Chapter 22

GEOGRAPHIC ECOLOGY

Chapter Concepts

- On islands and habitat fragments on continents, species richness increases with area and decreases with isolation
- Species richness on islands can be modeled as a dynamic balance between immigration and extinction of species
- Species richness generally increases from middle and high latitudes to the equator
- Long-term historical and regional processes significantly influence ecosystem structure

Introduction

- *MacArthur* defined geographic ecology as the search for patterns of plant and animal life that can be put on a map
  - Above level of landscape ecology
  - Vast breadth
    - Chapter only focuses on a few aspects

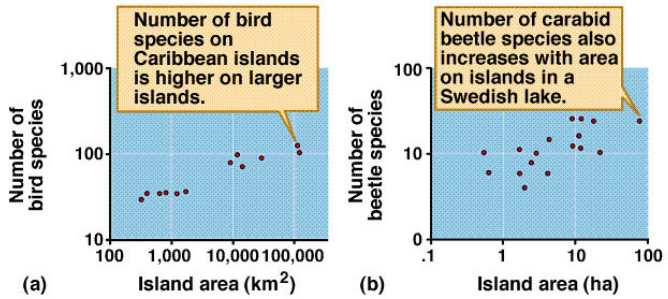
Robert H. MacArthur

- 1930-1972
- First a mathematician, then an ecologist
- Yale PhD
- *The Theory of Island Biogeography*, *Geographical Ecology*
- MacArthur's Warblers
- 大自然的獵人 by E. O. Wilson

Island Area and Species Richness

- *Preston* found fewest bird species live on smallest islands and most species on largest islands
- *Nilsson et al.* found island area was best single predictor of species richness among woody plants, carabid beetles, and land snails

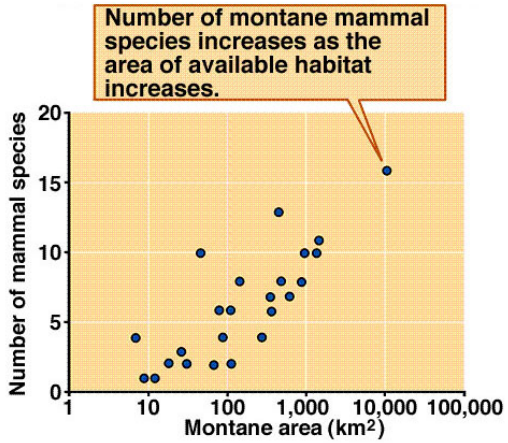
Island Area & Species Number



Habitat Patches on Continents: Mountain Islands

- As Pleistocene ended and climate warmed, forest and alpine habitats contracted to the tops of high mountains across American Southwest
  - ❖Woodlands, grasslands, and desert scrub, invaded lower elevations
  - ❖Once continuous forest converted to series of island-like fragments associated with mountains: montane

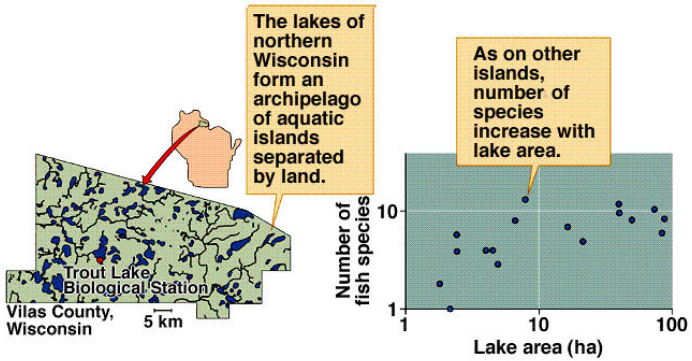
Montane Area & Species



Habitat Patches on Continents: Lake 'Islands'

- Isolated lakes
  - Tonn and Magnuson (1982) studied fish species richness in northern Wisconsin and upper peninsula of Michigan

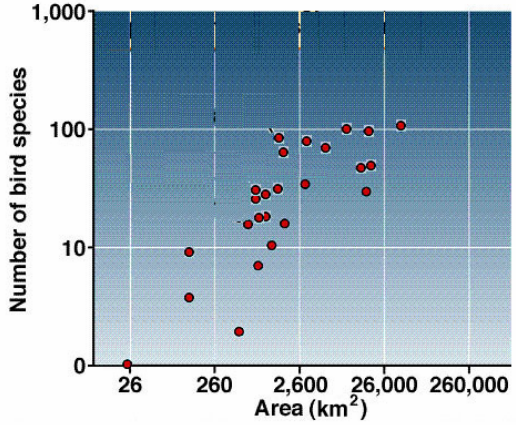
Lake Area & Fish Species



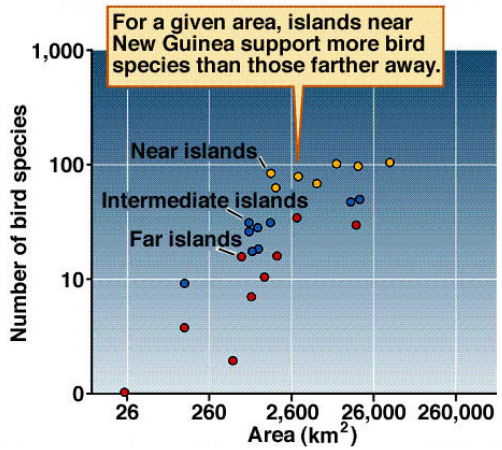
Marine Islands

- *MacArthur and Wilson* found isolation reduces bird diversity on Pacific Islands.
- *Williamson* summarized data from relationship between island area and species richness in Azore Islands:
  - Birds show clear influence of isolation on diversity, pteridophytes do not.
  - Land birds fly across water barriers, pteridophytes produce large quantities of light spores easily dispersed in the wind.

