Island biogeography and fragmentation

Loss in habitat area usually leads to habitat fragmentation

“Headline” rates of deforestation do not tell the whole story

To understand current thinking with regard to the impact of fragmentation on biodiversity we need to look at some underlying theory

Island biogeography and fragmentation

- The “Equilibrium Theory of Island Biogeography (ETIB) developed by Robert MacArthur and Edward Wilson 1967
- Aimed at generality through simplification
- Implications for contemporary landscape ecology are explicit in their original work.
- “Theories, like islands, are often reached through stepping stones”

Habitat implications

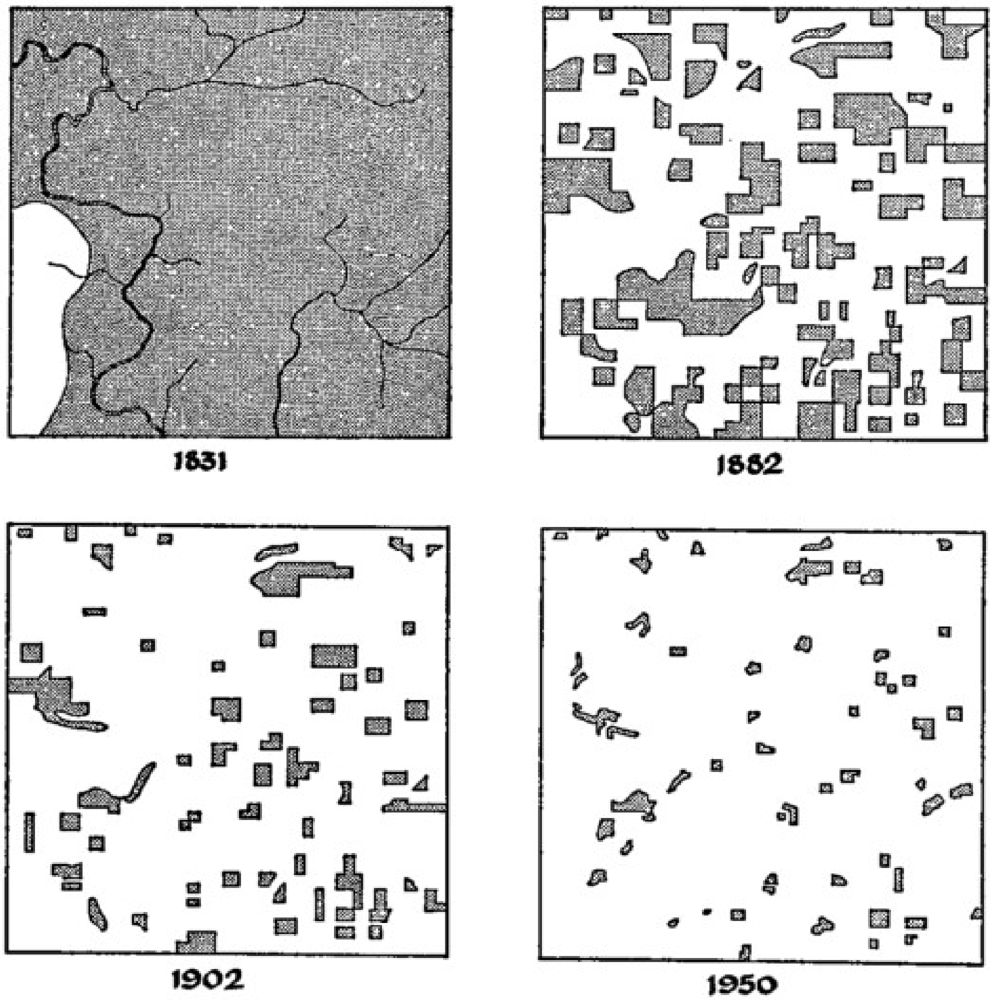


FIGURE 1. Reduction and fragmentation of the woodland in Cadiz Township, Wisconsin, 1831–1950. (After Curtis, 1956.)

Habitat implications

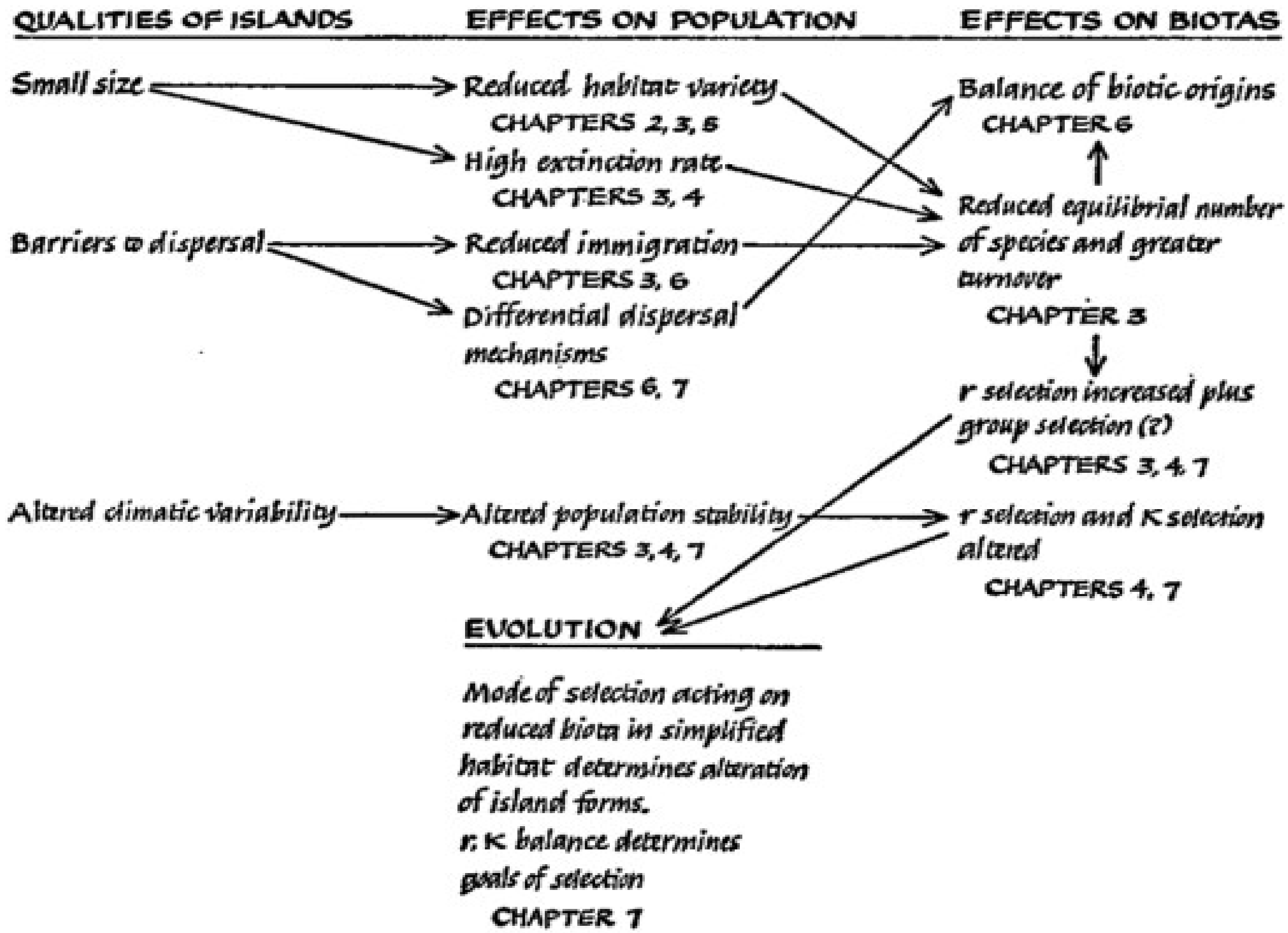
- For island read “habitat patch” or “fragment”.
- The ETIB has similar strengths and weaknesses in both contexts

Theory and practice

- The ETIBG has been intensely criticised since its inception
- However the ideas encapsulated in the theory explain why Biogeographers, landscape ecologists and conservationists are so interested in fragmentation and connectivity
- Many themes used in the study of fragmentation were first mentioned by McArthur and Wilson in their book

Themes of landscape ecology in MacArthur and Wilson

TABLE 1. Interrelations of chapters



The famous figure

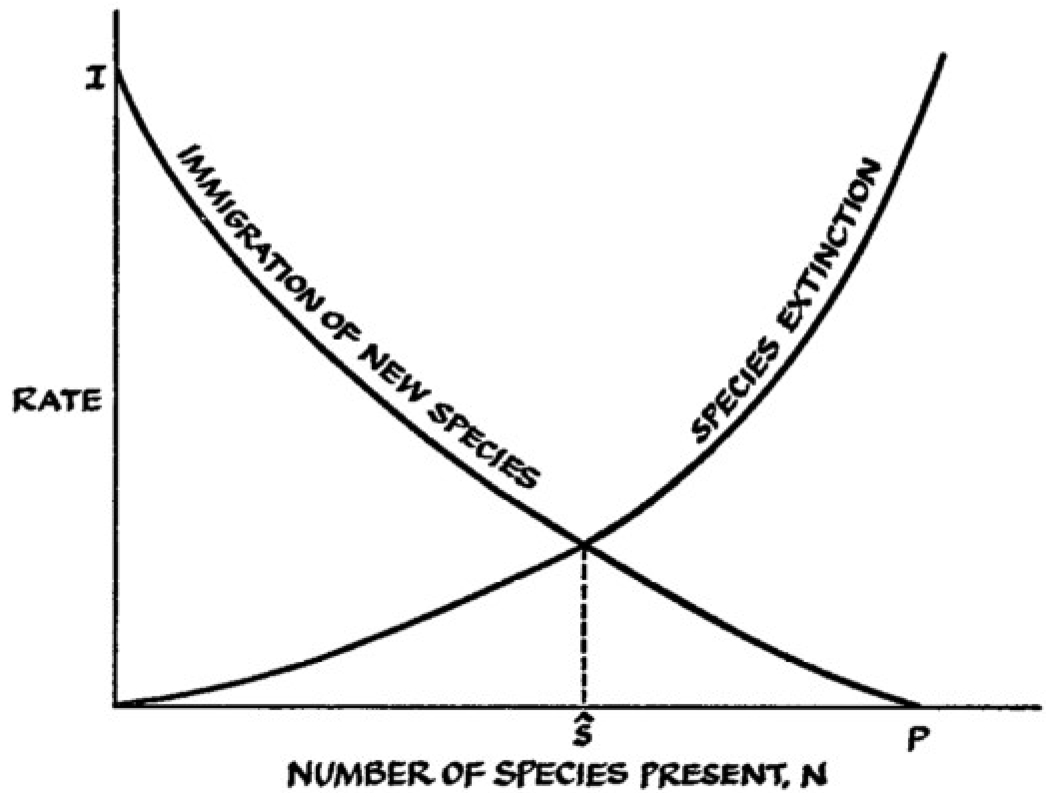
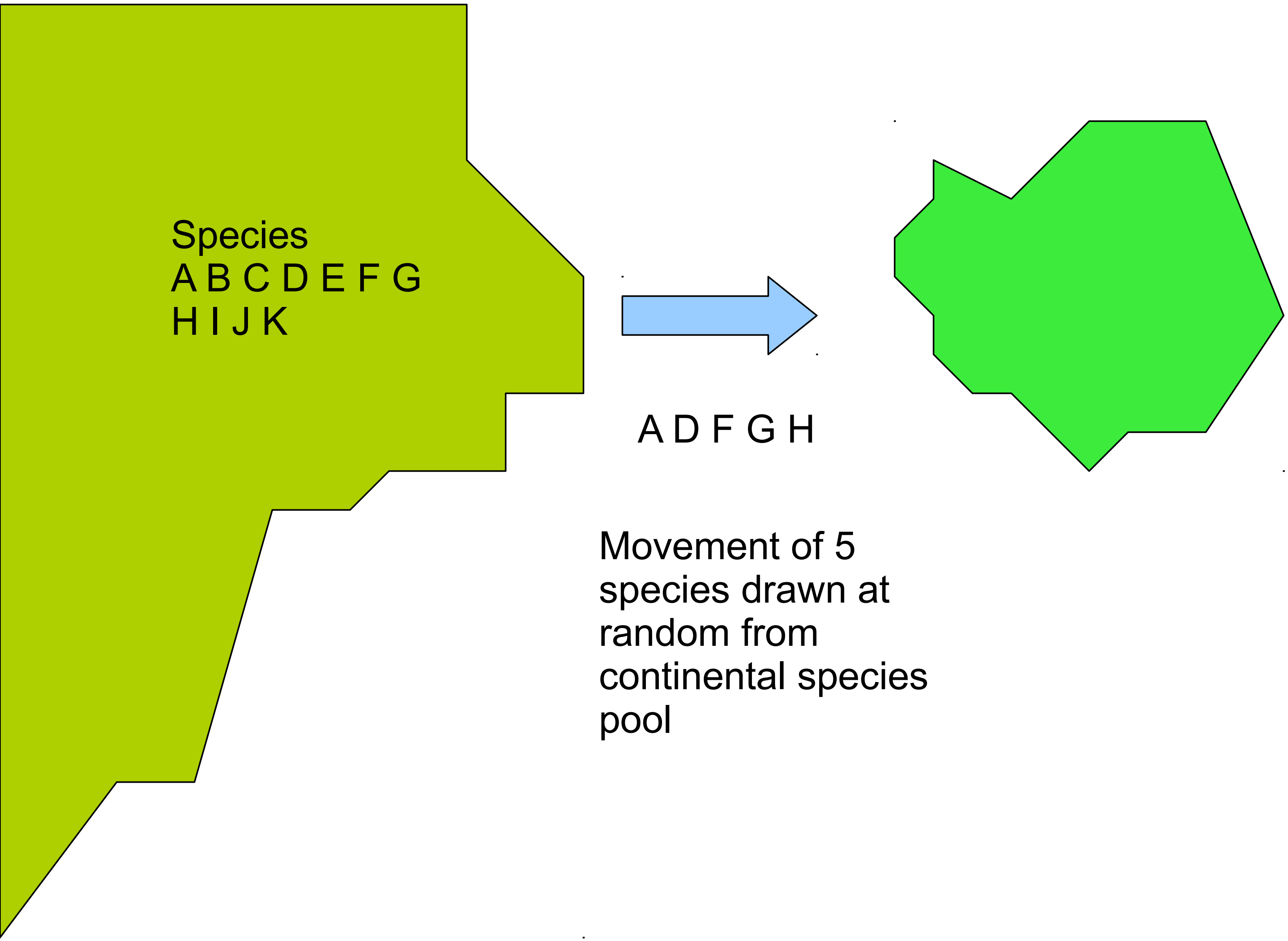


