Theory of Island Biogeography

BI 201 Natural History of Guam

Class Presentation 26

- What is **Biogeography**?
  - Biogeography is the study of the distribution and diversity of living organisms
  - There are two subdivisions of biogeography
    - *Zoogeography* is the study of animal distribution and diversity
    - *Phytogeography* is the study of plant distribution & diversity

- Island Biogeography
  - Island biogeography is a topic of special interest to ecologists
  - Oceanic islands, by definition, have no connection w/ continental land masses
  - To inhabit an island, organisms must be able to disperse there and colonize successfully by establishing a breeding population

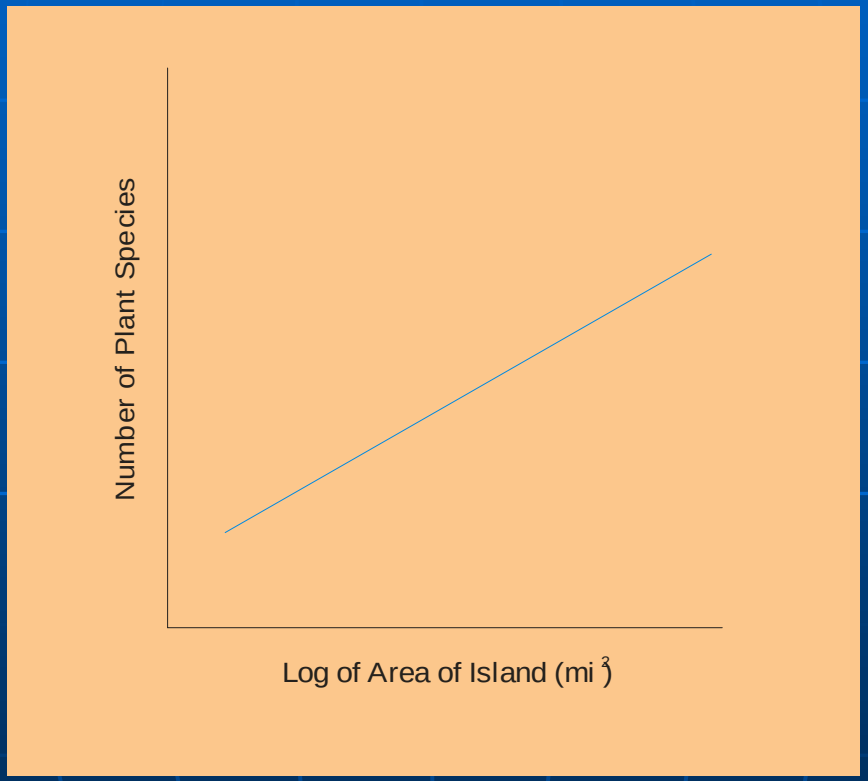
- What determines which species inhabit an island?
  - That is, what adds and subtracts species on an island?
  - Species may be added to an island by dispersal from a source area on a continental land mass
  - Species may also be added to an island by localized evolution
  - Species are subtracted from an island by extinction, both natural and human-caused

- Area Effects
  - The number of species on an island is related to the **area** of the island
  - This relationship can be expressed mathematically by the following equation:

$$S = cA^Z$$

    - Where,
      - S = the number of species,
      - c = a constant related to the ratio of species:area,
      - A = the area of the island (in square units, e.g., square miles), and
      - Z = a constant related to the slope of the line generated by plotting the number of species vs the area of the island

- For islands, the constant Z ≈ 0.3; and for continents, Z = 0.15 – 0.24



Species-area curve. The number of species on an island is related to the area of the island.