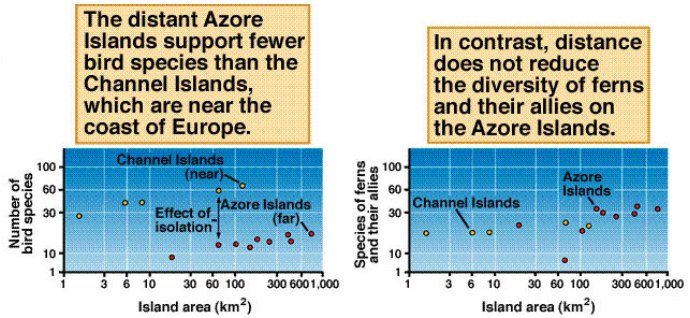
Area & Bird Species



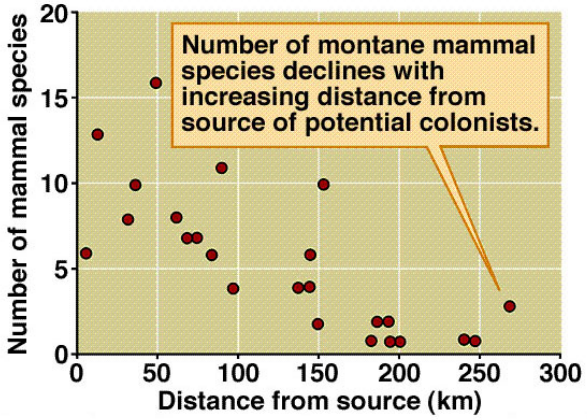
Area & Bird Species



Isolation & Diversity



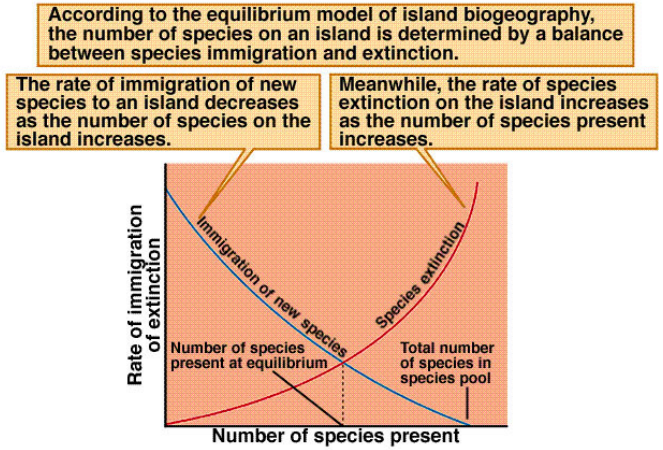
Distance & Species



Equilibrium Model of Island Biogeography

- *MacArthur and Wilson:* model explaining patterns of species diversity on islands as result of immigration and extinction rates.
  - Reasoned rates of immigration would be highest on new island with no organisms.
    - As species began to accumulate, rate of immigration would decline since fewer arrivals would be new species.

Equilibrium Model



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Equilibrium Model of Island Biogeography

- Predicted rate of extinction would rise with increasing number of species on an island for three reasons:
  - Presence of more species creates a larger pool of potential extinctions.
  - As # of species increases, population size of each must diminish.
  - As # of species increases, potential for competitive interactions between species will increase.

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Equilibrium Model of Island Biogeography

- Point where two lines cross predicts the number of species that will occur on an island
- Proposed rates of extinction on islands would be determined mainly by island size
  - LG, near islands will support greatest #
  - SM, far islands will support lowest #
  - SM near and LG far will support intermediate #

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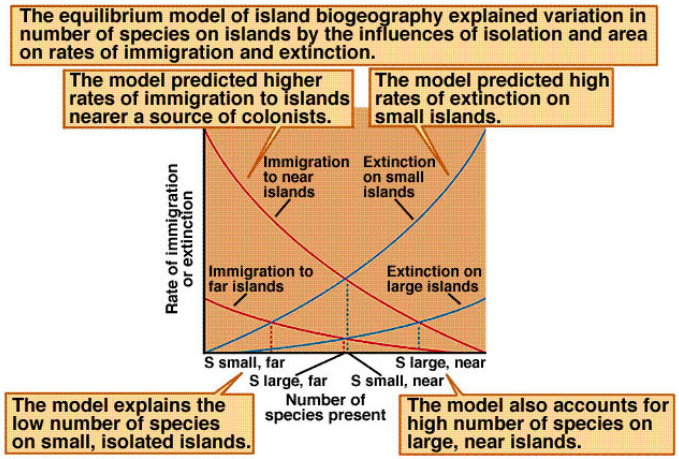
Equilibrium Model Example



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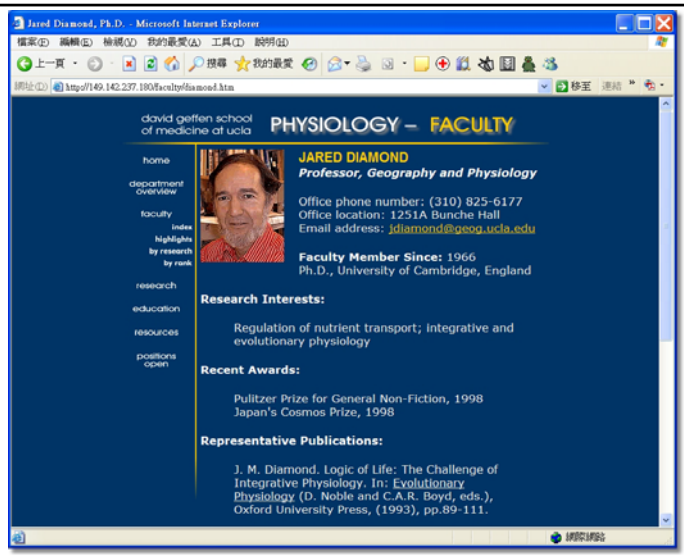
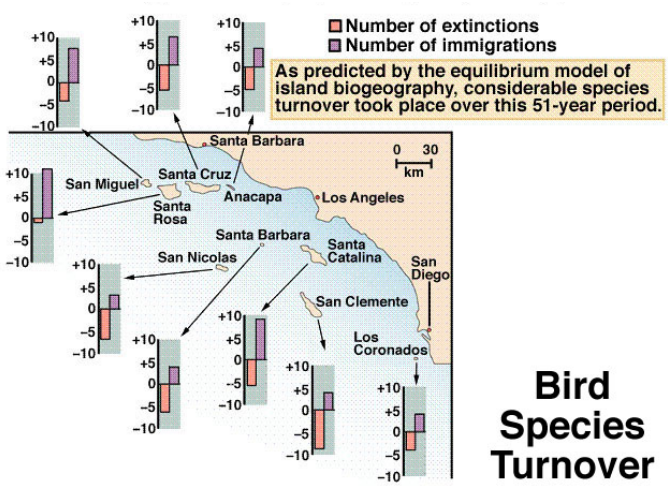
Species Turnover