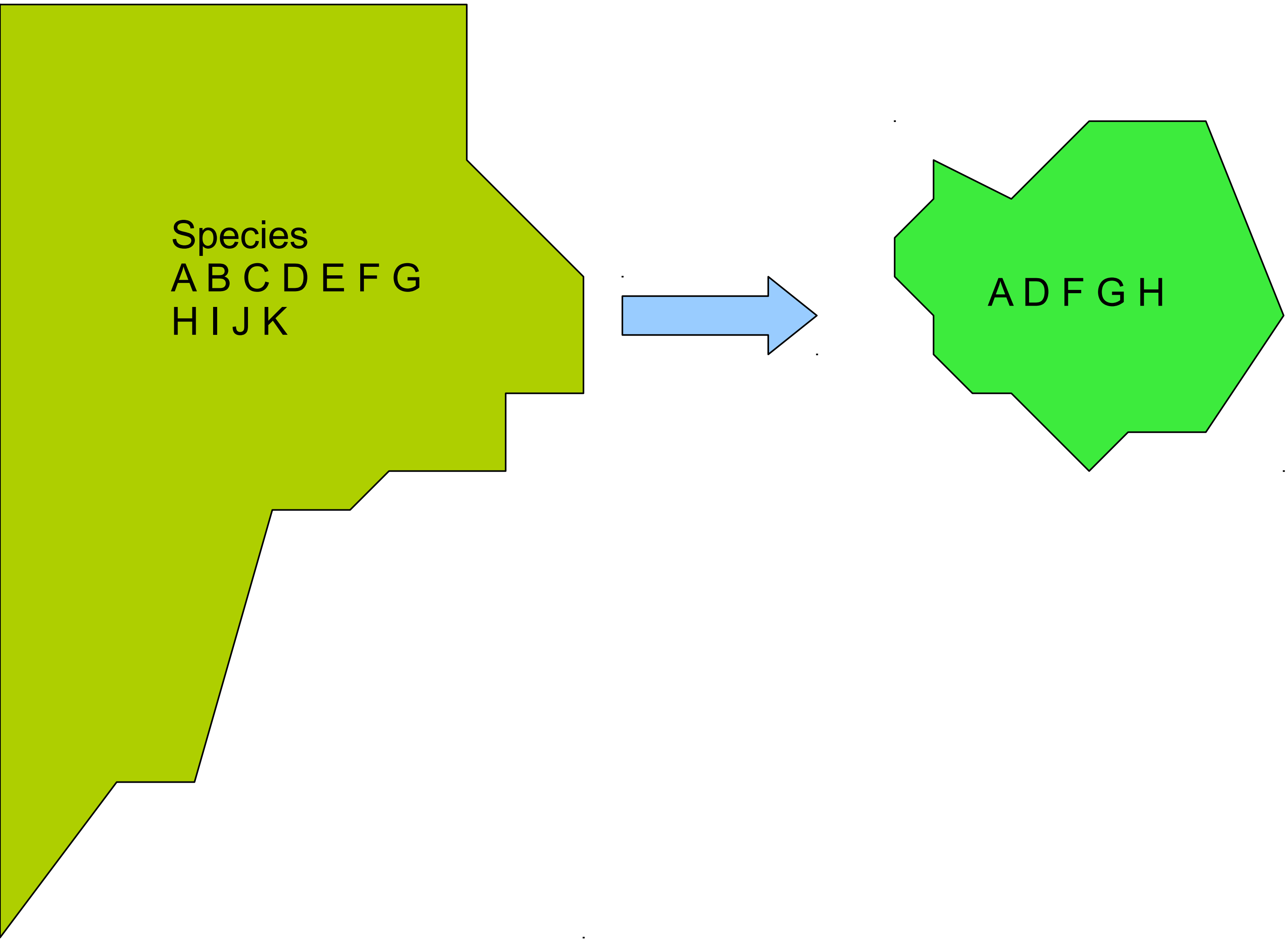
FIGURE 7. Equilibrium model of a biota of a single island. The equilibrial species number is reached at the intersection point between the curve of rate of immigration of new species, not already on the island, and the curve of extinction of species from the island. (After MacArthur and Wilson, 1963.)

Immigration



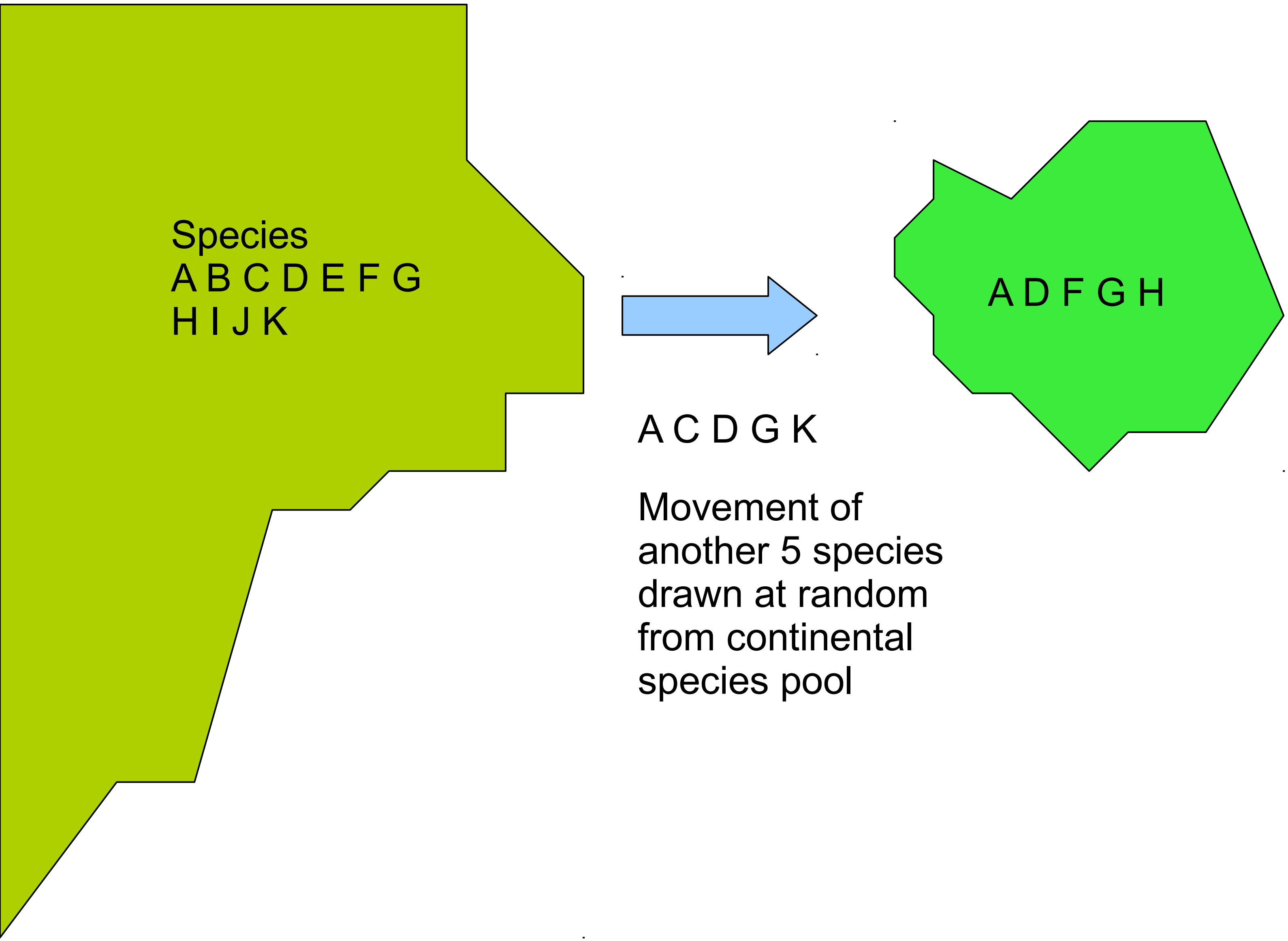
Movement of 5 species drawn at random from continental species pool