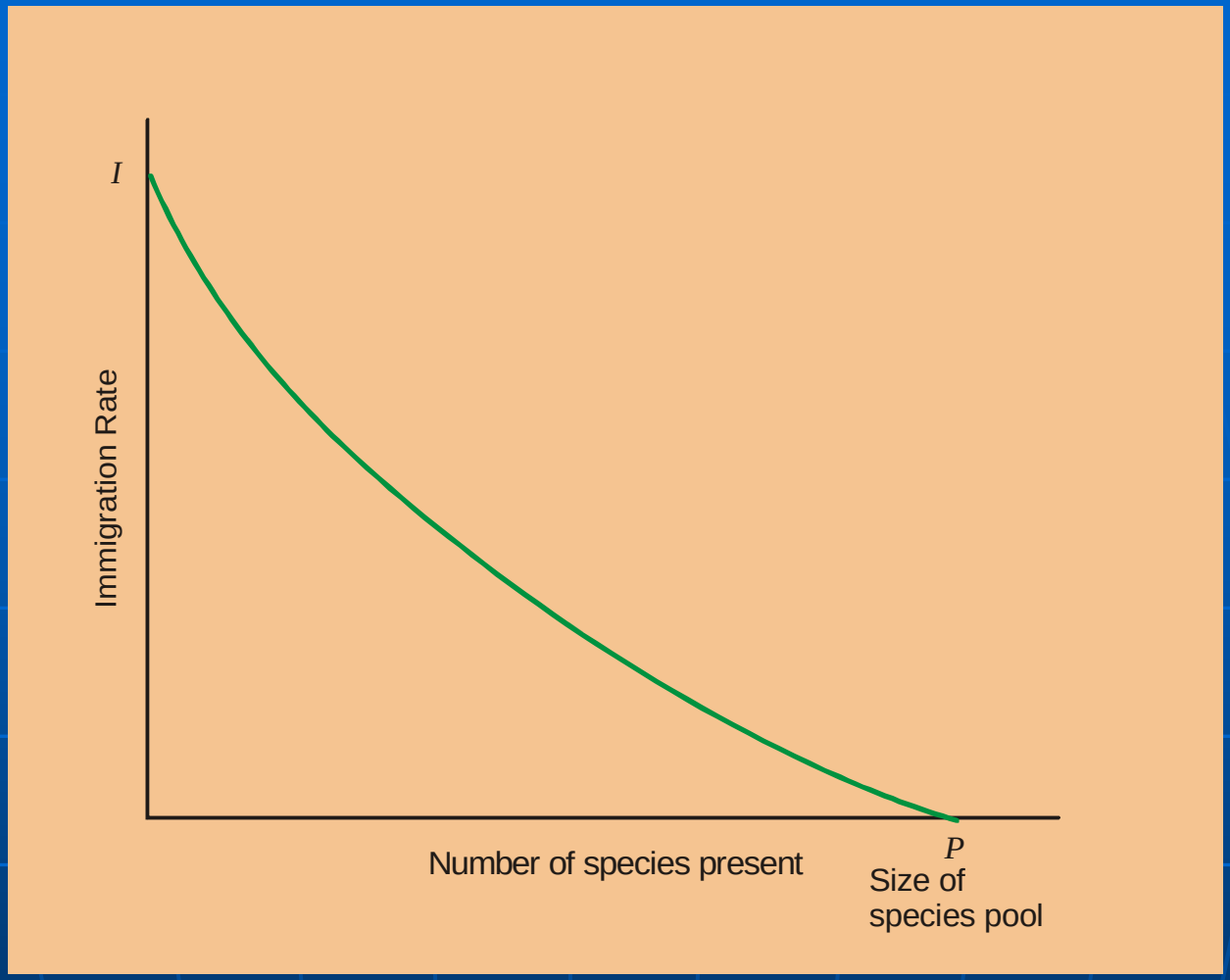
- Therefore, area is an important factor in determining the number of species that a biogeographer might expect to be found on an island
- The model also hints at a limit to the amount of diversity to be expected

- Theory of Island Biogeography
  - Why might there be such limits to diversity on islands?
    - The number of species on any given island (or continent) is the balance between the rate of immigration and the rate of extinction of species on the island

- If immigration of new species is greater than extinction of established species, then the island will gain species over time, and diversity will increase
- Therefore, diversity is similar to population size in which

Population Size = (Immigration + Births) – (Emigration + Deaths)

- The **immigration rate** is the number of new species successfully colonizing the island per unit of time
  - The immigration rate falls over time, because, as more species become established on the island, most of the arriving immigrant species will be species that are already present from previous dispersals
  - Also, many (most?) species in the source area will not be able to disperse to island
  - The hypothetical upper limit is the total faunal diversity of the source region



The immigration rate is expressed as the number of new species successfully established per unit time. This rate falls continuously because as more species become established on the island, the greater the probability that new immigrants will be from species that are already present.