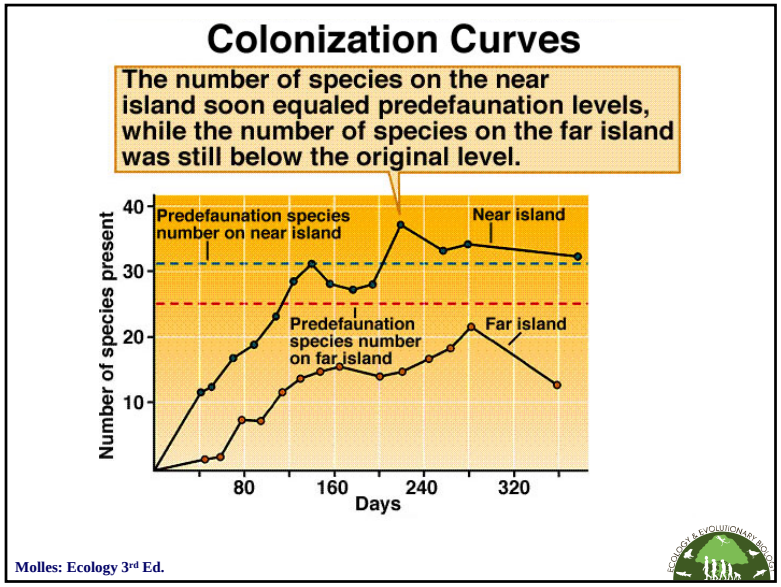
- Equilibrium model predicts spp. composition on islands is fluid:
  - ❖Change referred to as *species turnover*
- *Diamond* found birds in nine CA Channel Islands in a stable equilibrium as a result of immigration and extinction





Experimental Island Biogeography

- *Simberloff and Wilson* studied insect recolonization in Florida Keys (fig 22.11)
  - ❖Chose 2 stands of mangroves as control islands, and 6 others as experimental islands
    - Defaunated islands
      - Followed recolonization for 1 yr
        - Species number stayed constant, but composition changed considerably



Colonization of New Islands By Plants

- *Rydin and Borgegard* found variation in spp. richness correlated positively with island area and accounted for 44-85% of variation in spp. richness among islands
  - Small and medium islands continued to accumulate species
  - Large islands attained equilibrium of immigration and extinction
    - Difficult to separate effects of habitat diversity from area affects

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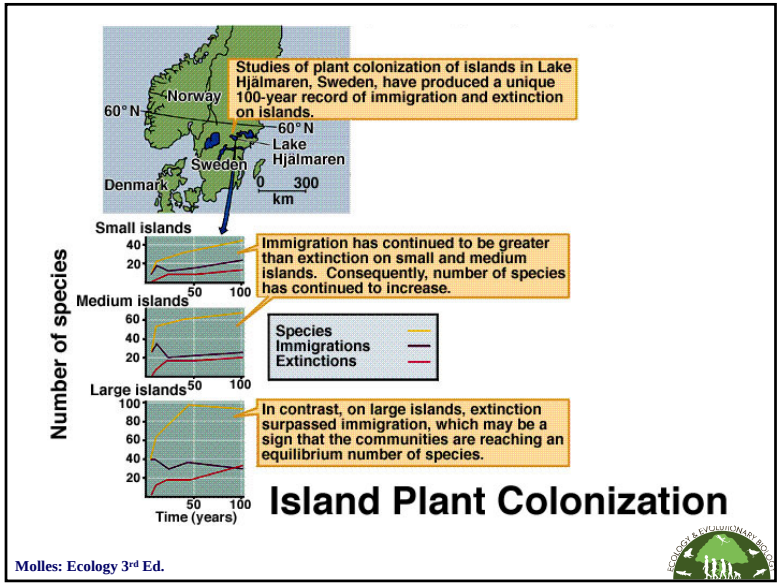

Manipulating Island Area

- *Simberloff* tested effect of island area on species richness
  - In all cases where area was reduced, species richness decreased
    - Richness on control island increased slightly
  - Islands with reduced area lost species with each reduction in area
    - Showed area has positive influence on species richness

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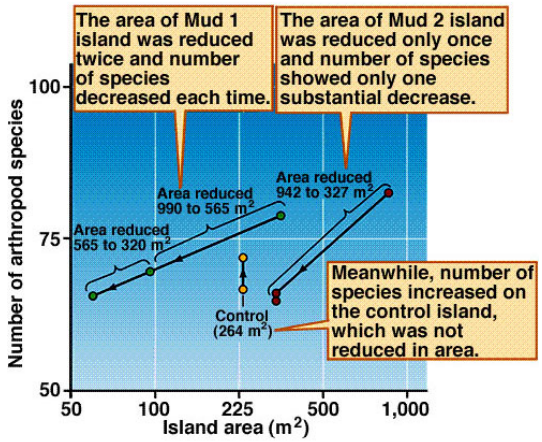
Area & Number of Species



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Latitudinal Gradients in Species Richness