Immigration



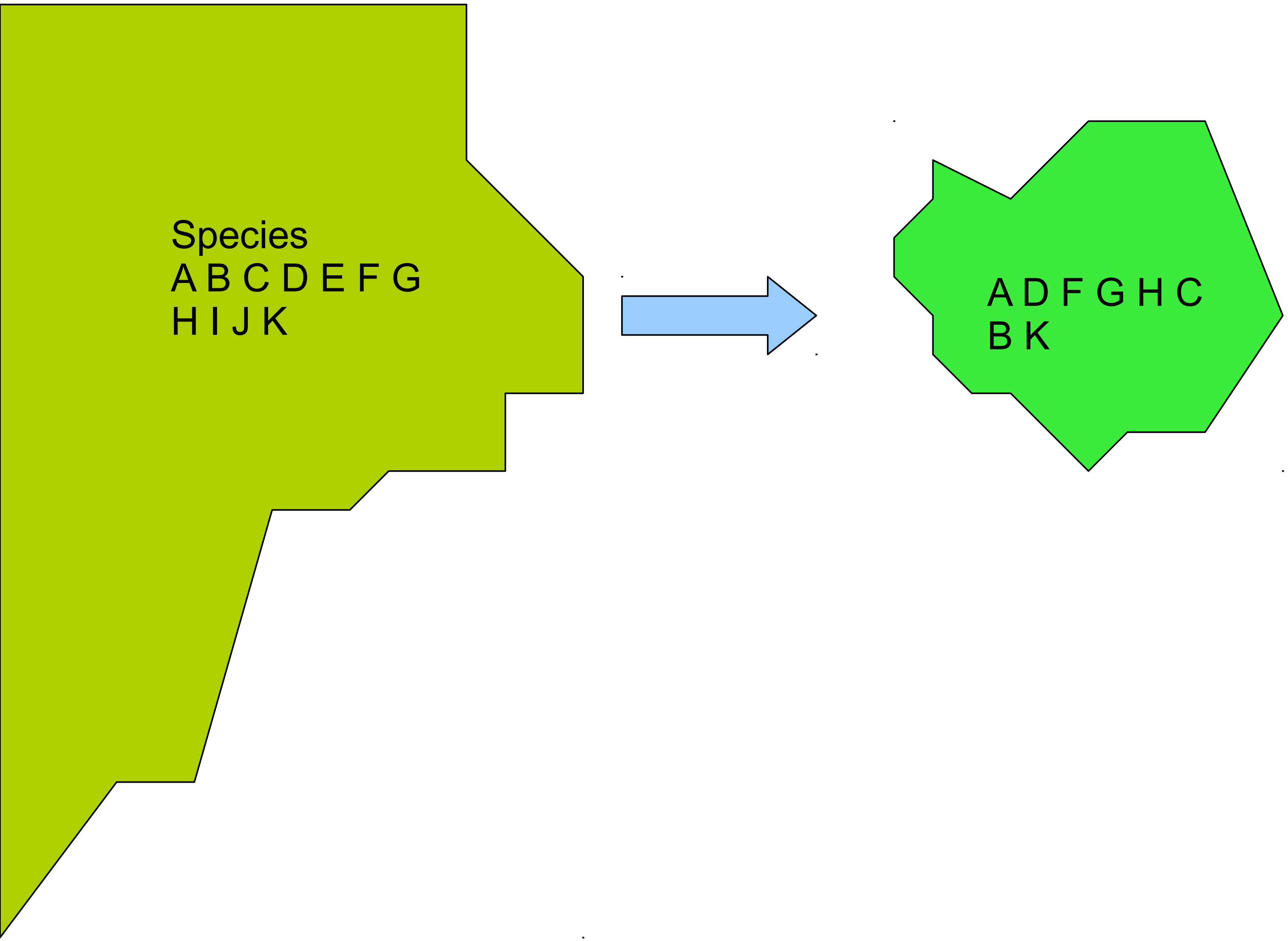
Island gains all
5 species

Immigration



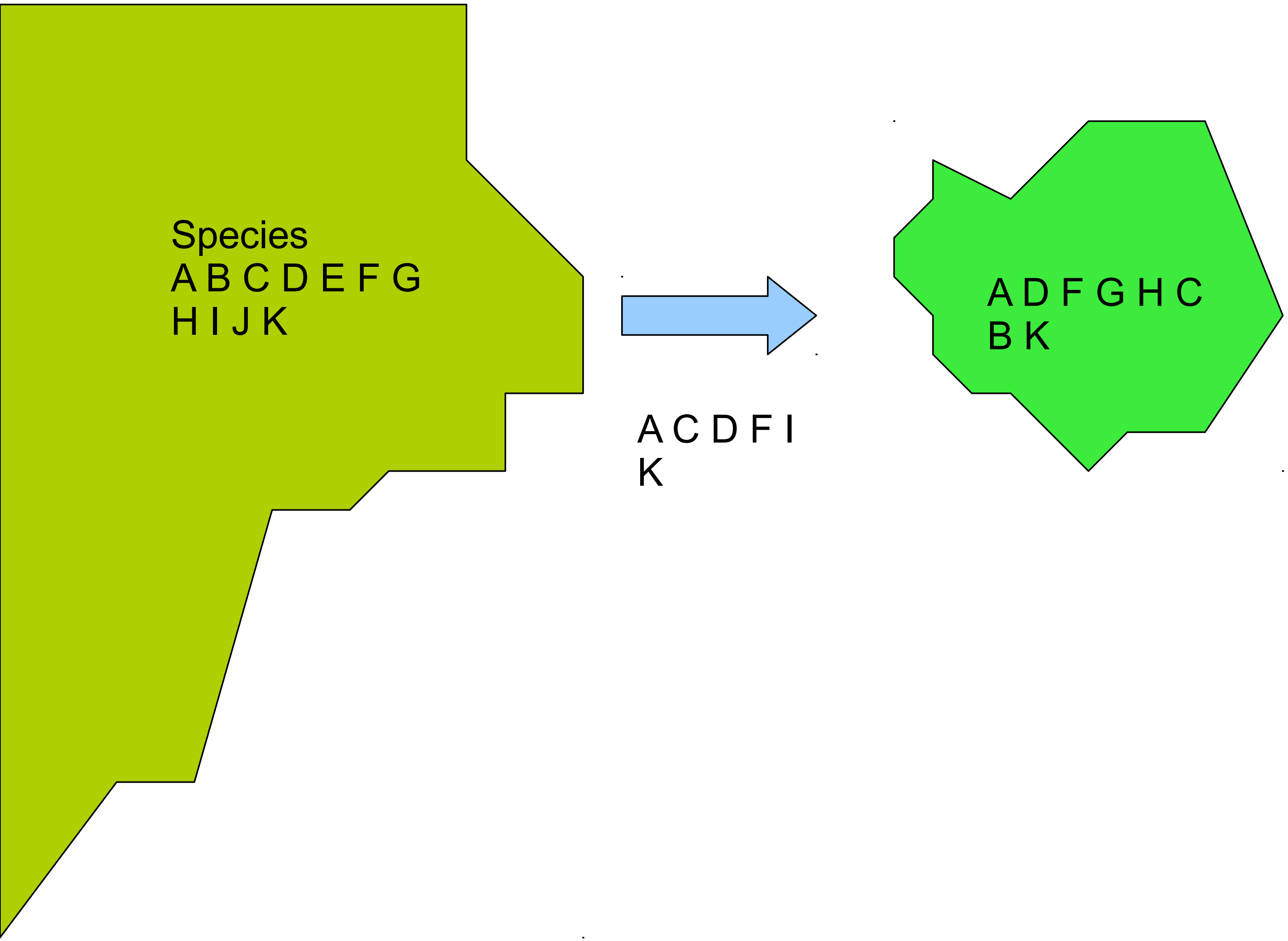
Movement of another 5 species drawn at random from continental species pool

Immigration

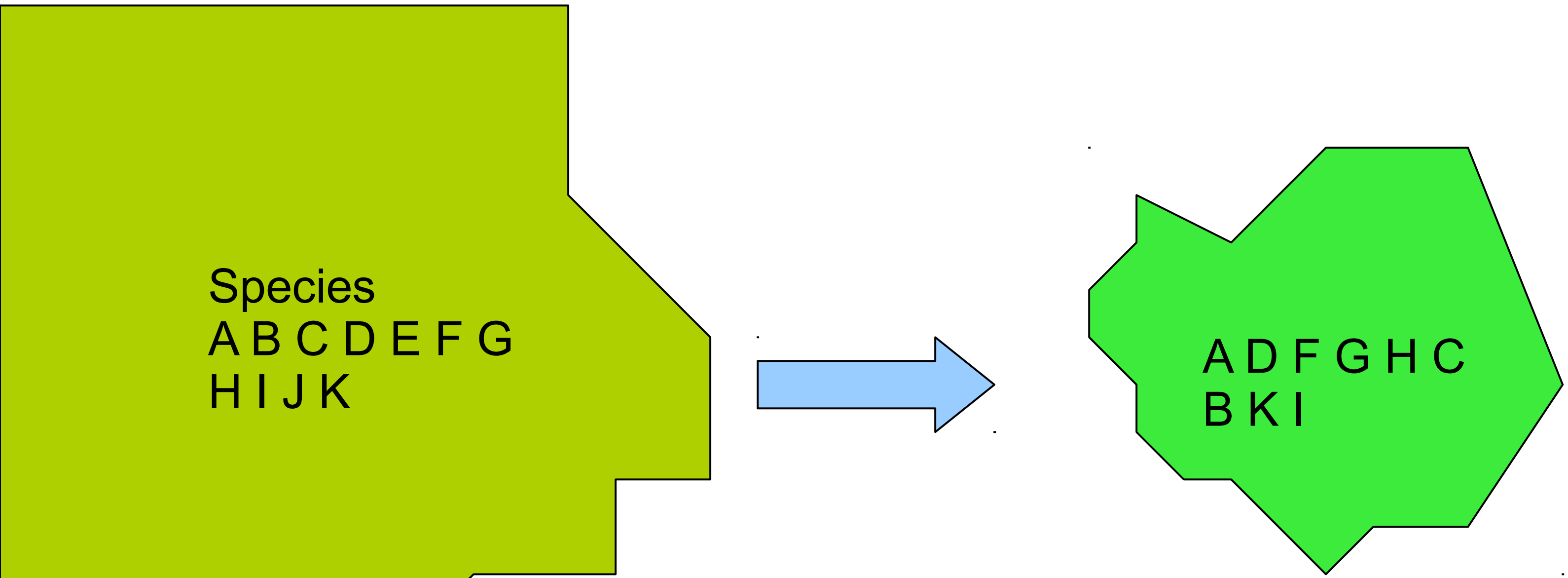


Island only gains 3 species as 2 species were already there.

Immigration



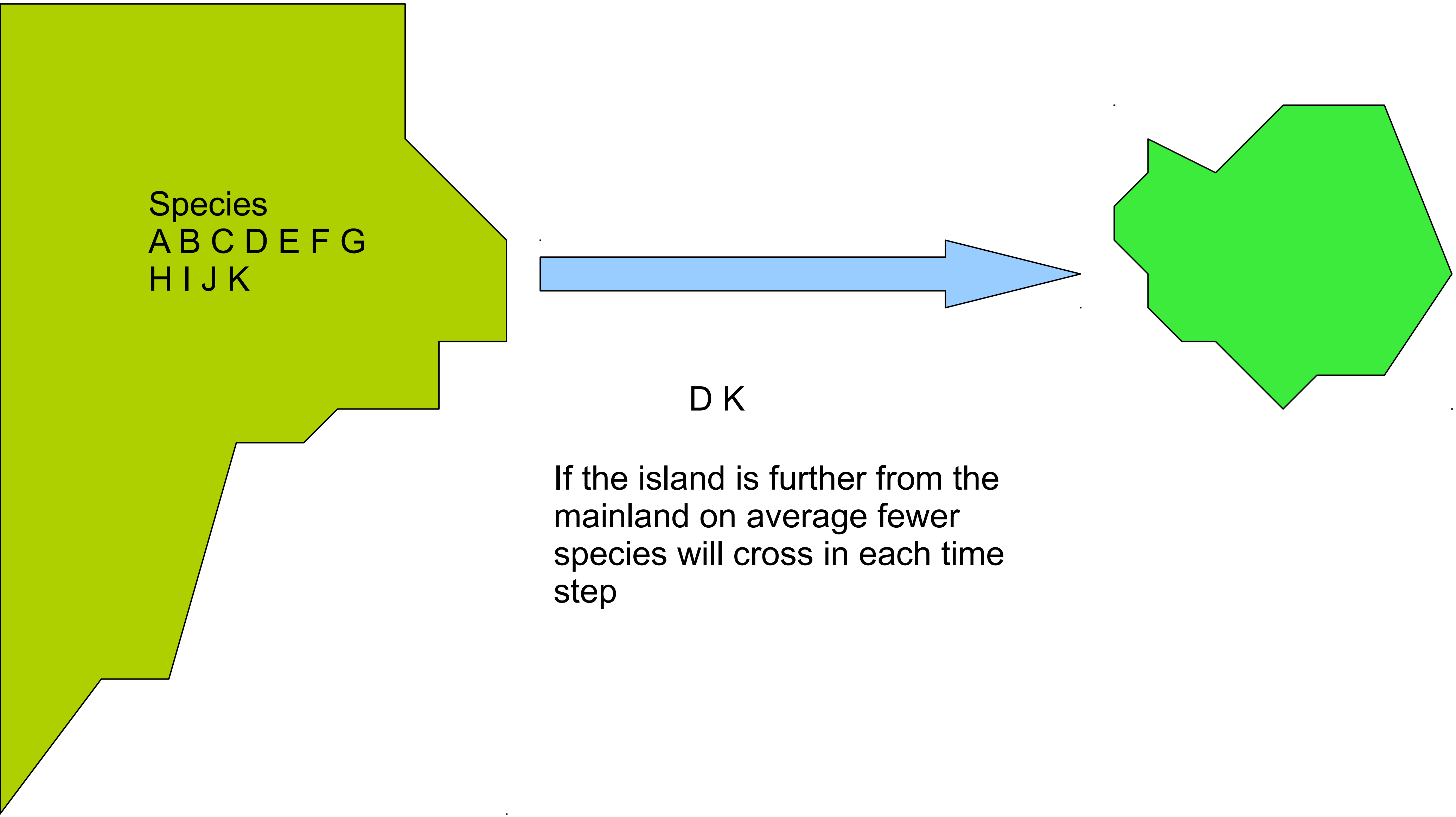
Immigration curve



This time only one species is new.