- What affects immigration rate?
  - The primary factor affecting immigration rate is largely the organism itself and its ability or inability to disperse
    - Poor dispersers usually are large, non-flying species, such as amphibians and mammals
    - Good dispersers usually are very small species or they are able to fly, such as birds, butterflies, ferns, and conifers

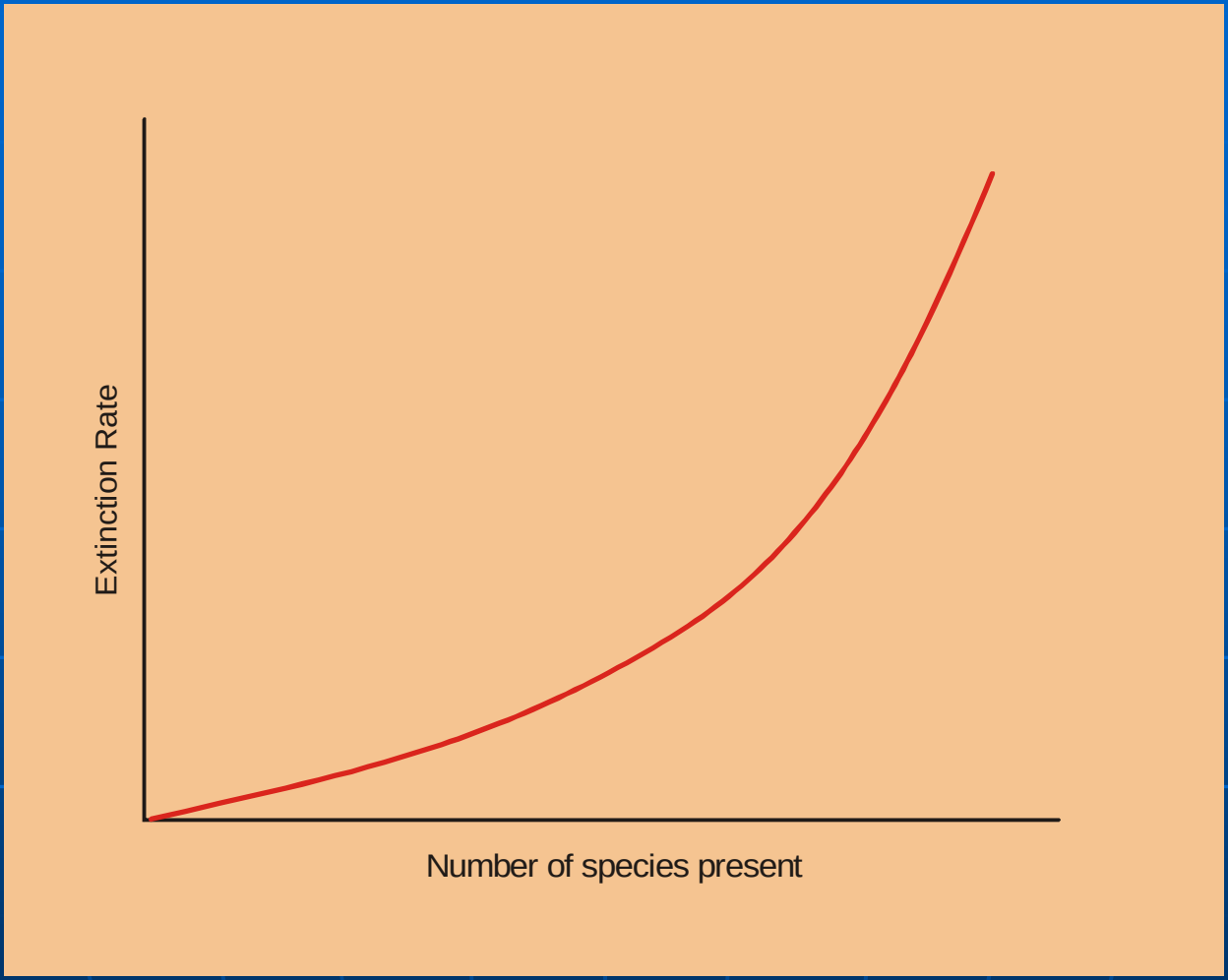
- Methods of dispersal include
  - Transport by air
    - For example, spores of ferns or orchids
  - Transport by water currents
    - For example, water-borne seeds drifting on currents, or species rafting on floating objects
  - Transport by birds
    - For example, snails stuck to feathers of birds, or seeds carried undigested in the intestines of birds