- Most groups of organisms are more species-rich in the tropics

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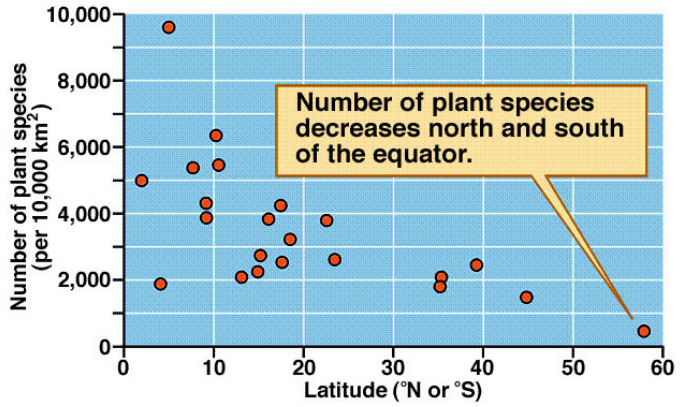
Latitude & Species Number



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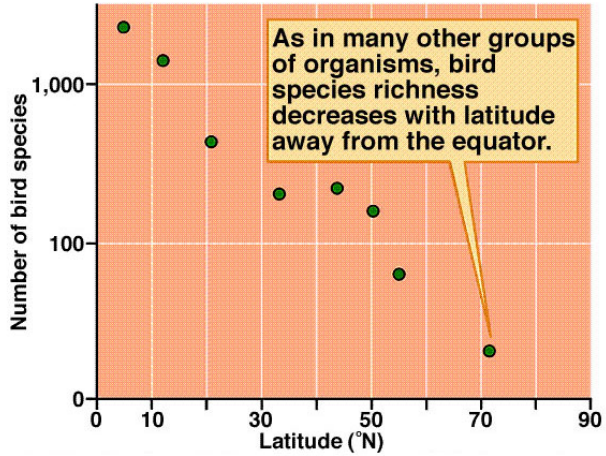
Latitude & Bird Species



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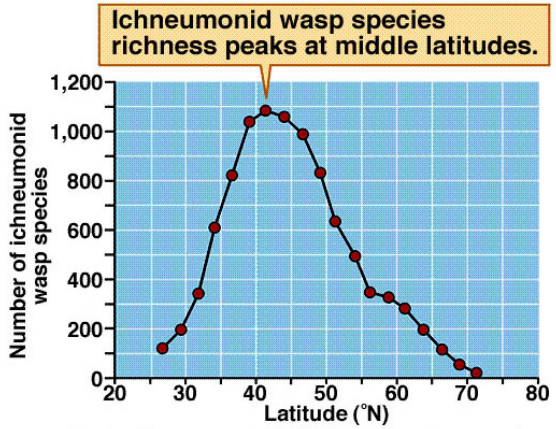
Species Decline & Latitude



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Latitudinal Gradients in Species Richness

Brown grouped hypotheses into six categories:

1. Time Since Perturbation
   - More species in the tropics because tropics are older and disturbed less frequently
     - More time for speciation, and less frequent disturbance reduces extinction rate
2. Productivity
   - High productivity contributes to high species richness
     - More energy to divide among population

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Latitudinal Gradients in Species Richness

3. Environmental Heterogeneity
   - More heterogeneity thus more potential habitat areas and niches
4. Favorableness
   - Tropics have more favorable environments.
     - No extremes to limit diversity.
5. Niche Breadth and Interspecific Interactions
   - Various themes
     - *Brown* suggests biological processes must play secondary role.
       - Ultimate causes must by physical differences.

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Latitudinal Gradients in Species Richness

6. Speciation and Extinction Rates
   - *Rosenzweig* proposed immigration can be largely discounted at broad scales, thus speciation will be primary source of new species
     - Species removal via extinction
       - Tropics richness is greater due to higher rates of speciation and/or lower rates of extinction

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Area, Latitude and Species Richness

- Terborgh (1973) and Rosenzweig (1992) – higher species richness in the tropics due to its larger areas
- Overall higher temperature

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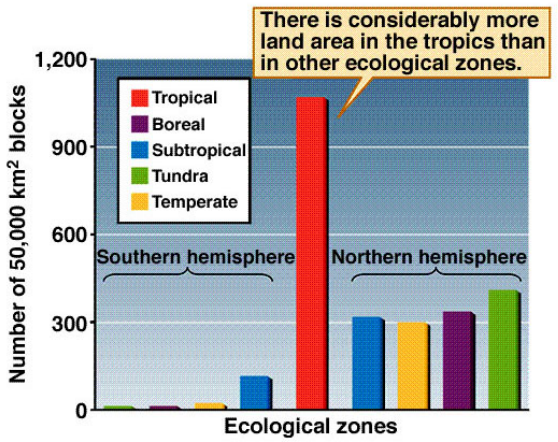
Area & Ecological Zones



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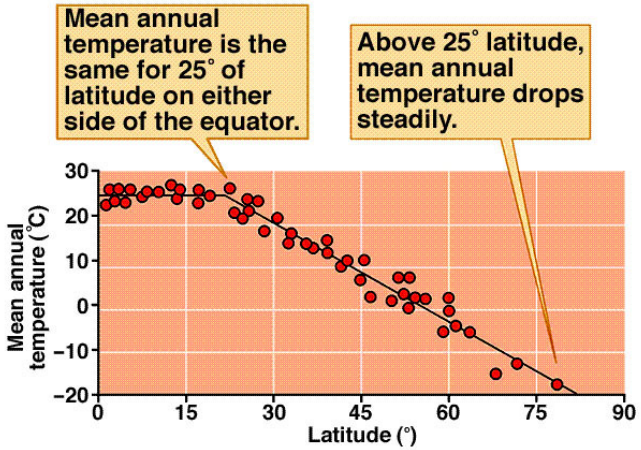
Temperature & Latitude



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Continental areas and species richness

- Positive correlation in mammal species richness and continental areas (Flessa, Brown)
- Fruitivores and plant species richness vs. areas (Rosenzweig)

