆蓋程度
- 大量入侵農地、廢耕地、裸露地
- 早期許多之瓊麻園，被銀合歡取代
- 改變植被景觀
- 阻止其他種植物之生長
- 改變生態系之營養鹽循環（尤其是氮循環，因為銀合歡屬於豆科植物，具有固氮能力）

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Summary

- Landscape structure includes size, shape, composition,number, and position of ecosystems within the landscape
- Landscape structure influences processes such as the flow of energy, materials, and species between the ecosystems within a landscape
- Landscapes are structured and change in response to geological processes, climate, organisms activities, and fire

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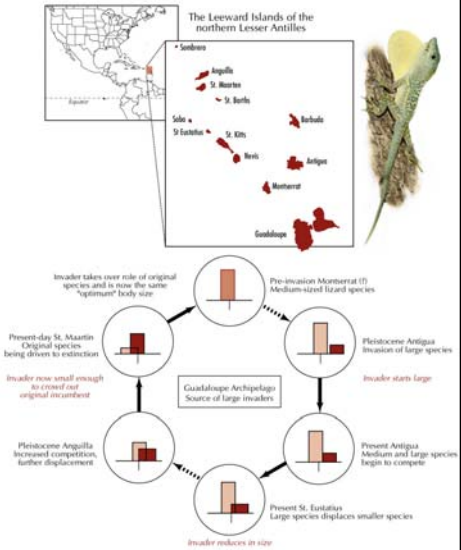
Link to other kinds of ecology

- Metapopulation dynamics
- Corridor design
- Reserve design



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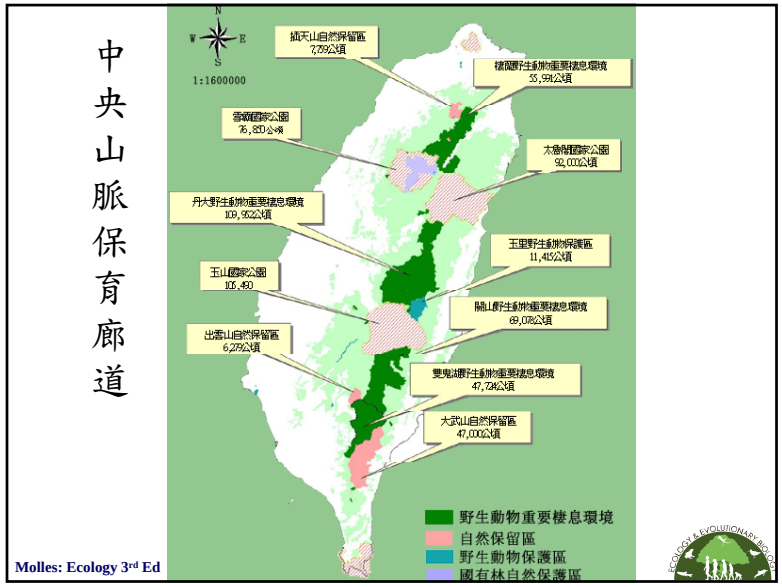
中央山脈保育廊道
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1:1600000
插天山自然保留區
7,759公頃
棲蘭野生動物重要棲息環境
55,934公頃
雪霸國家公園
76,850公頃
太魯閣國家公園
92,000公頃
丹大野生動物重要棲息環境
109,962公頃
玉里野生動物保護區
11,415公頃
玉山國家公園
105,490
關山野生動物重要棲息環境
69,078公頃
出雲山自然保留區
6,279公頃
雙鬼湖野生動物重要棲息環境
47,724公頃
大武山自然保留區
47,000公頃
野生動物重要棲息環境
自然保留區
野生動物保護區
國有林自然保護區
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白頭翁
台灣畫眉
泰國八哥
烏頭翁