- For islands, the ocean distance to be crossed is also important
  - For example, the flora of Samoa has been studied in detail, and plant species immigrating to Samoa arrived by
    - Air
      - flying or wind transport – 15.1%
    - Birds
      - seeds w/ barbs or bristles – 4%
      - seeds viscid (sticky, adhesive) – 4.3%
      - internal – 50.8%
      - in mud on feet – 5.5%
    - Water currents
      - floating seeds drifting on current – 17.8%
      - rafting seeds – 7.5%

- In Guam,
  - Land snails are mostly very small, so they probably dispersed by aerial transport
  - Insects arrived by aerial transport (e.g., aerial plankton samples in high altitude jet stream)
  - Almost all freshwater species have a marine larval stage, hence they are called **amphidromous** species
    - Freshwater prawns have marine larvae
    - Freshwater fish have marine eggs or larvae
  - Tropical storms probably are responsible for immigration of many species

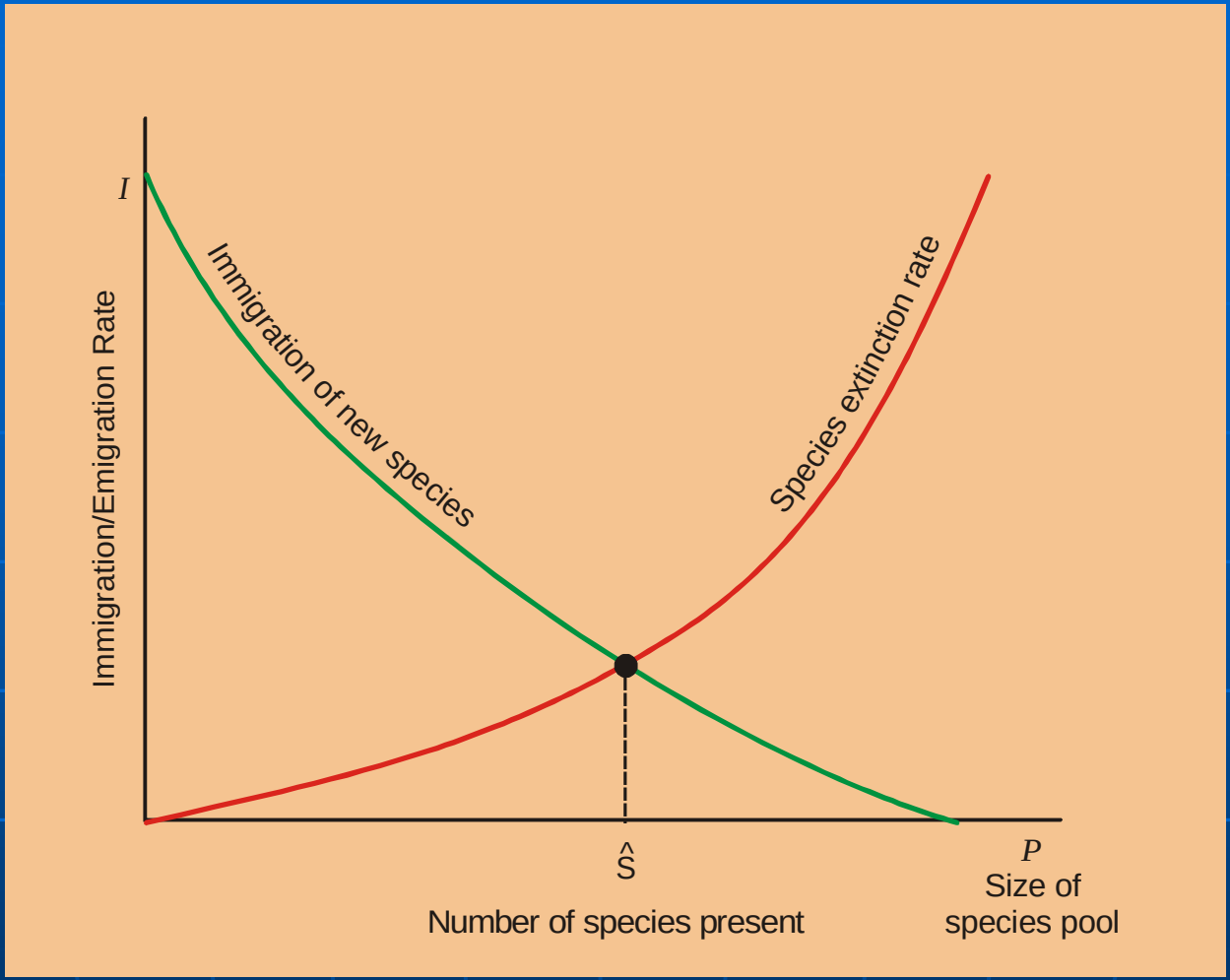
***Elasmias quadrasi* on underside of a *Terminalia* leaf**