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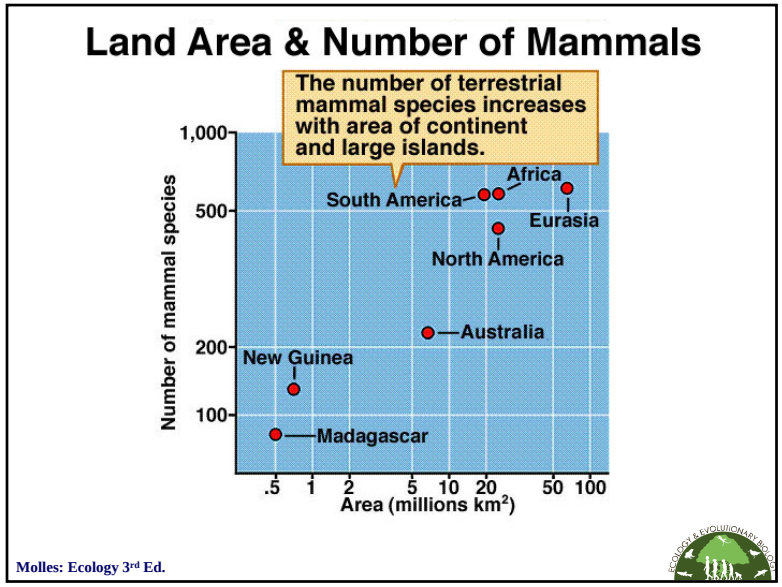
Land Area & Number of Mammals
The number of terrestrial mammal species increases with area of continent and large islands.
Number of mammal species
1,000
500
200
100
Africa
South America
Eurasia
North America
Australia
New Guinea
Madagascar
.5
1
2
5
10
20
50
100
Area (millions km²)
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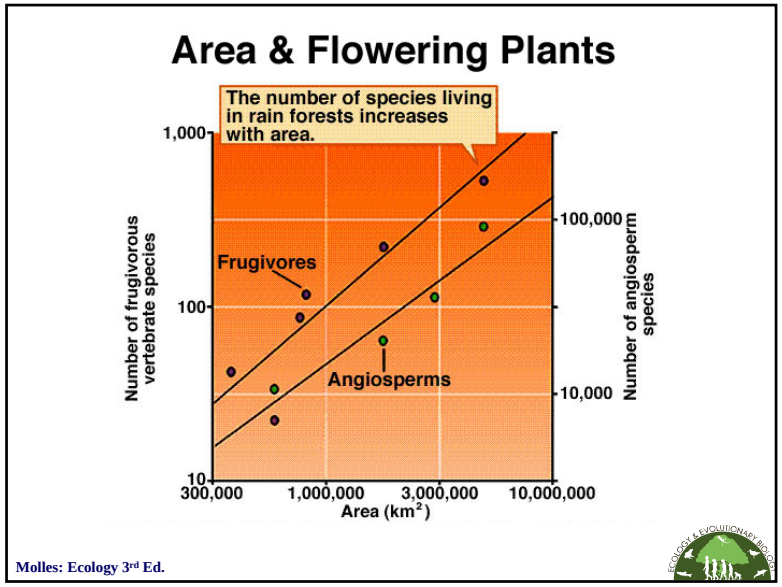
Area & Flowering Plants
The number of species living in rain forests increases with area.
Number of frugivorous vertebrate species
1,000
100
10
Frugivores
Angiosperms
100,000
10,000
Number of angiosperm species
300,000
1,000,000
3,000,000
10,000,000
Area (km²)
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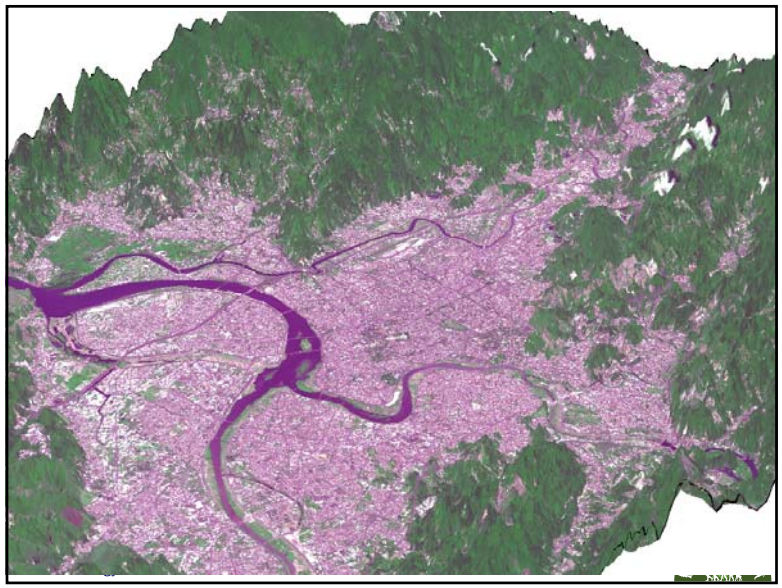

