Lecture 22 - ENV 330 – Geographic Ecology, Island Biogeography, Metapopulations

Species- Area Relationship – Large islands (habitats or land areas) support more species than smaller islands (habitats or land areas)

e.g., bird species on the Caribbean islands
woody plants, land snails and beetles on islands in Swedish lakes

e.g., montane mammal species on isolated mountain islands in the American Southwest

e.g., lakes as islands, number of species of fish increases with lake area in Wisconsin
sample lakes range from 0.8 to 436,000 km^2 and fish species range from 5 to 245.

- *MacArthur and Wilson (1963)* - Island Biogeography

The number of species of a given taxon that become established on an island represents a dynamic equilibrium controlled by the rate of immigration of new species and the rate of extinction of previously established species.

Immigration varies with the distance of the island from the mainland (or the pool of potentially colonizing species).

- More distant islands are colonized less frequently.
- The rate of colonization declines as species richness increases, because there are fewer potential colonists and fewer unexploited niches.

e.g., Azores islands support fewer species of birds than Channel Islands which are near the coast of Europe, farther to fly to and colonize. Exception for ferns, which use wind dispersed spores to colonize over long distances.

e.g., American SW, number of montane animal species declines with distance from potential source areas

Extinction varies with the size of the island.

- Big islands can support larger population sizes, and large populations are less prone to extinction. So, the smaller the island, the greater the probability of extinction.
- Extinction rates rise as colonization increases; interspecific competition displaces of some species and lowers population sizes when species can coexist.

At equilibrium between immigration and extinction, the number of species remains stable, although the composition of species may change.

- This is the *dynamic equilibrium*.

The rate at which some species are lost and others become established is the *turnover rate*.

THEORY OF ISLAND BIOGEOGRAPHY: GRAPHICAL TREATMENT

See Figures 22.8 and 22.9 in Molles, Figure 7.6 and 7.7 in Gotelli

Empirical tests:
Insects on Mangrove Islands in Florida Keys (Simberloff and Wilson 1969)(Fig. 22.11 and 22.12 Molles)

- Insect recolonization of four defaunated mangrove islands (Fig. 7.12 Gotelli)
- Colonizationa and extinction records for a single island (Fig. 7.13 Gotelli)
- Also manipulation of land area. Reduced area resulted in decrease in number of species (Fig. 22.14 Molles)

Channel Islands Birds (Diamond 1969)

- Species turnover on islands, number of bird species remained constant over 50 years and this stability was the result of approximately equal number of extinctions and immigrations (Fig. 22.10 Molles)

30 New Islands and studies of plant colonization in Sweden (Fig. 22.13 Molles)

Relaxation - the loss of species, following isolation of an island or habitat patch.

- The case of Land-bridge islands.
- Land-bridge islands were connected to each other or to continents during the Pleistocene, when sea level was up to 100 m lower than today.
- Since becoming isolated, these islands have apparently lost species

Consider the analogy between land-bridge islands and terrestrial habitat patches isolated by habitat fragmentation and the development of surrounding landscape.

Crowding Effect - increase in species richness following habitat fragmentation caused by the displaced animals seeking suitable habitat in the remaining patches. Crowding is followed by relaxation, over a longer period of time, as population sizes and species reach equilibrium.

Geographic Ecology: Area and latitudinal Gradients in Species Richness

- Tropics have more land area than other ecological zones,
- Mean annual temperature is same (25° C) for 25° latitude on either side of equator,
- Continental area linked to number of mammal species present,

Exceptions where long term historical and regional processes influence structure of biotas and ecosystems

e.g., plant diversity in Mediterranean climate zones,

- Cape region of South Africa has higher plant diversity because of more southward position of Africa during the Tertiary (26 million years ago), dry climate covered a larger area

e.g., Diversity of tree in temperate areas of Europe, East Asia and eastern NA

- mountain barriers during glaciation in Europe resulted in higher extinction rate and lowered diversity

- land bridge linking NA and east Asia open only periodically therefore not as many species can migrate over, most taxa originated from east Asia (many endemics),

So what is Island Biogeography Theory good for?

- provides a theoretical basis for explaining the relatively impoverished island biotas.
- provides a predictive framework for estimating species diversity.
- analogies to terrestrial island-like situations is extremely attractive.
- applications to an increasingly fragmented, island-like terrestrial habitats can be very powerful.

What are its weaknesses:

- no mechanistic foundation to explain patterns
- does not account for specific species
- tendency to over-interpret and over-apply

Applications To Terrestrial Habitats:
1. Mountain tops (Brown)
2. Bogs
3. Ponds
4. Dunes
5. Fragmented forests
6. Grasslands surrounded by agriculture
7. Semi-natural parklands in a sea of urban sprawl
8. Hosts are “islands” for parasites

Metapopulations

Source and Sink Dynamics of Populations

Metapopulations are of special interest to conservation biology because of their potential to buffer against the loss of individual small populations: a small population could persist indefinitely if regularly bolstered by immigrants from some outside location.

Metapopulation dynamics have been long appreciated by population geneticists, but only more recently are of focal interest to ecologists studying abundance dynamics.

It emphasizes metapopulation dynamics of single species, but there is a growing interest in the role that it may play in species richness of communities

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Metapopulation dynamics of bubonic plague

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Bubonic plague is widely regarded as a disease of mainly historical importance; however, with increasing reports of incidence and the discovery of antibiotic-resistant strains of the plague bacterium *Yersinia pestis*, it is re-emerging as a significant health concern. Here we bypass the conventional human-disease models, and propose that bubonic plague is driven by the dynamics of the disease in the rat population. Using a stochastic, spatial metapopulation model, we show that bubonic plague can persist in relatively small rodent populations from which occasional human epidemics arise, without the need for external imports. This explains why historically the plague persisted despite long disease-free periods, and how the disease re-occurred in cities with tight quarantine control. In a contemporary setting, we show that human vaccination cannot eradicate the plague, and that culling of rats may prevent or exacerbate human epidemics, depending on the timing of the cull. The existence of plague reservoirs in wild rodent populations has important public-health implications for the transmission to urban rats and the subsequent risk of human outbreaks.