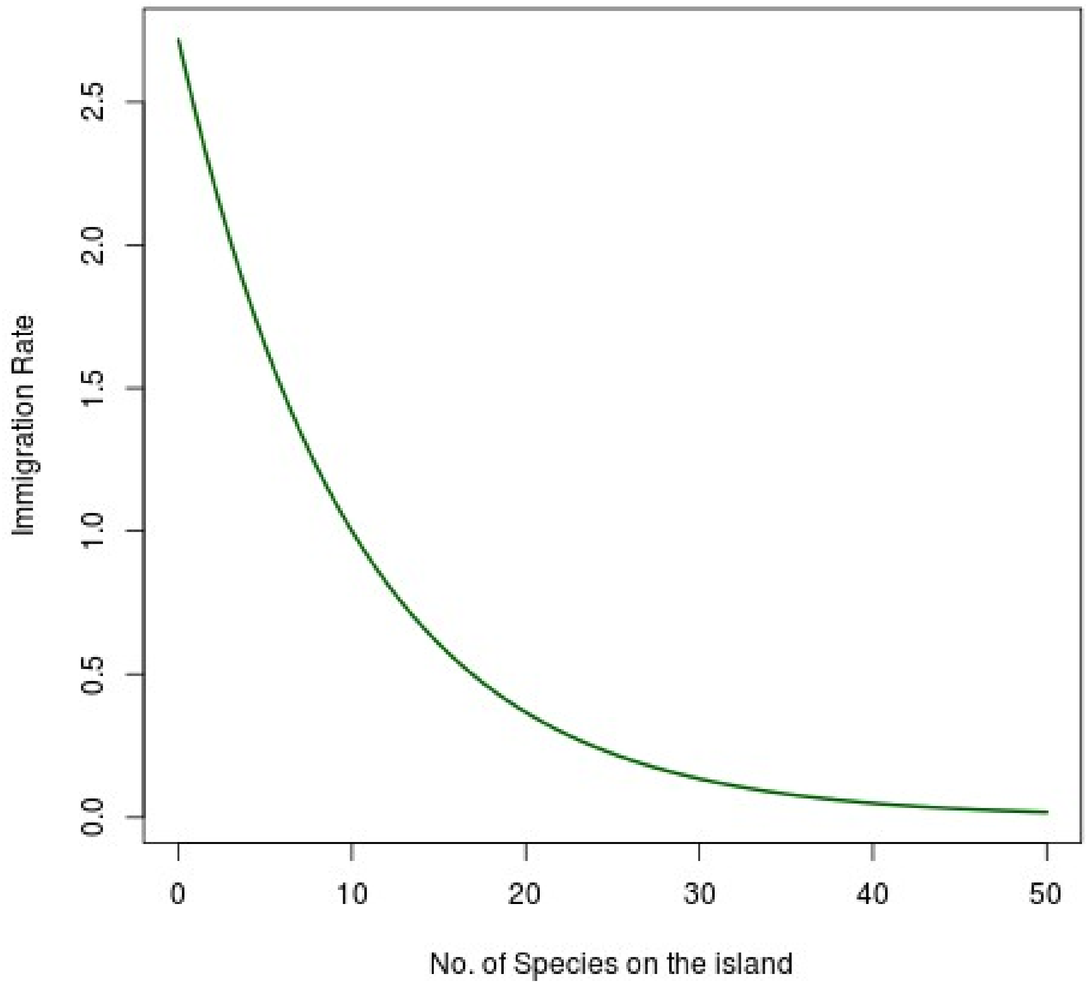
As time goes on it becomes less and less likely that a **new** species will cross to the island. If there were no extinctions the island would eventually have all the species found on the mainland

Immigration curve

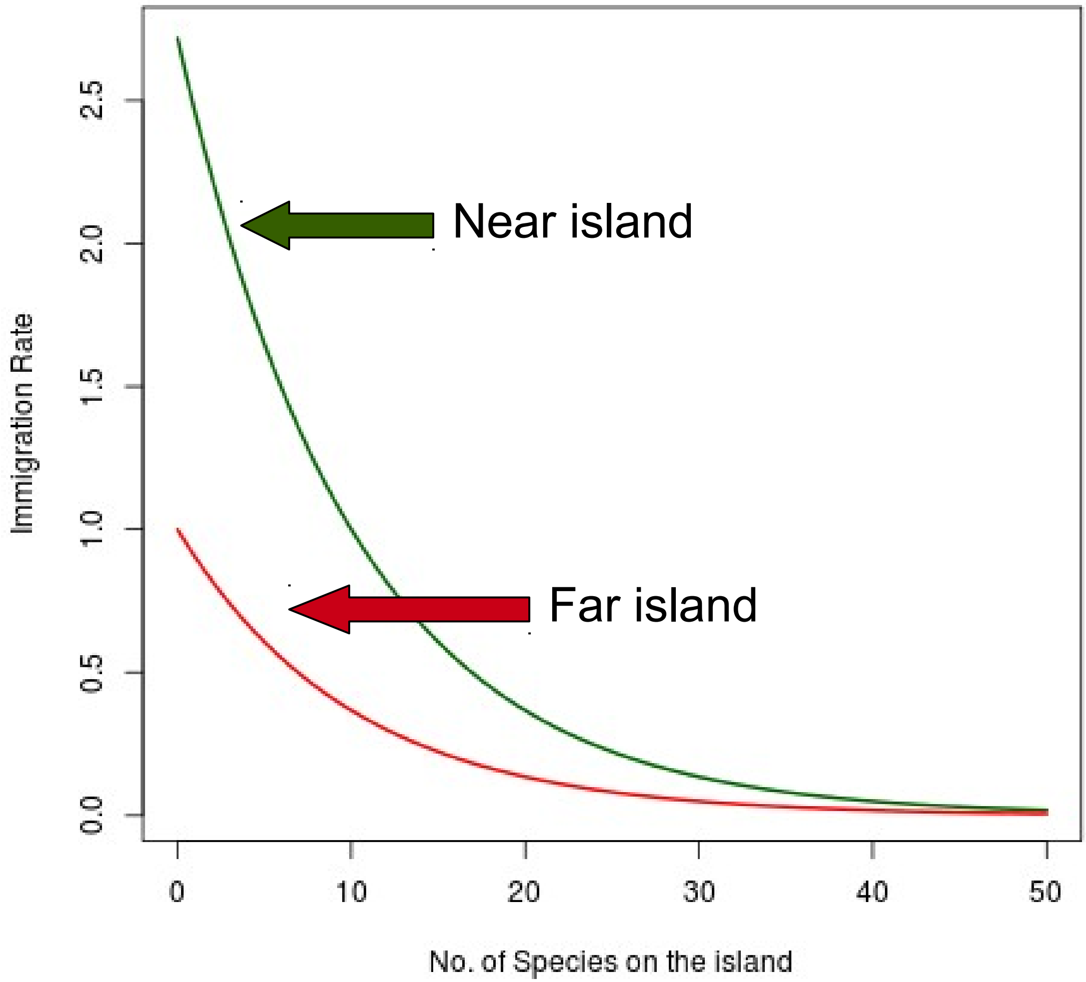


If the island is further from the mainland on average fewer species will cross in each time step

Immigration curve

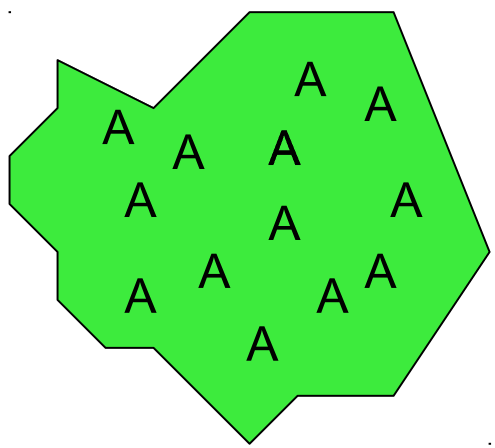


Immigration curve



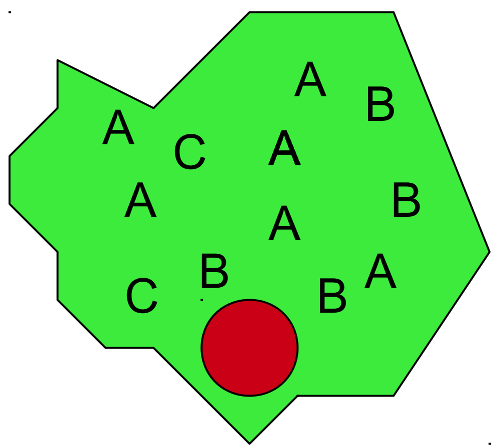
Extinction curve

- If an island has no species, none can go extinct.
- If an island has only one species it can occupy all the area.



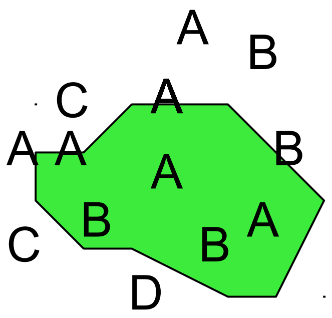
Extinction curve

- If an island has many species it will have more rare species as space becomes filled.
- Rare species are more likely to become extinct