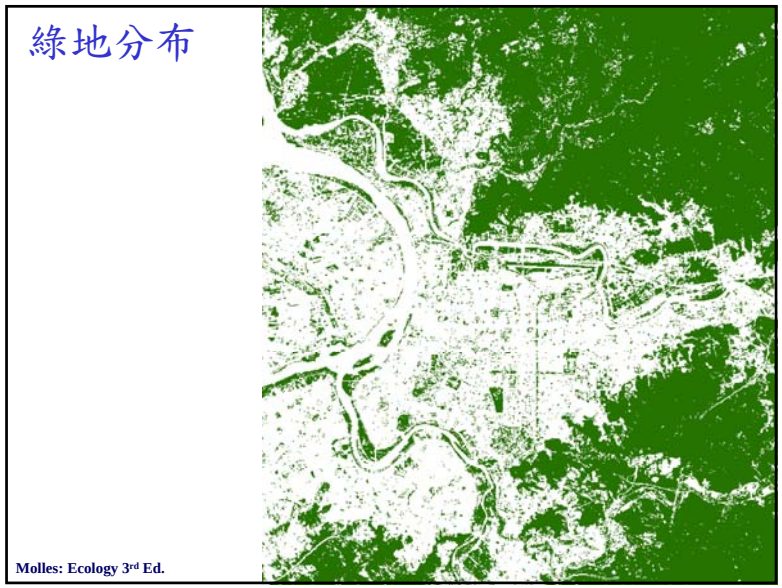
綠地分布
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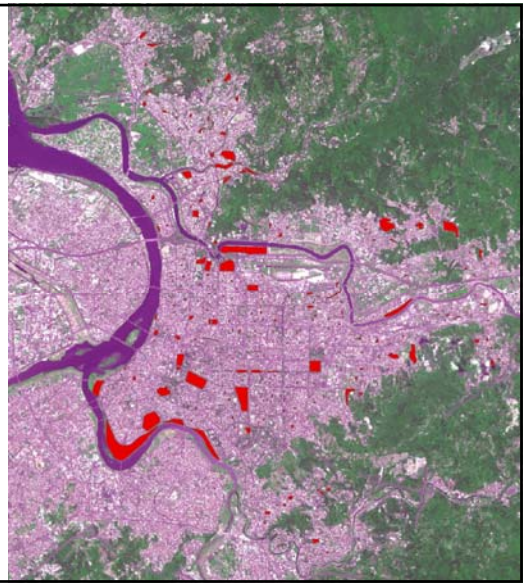
公園綠地分布



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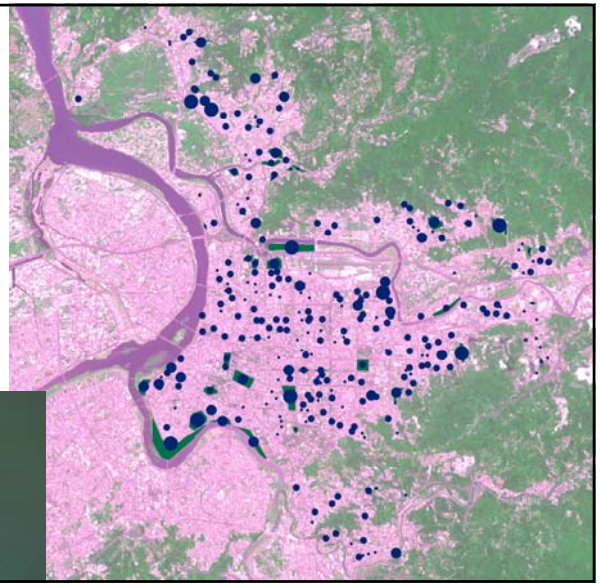
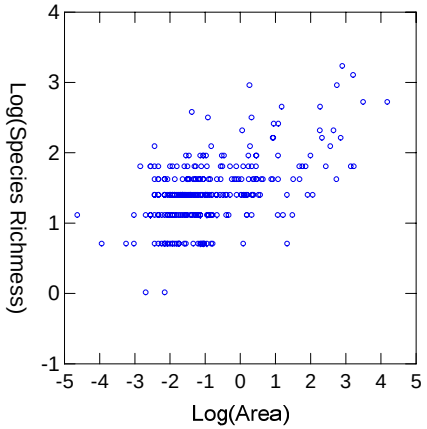
白頭翁

台北鳥會調查



Species Richness and Park Area



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Exceptions

- Plant species richness in Mediterranean region and three major continents
- Bird species richness
- Asian bird species richness
- Phytoplankton in the oceans

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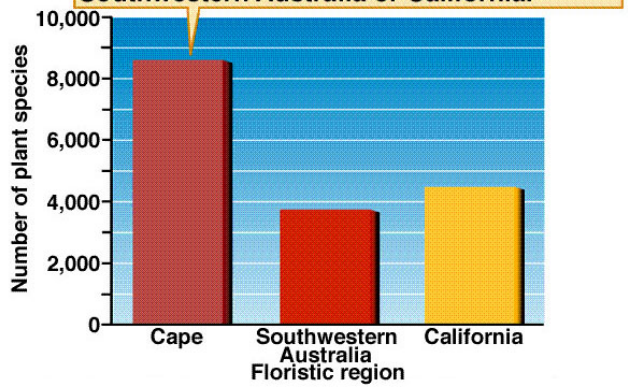
Same-Climate Plant Diversity



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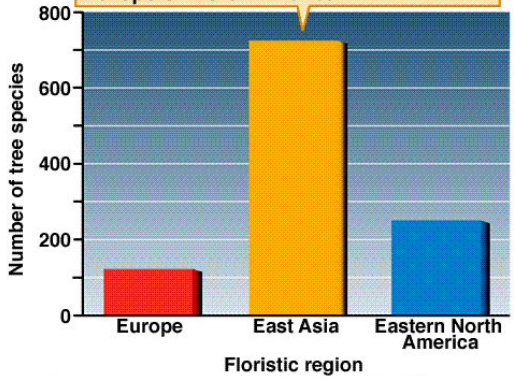
Temperate Forest Tree Species



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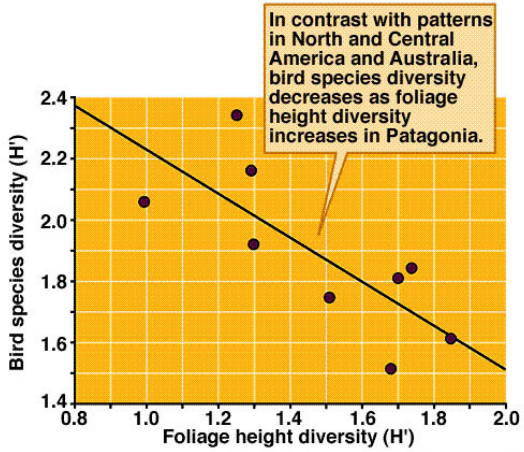
Patagonia Foliage & Birds