- The **extinction rate** is the number of species going locally extinct on an island per unit of time
  - The extinction rate rises over time, because the chances of extinction increase as the number of species established on the island increases
    - That is, as diversity increases so do competition, predation, and parasitism, causing populations to decrease in size and making them more vulnerable to extinction



The extinction rate (the number of species becoming extinct per unit of time) rises because the chances of extinction depend upon the number of species already present.

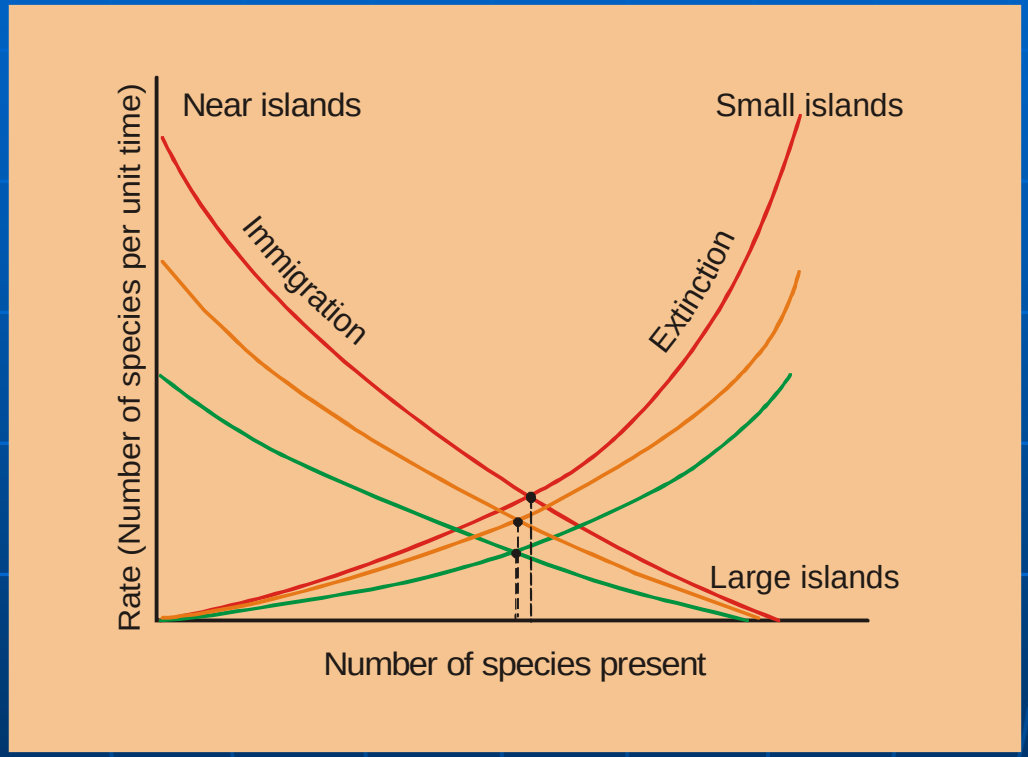
- How can scientists use this model?
  - When immigration rate and extinction rate are plotted on the same axes, the point where the immigration curve crosses the extinction curve is the equilibrium number of species ($\hat{S}$) for the island



Equilibrium model of a biota of a single island. The equilibrium number (S) is reached at the intersection point between the curve of the rate of immigration of new species not already on the islands and the curve of the extinction of species from the islands. [Adapted from MacArthur and Wilson, 1967].

- Island biogeography theory permits predictions about biota of islands:
  - Effects of distance (when size of islands is about the same)
    - Islands near the source area receive more dispersing species than distant islands
    - Increases in distance from the source area lower the immigration curve

- Effects of island size (when distance from the source area is about the same)
  - Smaller islands will have fewer species than larger islands
  - Increases in island size lower the extinction curve
- Thus, islands of varying sizes and varying distances from their source areas will have different equilibria of diversity


Near islands
Small islands
Immigration
Extinction
Large islands
Rate (Number of species per unit time)
Number of species present