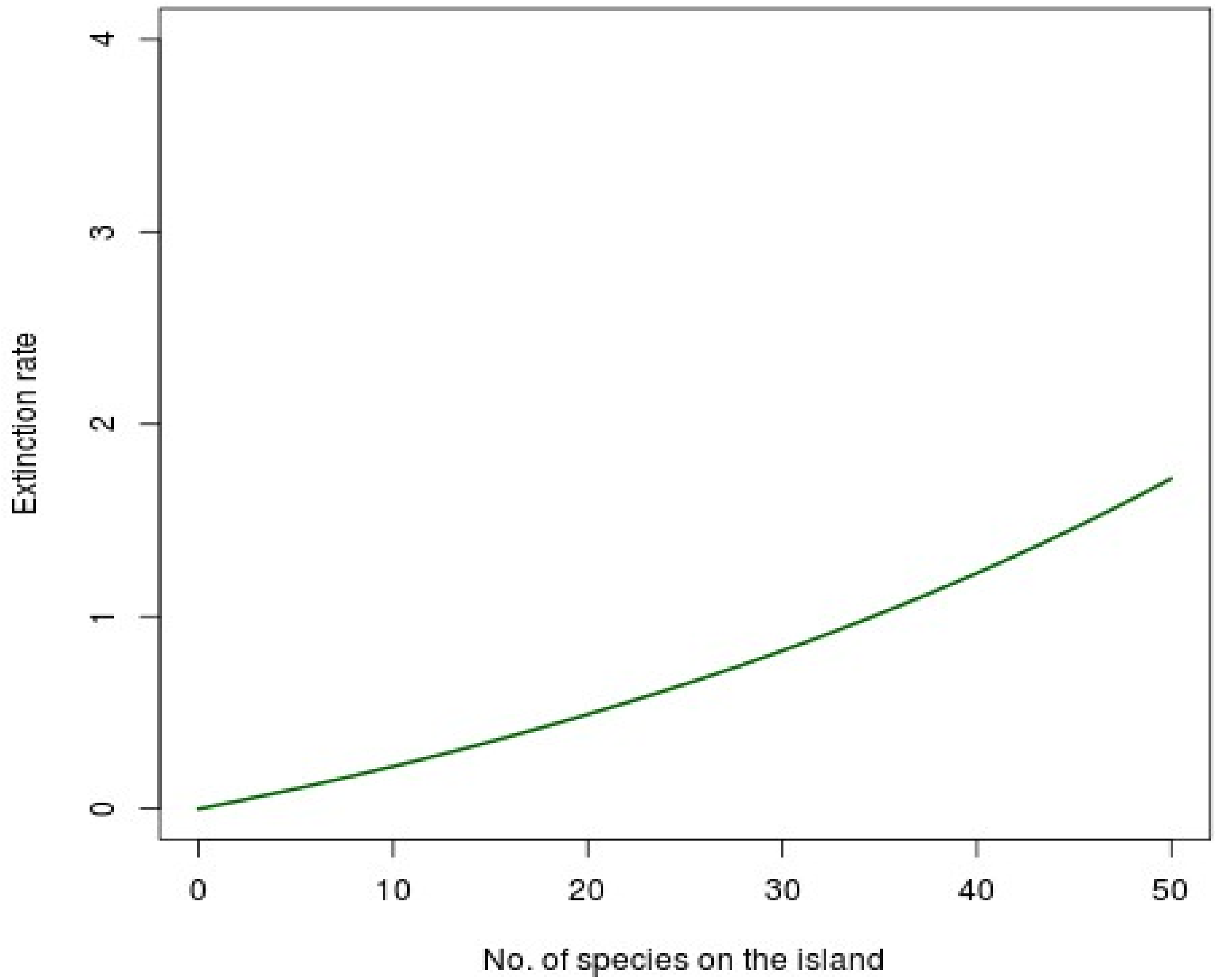


Extinction curve

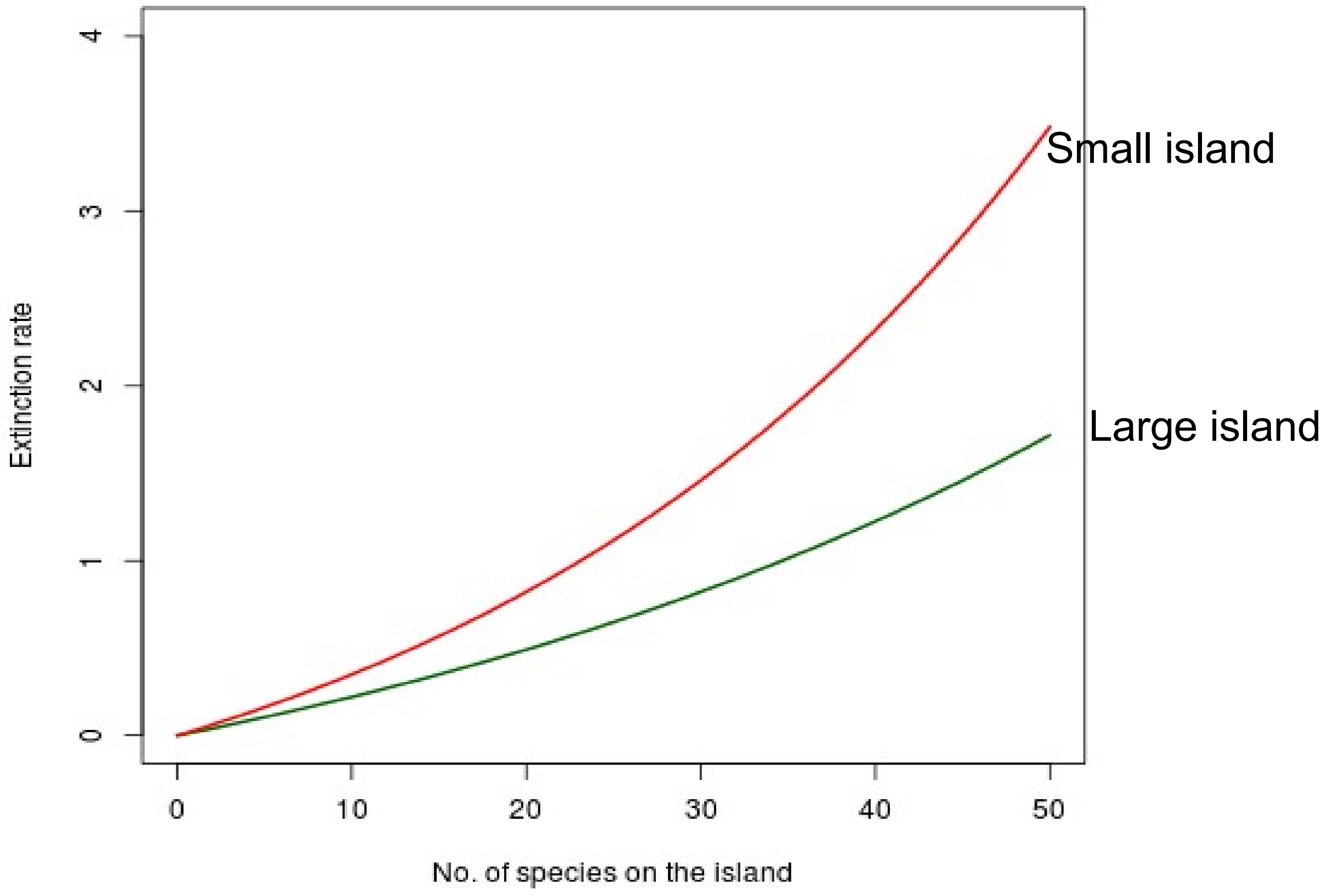
- Smaller islands can support fewer individuals and thus fewer species.



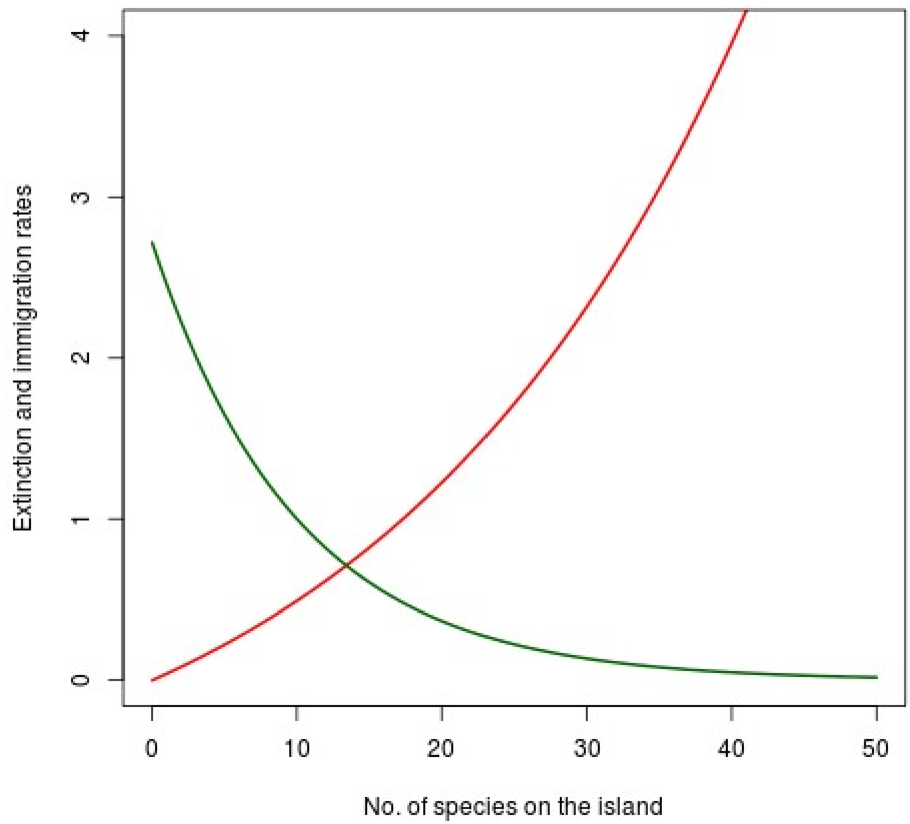
The extinction curve



Effect of island size



Putting the two together



That figure again

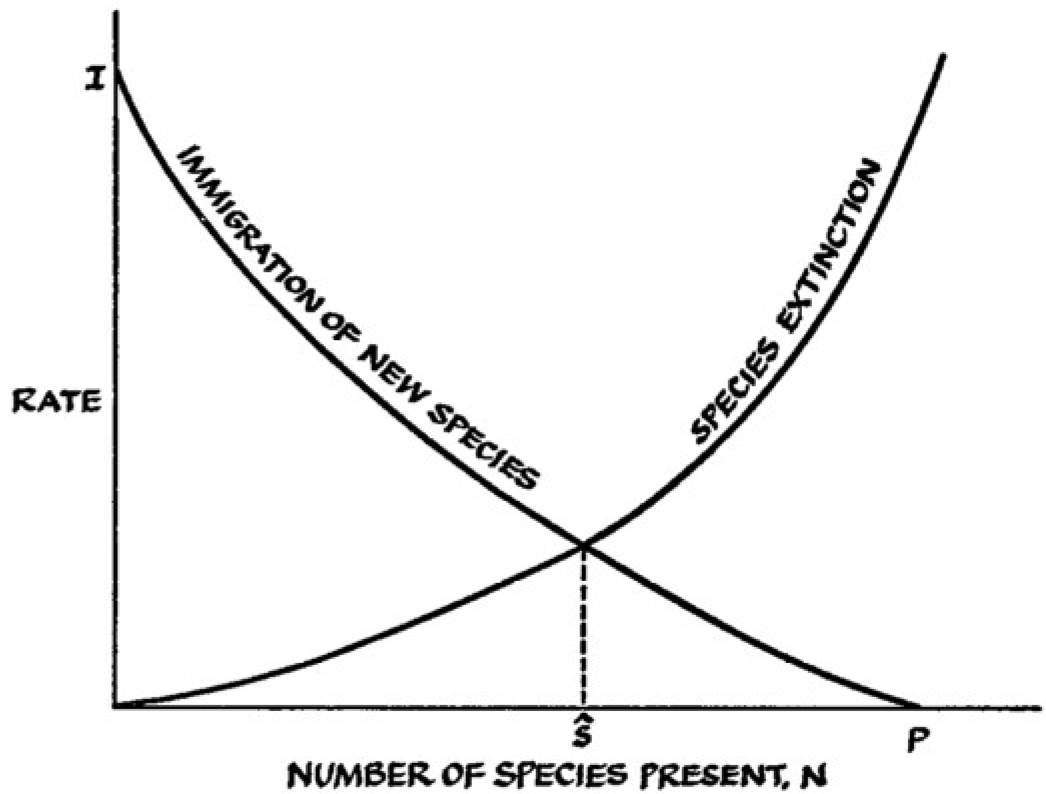


FIGURE 7. Equilibrium model of a biota of a single island. The equilibrial species number is reached at the intersection point between the curve of rate of immigration of new species, not already on the island, and the curve of extinction of species from the island. (After MacArthur and Wilson, 1963.)