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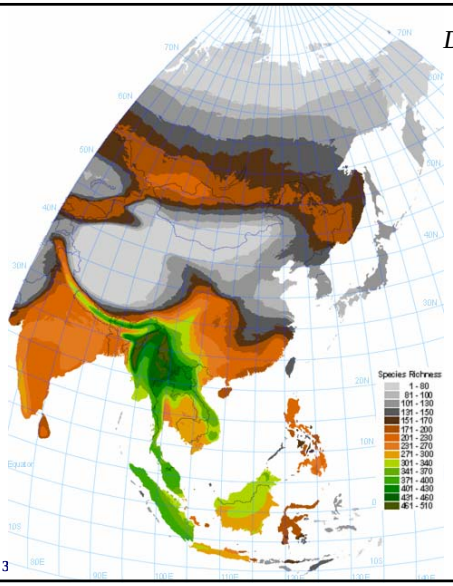

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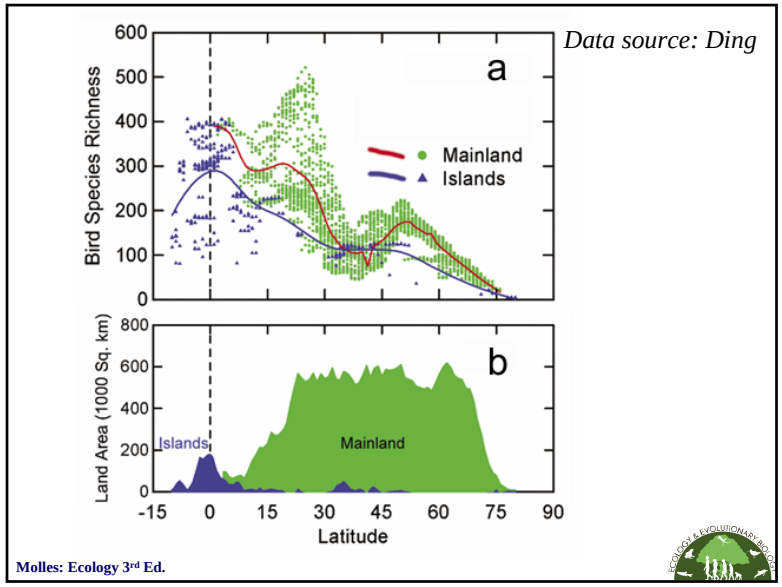

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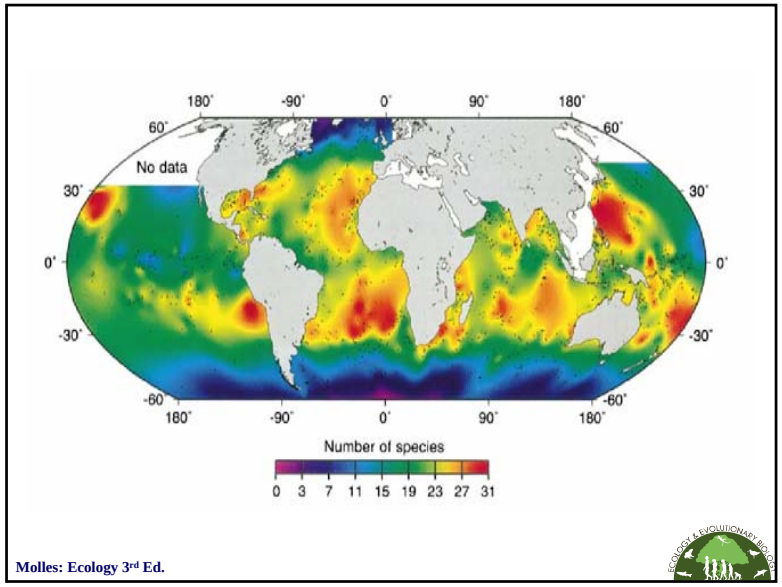

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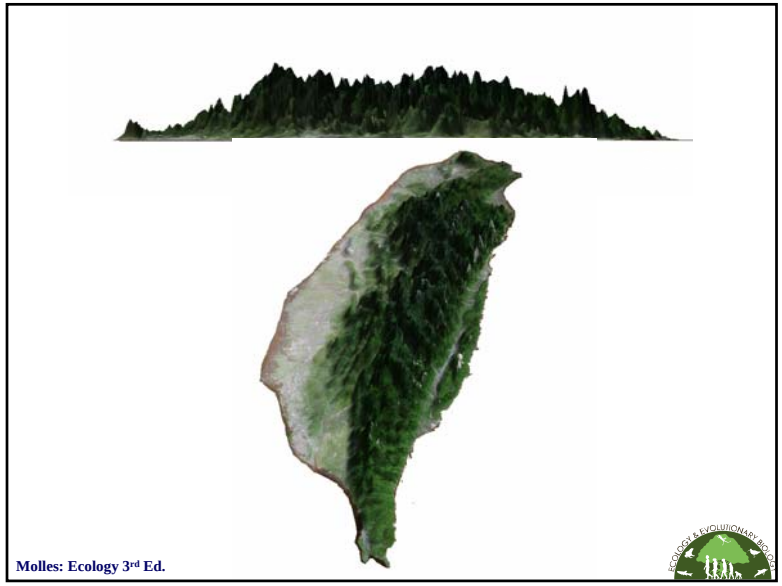

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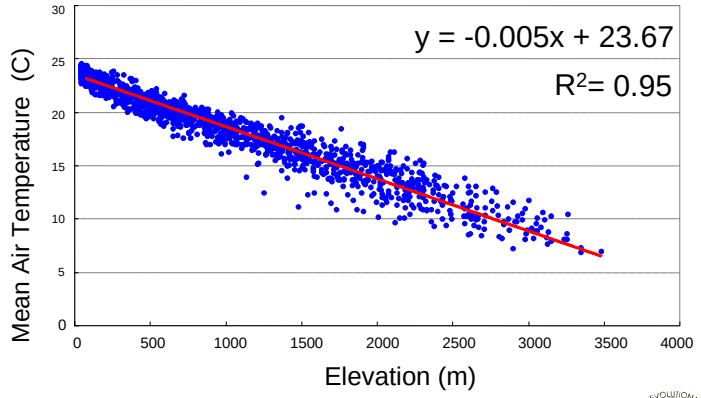
Mean Air Temperature with Mean Elevation in Central Taiwan based on 2km grid data



