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.

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.
Habitat Patches on Continents: Lake ‘Islands’

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

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.
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 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.

Equilibrium Model of Island Biogeography Example

- The equilibrium model of island biogeography explained variation in number of species on islands by the influences of isolation and area on rates of immigration and extinction.

- The model predicted higher rates of immigration to islands nearer a source of colonists.
- The model predicted high rates of extinction on small islands.

- The low number of species on small, isolated islands.
- The model also accounts for high number of species on large, near islands.
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

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

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.

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
Area, Latitude and Species Richness

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

Temperature & Latitude

Mean annual temperature is the same for 25° of latitude on either side of the equator. Above 25° latitude, mean annual temperature drops steadily.

Continental areas and species richness

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

白頭翁台北鳥會調查

Species Richness and Park Area

Exceptions
- Plant species richness in Mediterranean region and three major continents
- Bird species richness
- Asian bird species richness
- Phytoplankton in the oceans
**Same-Climate Plant Diversity**

The plant diversity of the Cape region of South Africa is far greater than that of either Southwestern Australia or California.

**Temperate Forest Tree Species**

The temperate forests of East Asia are far richer in species than those of either Europe or North America.

**Patagonia Foliage & Birds**

In contrast with patterns in North and Central America and Australia, bird species diversity decreases as foliage height diversity increases in Patagonia.

Data source: Ding
Mean Air Temperature with Mean Elevation in Central Taiwan based on 2km grid data

\[ y = -0.005x + 23.67 \]

\[ R^2 = 0.95 \]

Species Richness Pattern in Taiwan – Yushan Breeding Bird

(a) BSR  
(b) Density

(c) Energy Flux  
(d) NPP

Species Richness Pattern in Taiwan – Yushan Breeding Bird

Species Richness Pattern in Taiwan – Taiwan Breeding Bird
Species Richness Pattern in Taiwan – Amphibian: frogs

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

Extinction of Tree Genera

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
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

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