Different combinations lead to different equilibrium points

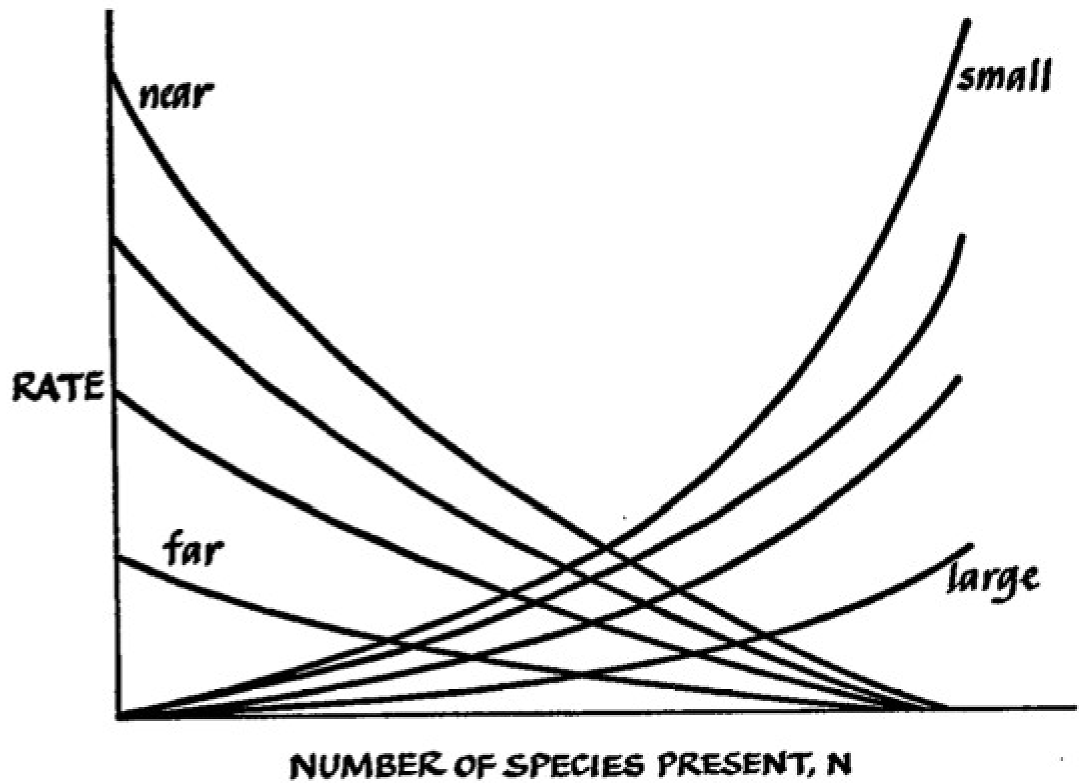
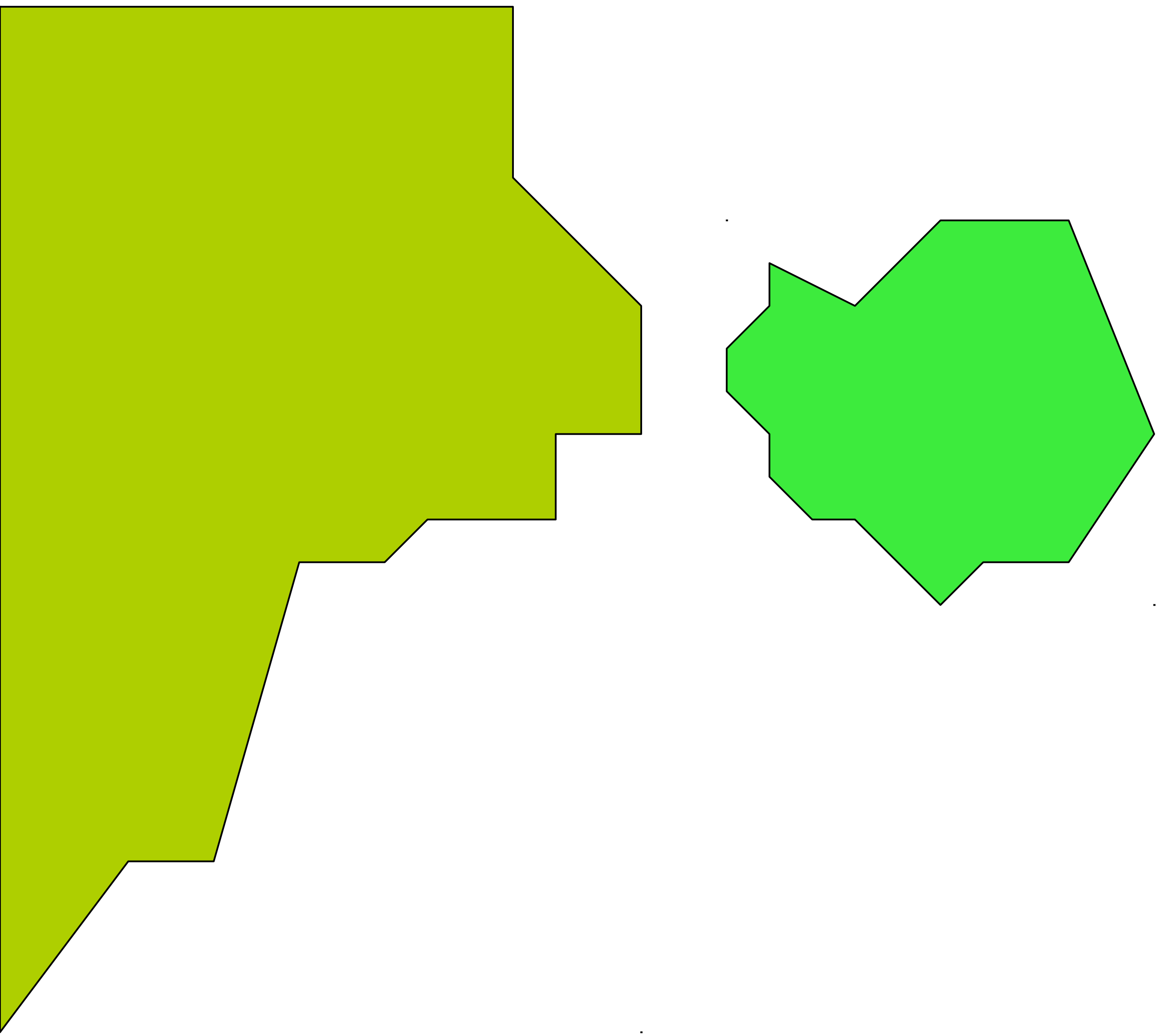
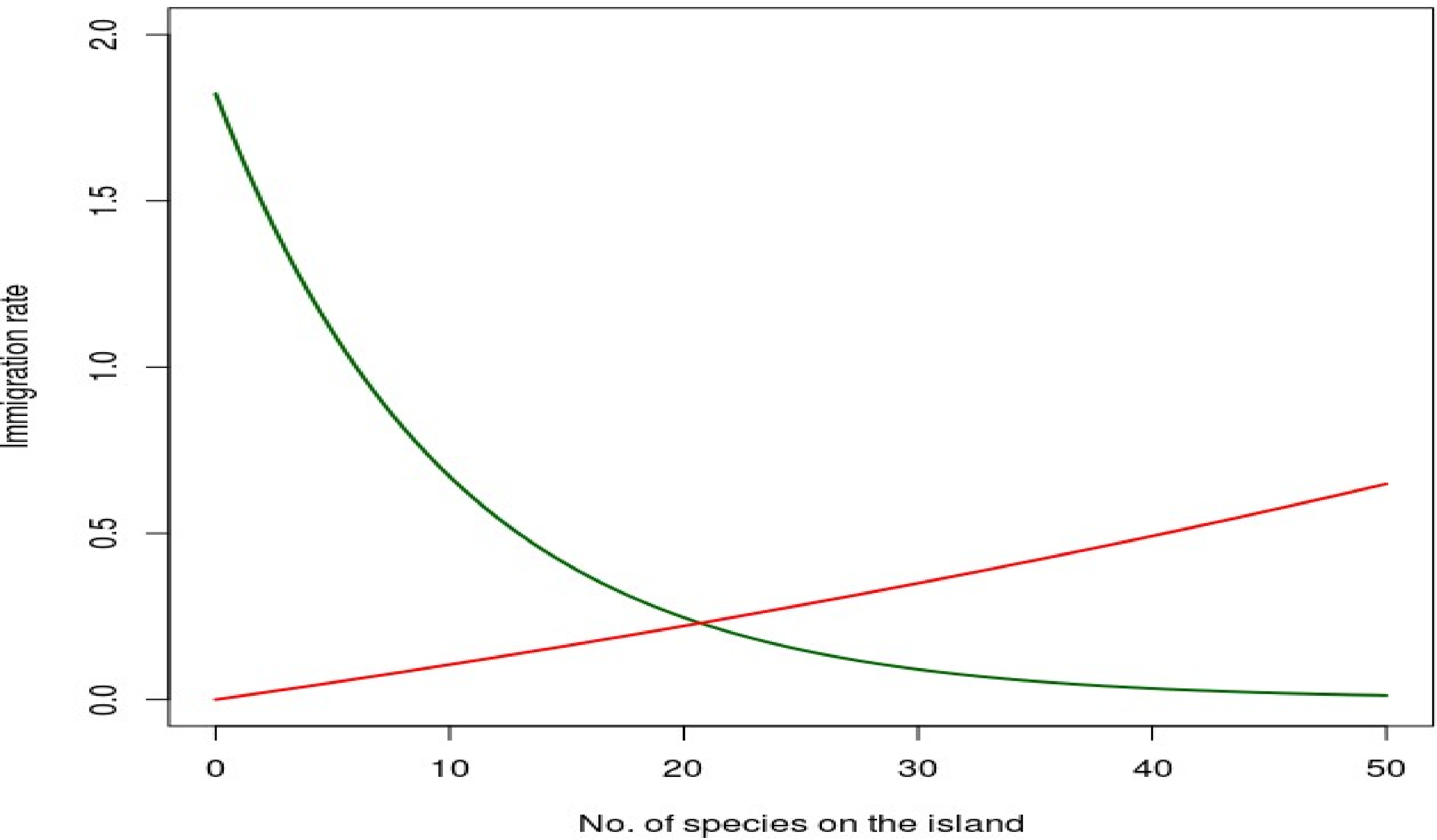


FIGURE 8. Equilibrium models of biotas of several islands of varying distances from the principal source area and of varying size. An increase in distance (near to far) lowers the immigration curve, while an increase in island area (small to large) lowers the extinction curve. (After MacArthur and Wilson, 1963.)