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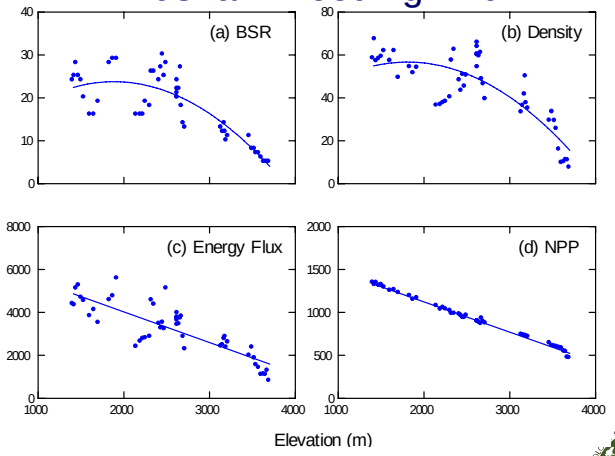
Species Richness Pattern in Taiwan – Yushan Breeding Bird



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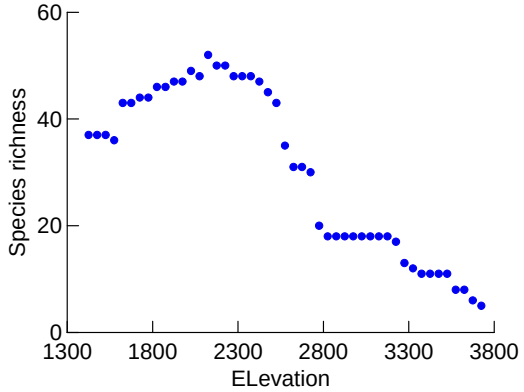
Species Richness Pattern in Taiwan – Yushan Breeding Bird



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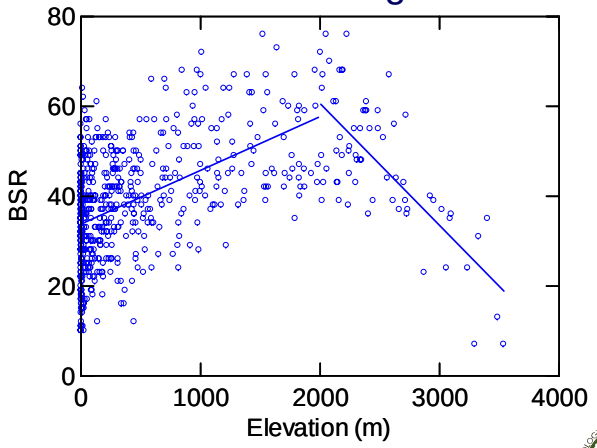
Species Richness Pattern in Taiwan – Taiwan Breeding Bird



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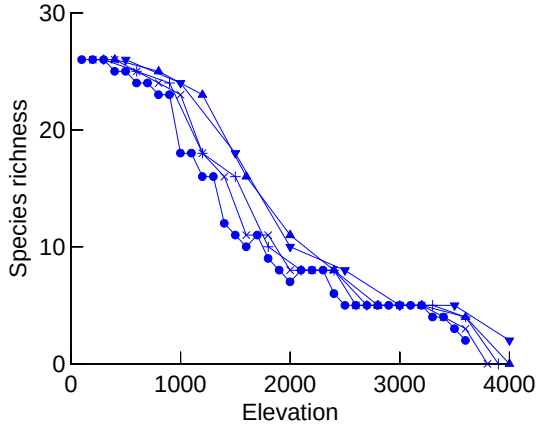
Species Richness Pattern in Taiwan – Amphibian: frogs



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Historical and Regional Influences

- *Latham and Ricklefs:* reported striking contrast in diversity of temperate zone trees that cannot be explained by area effect
  - Temperate forest biome in Europe, Eastern Asia, and Eastern North America all have roughly equitable area, but support vastly different levels of biological diversity
    - Eastern Asia: 3x NA and 6x Europe

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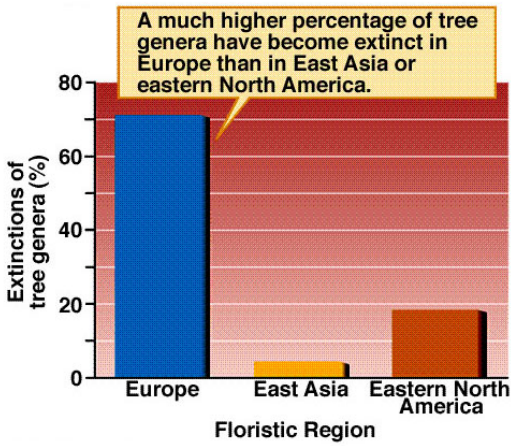
Extinction of Tree Genera



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Historical and Regional Influences

- *Latham and Ricklefs:* Must examine conditions trees in these regions faced during the last glacial period
  - Mountains in Europe form east-west oriented barriers
    - During last ice age, temperate trees had southward retreat largely cut-off
      - Lower species richness as consequence of higher extinction rate

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Historical and Regional Influences

- ❖Appalachian Mountains in N.A run north-south, thus temperate trees had an avenue of retreat as temperatures became colder
  - Also no mountain barriers in Asia
- Concluded from various lines of evidence that most temperate tree taxa originated in Eastern Asia and dispersed to Europe and N.A.
  - ❖After dispersal lines were cut, speciation continued in Asia

Summary

- On islands and habitat fragments on continents, species richness increases with area and decreases with isolation
- Species richness on islands can be modeled as a dynamic balance between immigration and extinction of species
- Species richness generally increases from middle and high latitudes to the equator
- Long-term historical and regional processes significantly influence ecosystem structure

紅尾伯勞 八色鳥