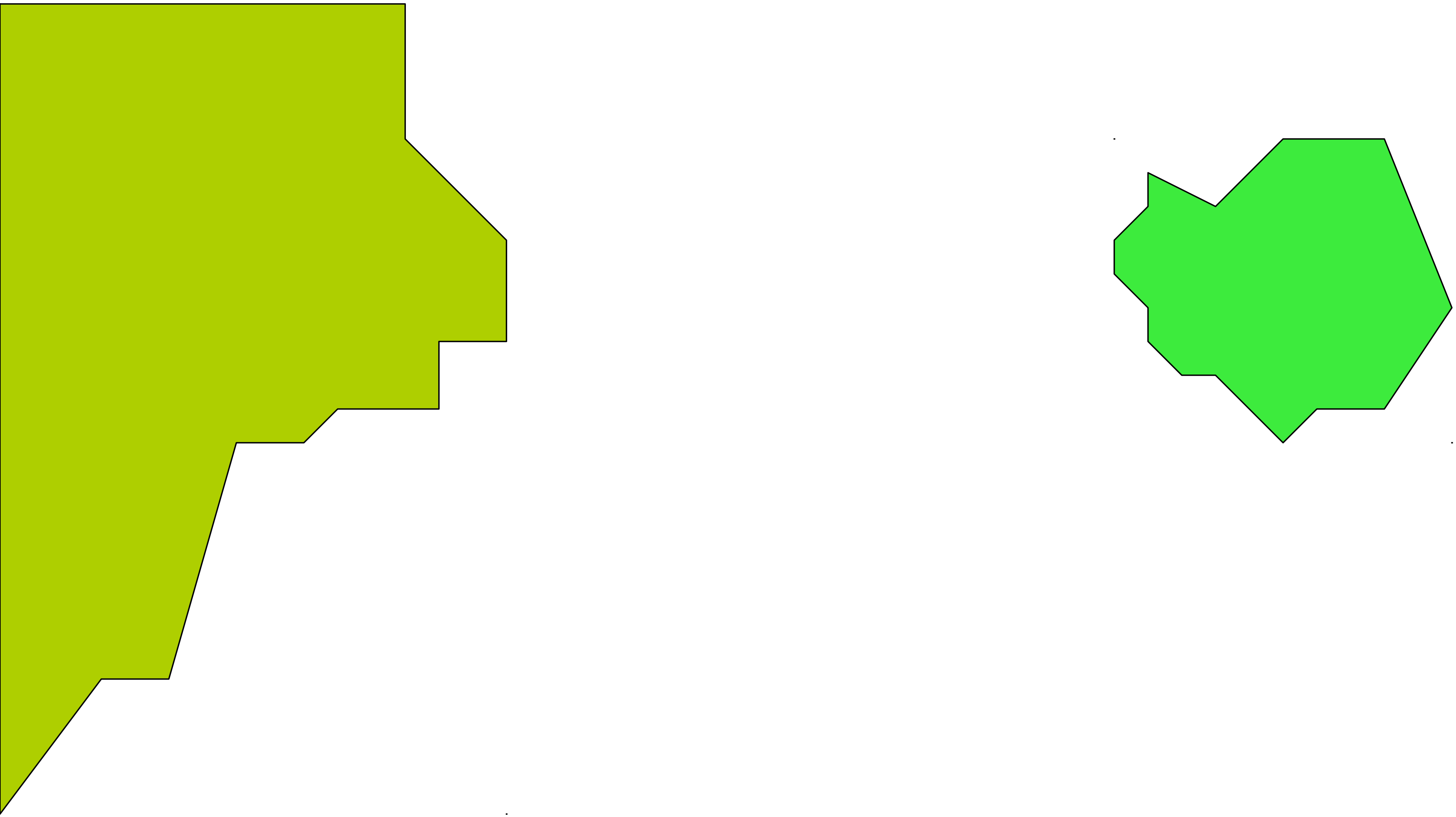
Contrasting situations



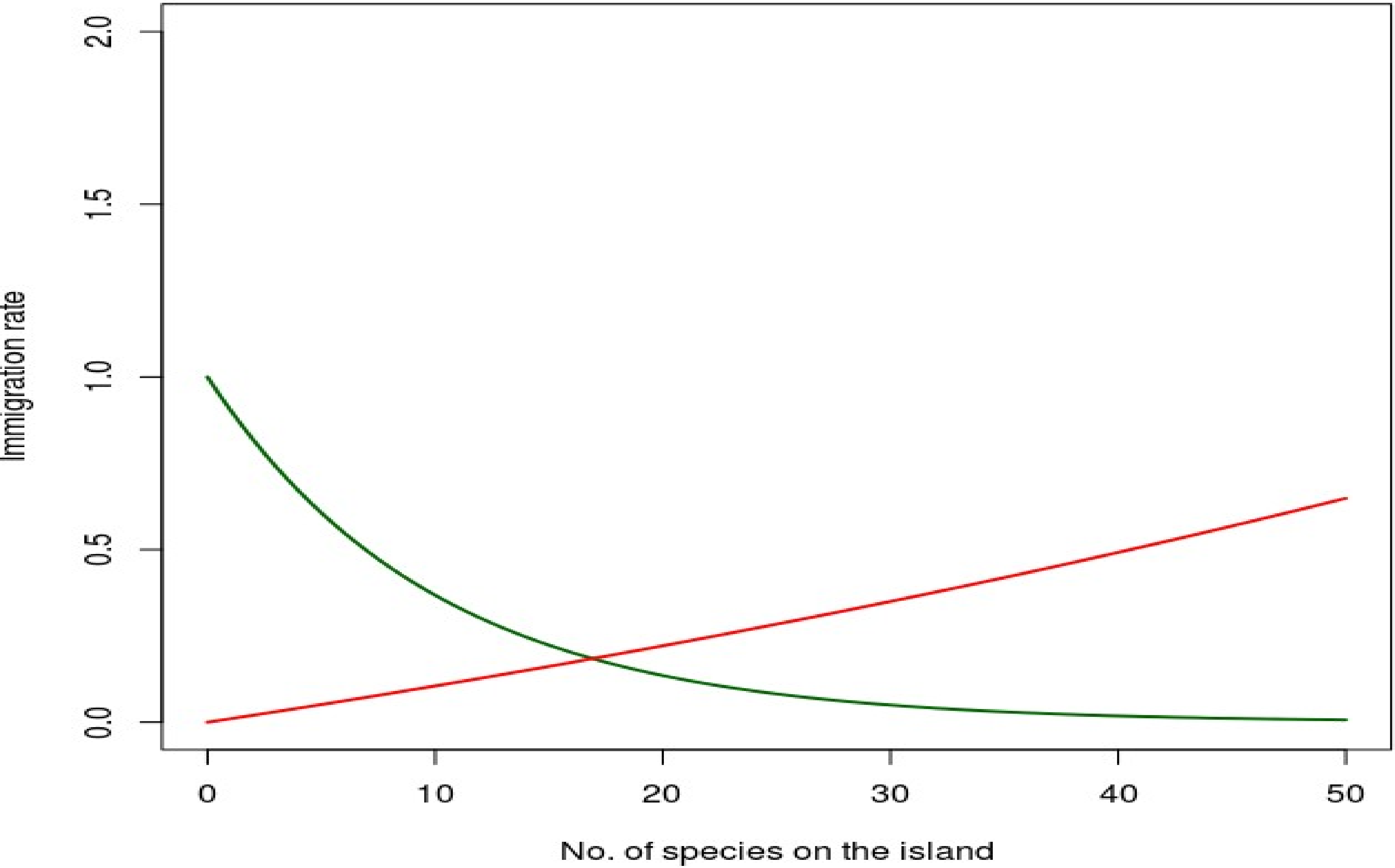
Contrasting situations



Contrasting situations



Contrasting situations



Contrasting situations

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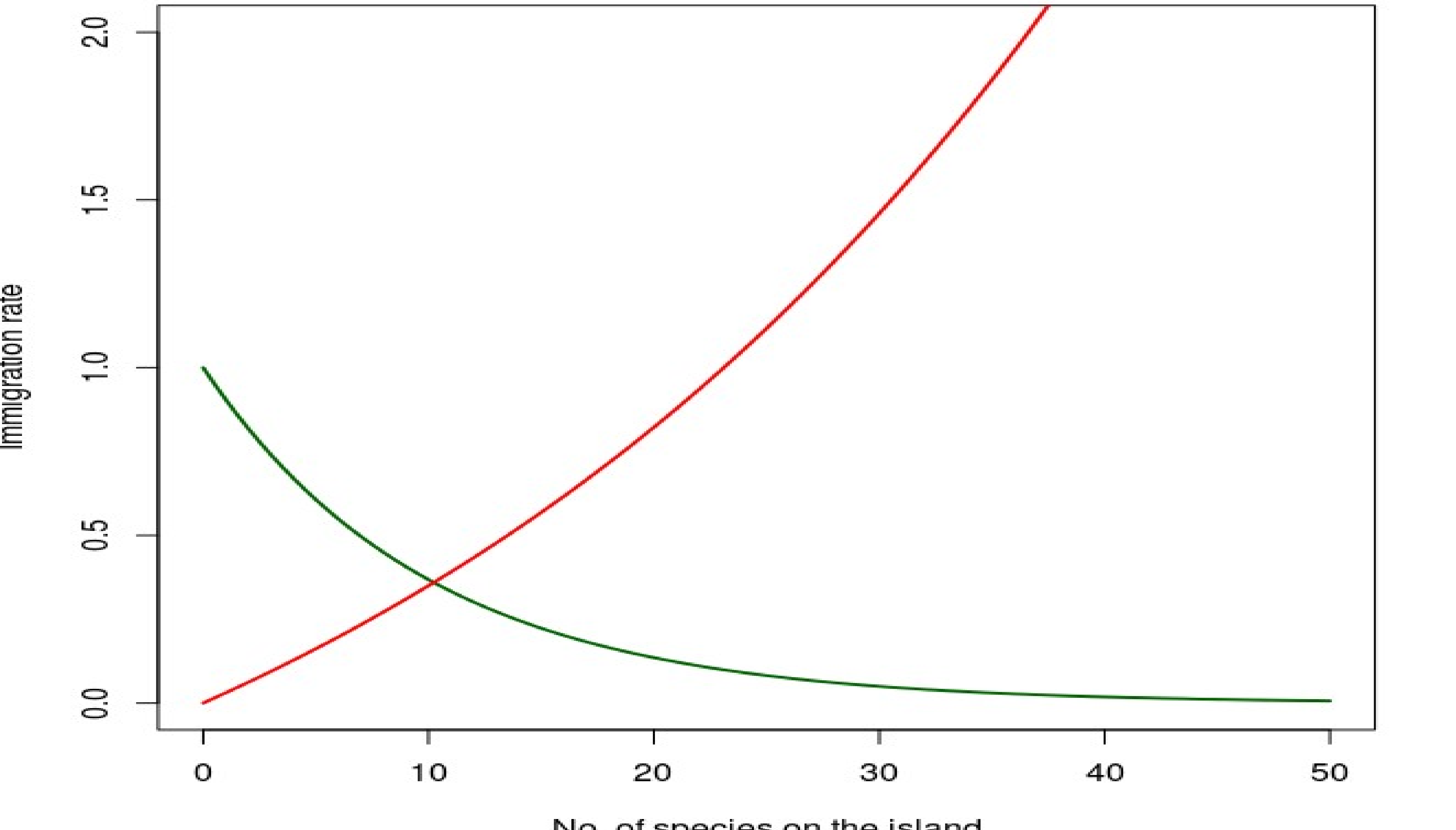
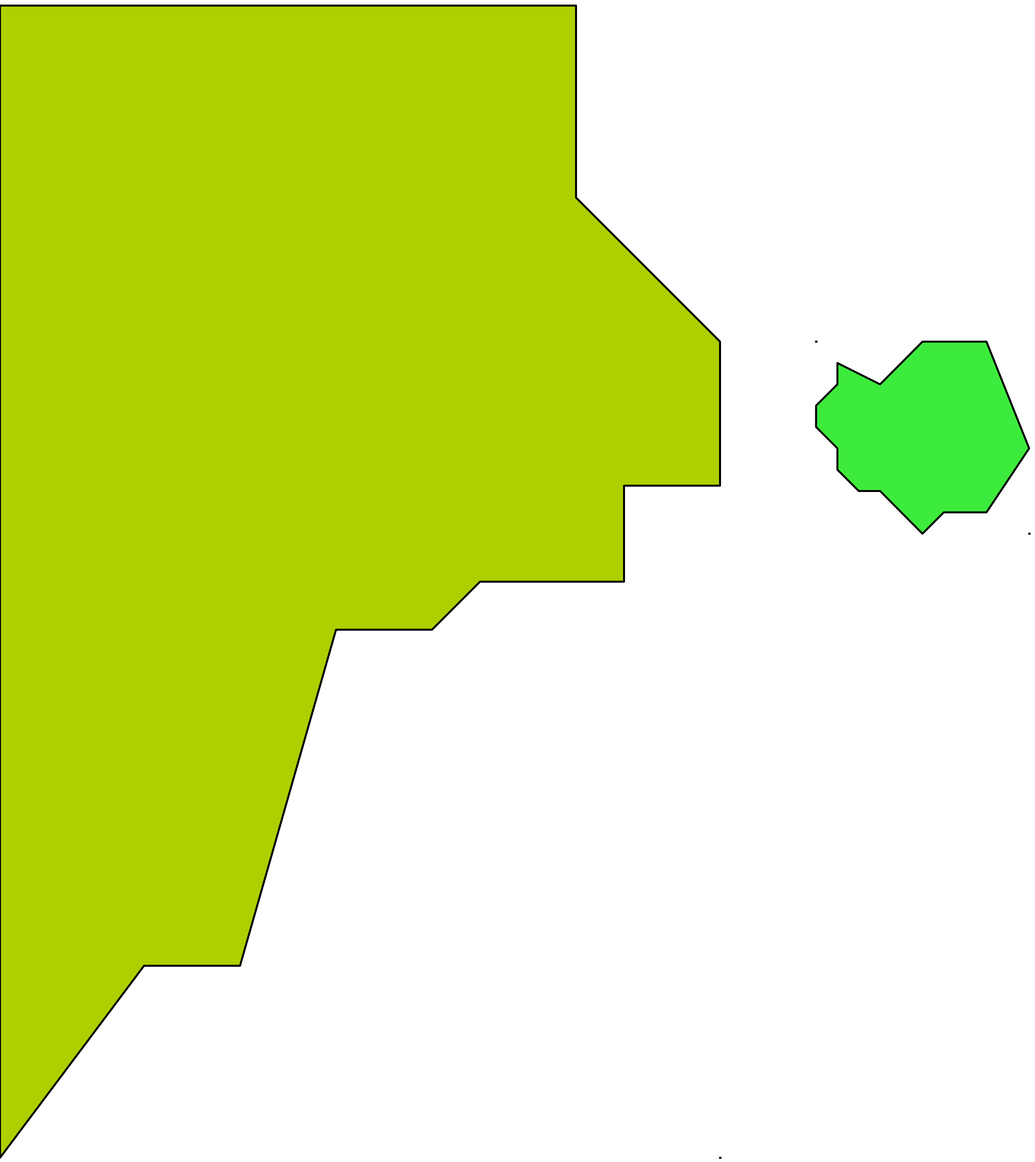
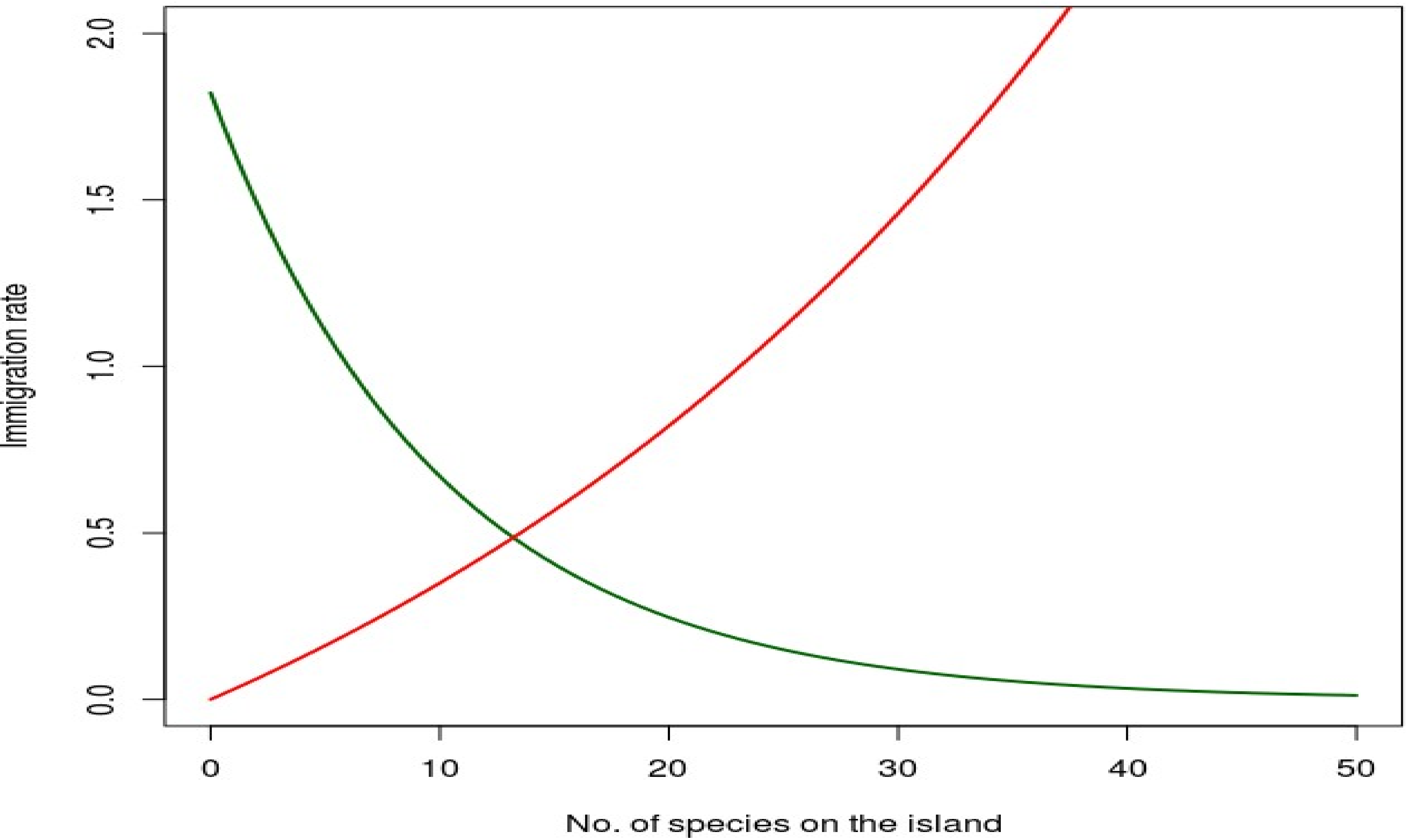


Contrasting situations



Contrasting situations



Evidence: The area effect

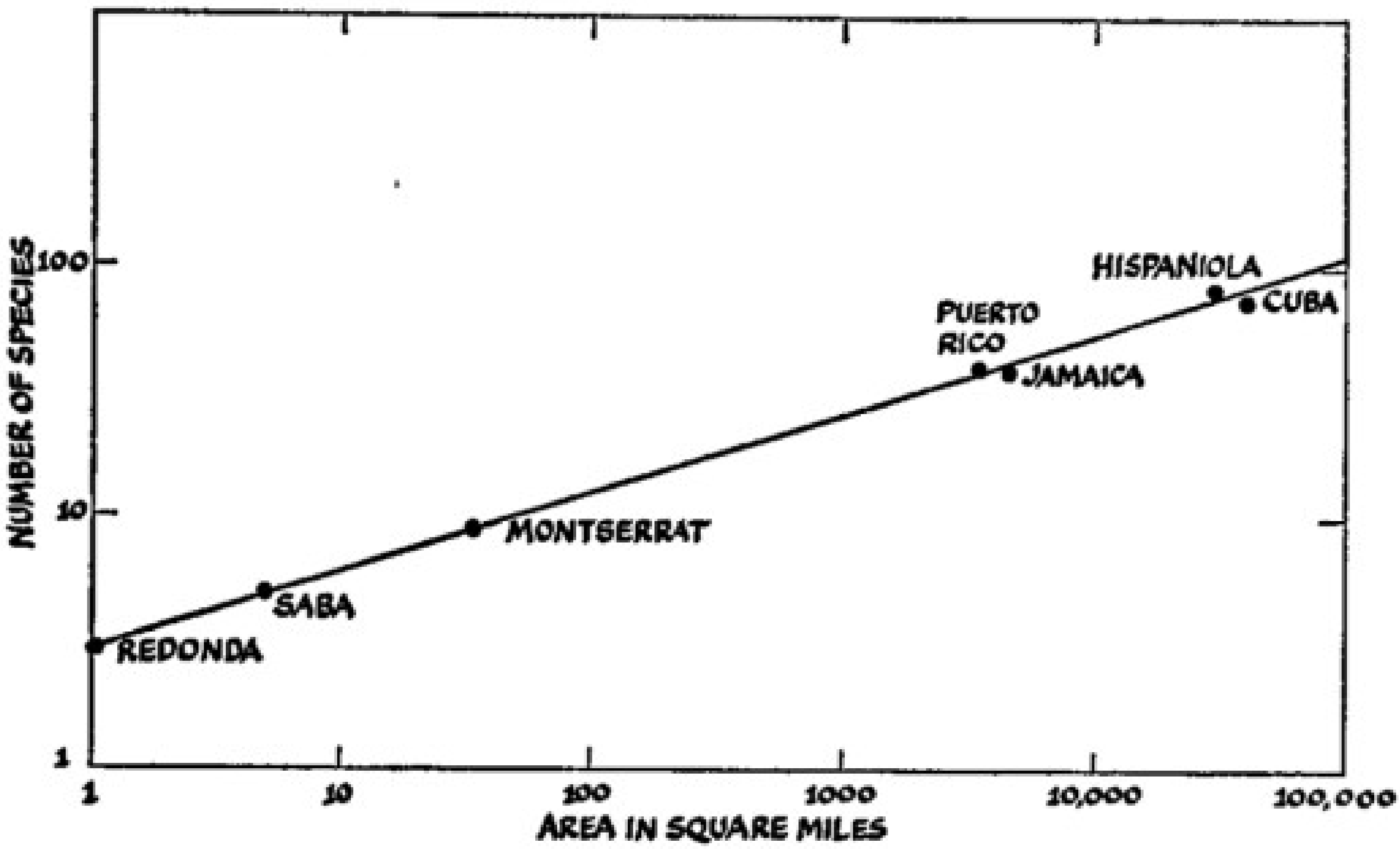


FIGURE 2. The area-species curve of the West Indian herpetofauna (amphibians plus reptiles).

Evidence: The area effect

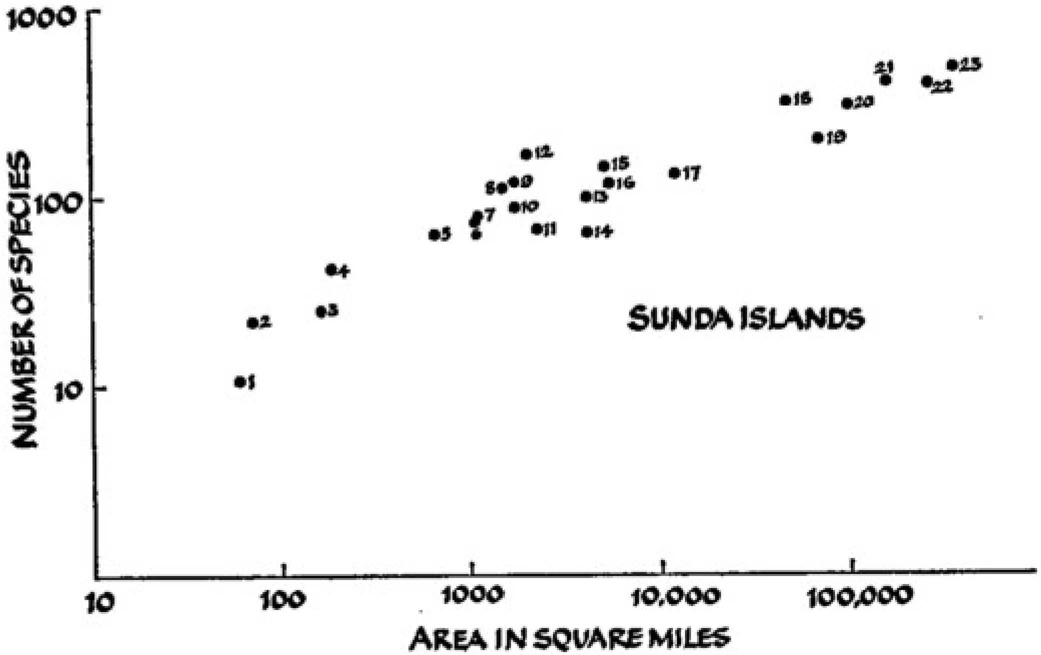


FIGURE 9. The numbers of land and fresh-water bird species on various islands and archipelagos of the Sunda group, together with the Philippines and New Guinea. The islands and archipelagos are grouped close to one another and to the Asian continent and Greater Sunda group, where most of the species live; and the distance effect is not apparent. Christmas, 1; Bawean, 2; Engano, 3; Savu, 4; Simalur, 5; Alors, 6; Wetar, 7; Nias, 8; Lombok, 9; Billiton, 10; Mentawei, 11; Bali, 12; Sumba, 13; Bangka, 14; Flores, 15; Sumbawa, 16; Timor, 17; Java, 18; Celebes, 19; Philippines, 20; Sumatra, 21; Borneo, 22; New Guinea, 23. (Modified from MacArthur and Wilson, 1963.)

Evidence: Population extinction on small islands

- Pimm, Jones and Diamond (1988) looked at the risk of extinction of populations of birds on 16 British islands ranging in size from 0.07 to 7.65 km²
- Monitored over several decades. Some populations became extinct and recolonised

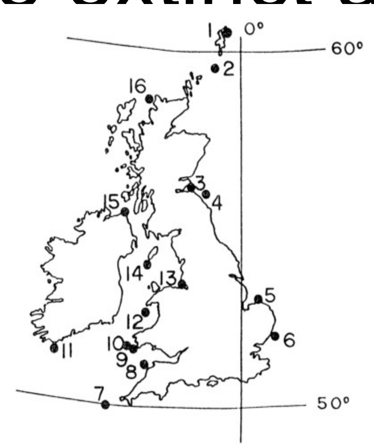
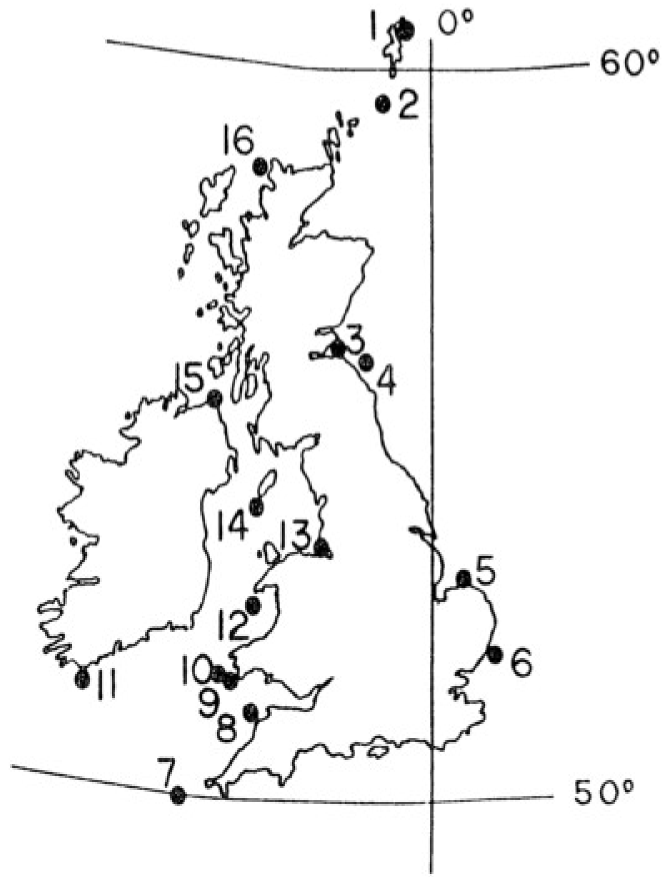


FIG. 2.—Locations of the 16 British islands used in this study. Numbers in parentheses are the island areas in square kilometers. 1, Hascosay (3.0); 2, Fair Isle (7.65); 3, Isle of May (0.49); 4, Inner Farne (0.29); 5, Scolt Head (3.34); 6, Havergate (1.08); 7, St. Agnes (1.09); 8, Lundy (4.52); 9, Skokholm (0.97); 10, Skomer (2.92); 11, Cape Clear (6.39); 12, Bardsey (1.8); 13, Hilbre (0.07); 14, Calf of Man (2.49); 15, Copeland (0.32); 16, Handa (3.10).

Evidence: Population extinction on small islands



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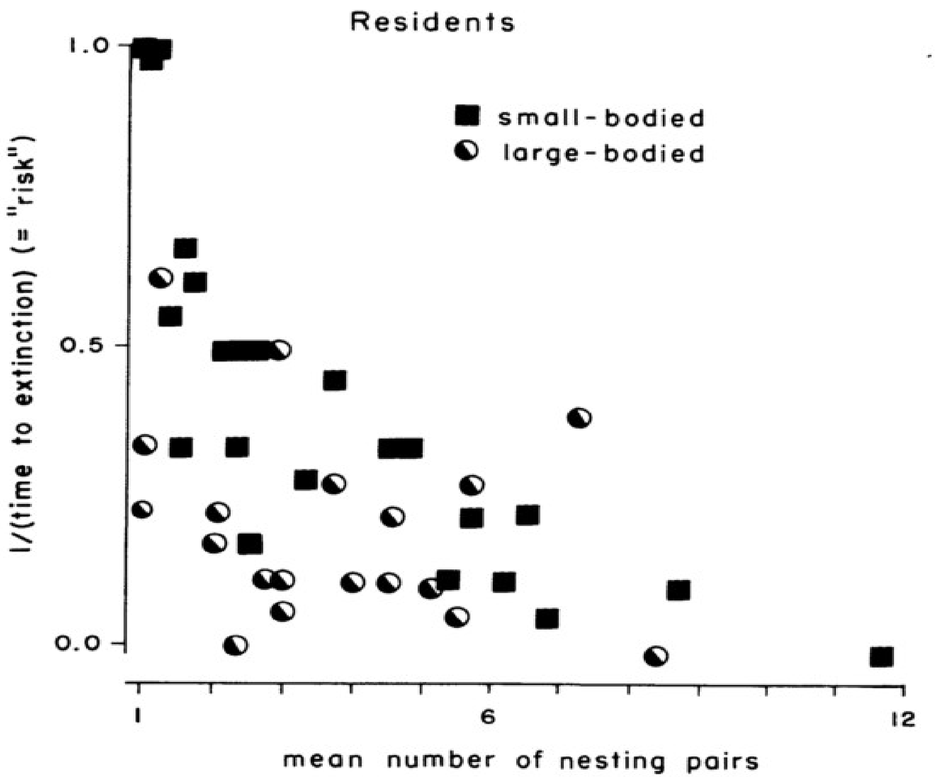
Evidence: Population extinction on small islands

- Small populations had shorter time to extinction.

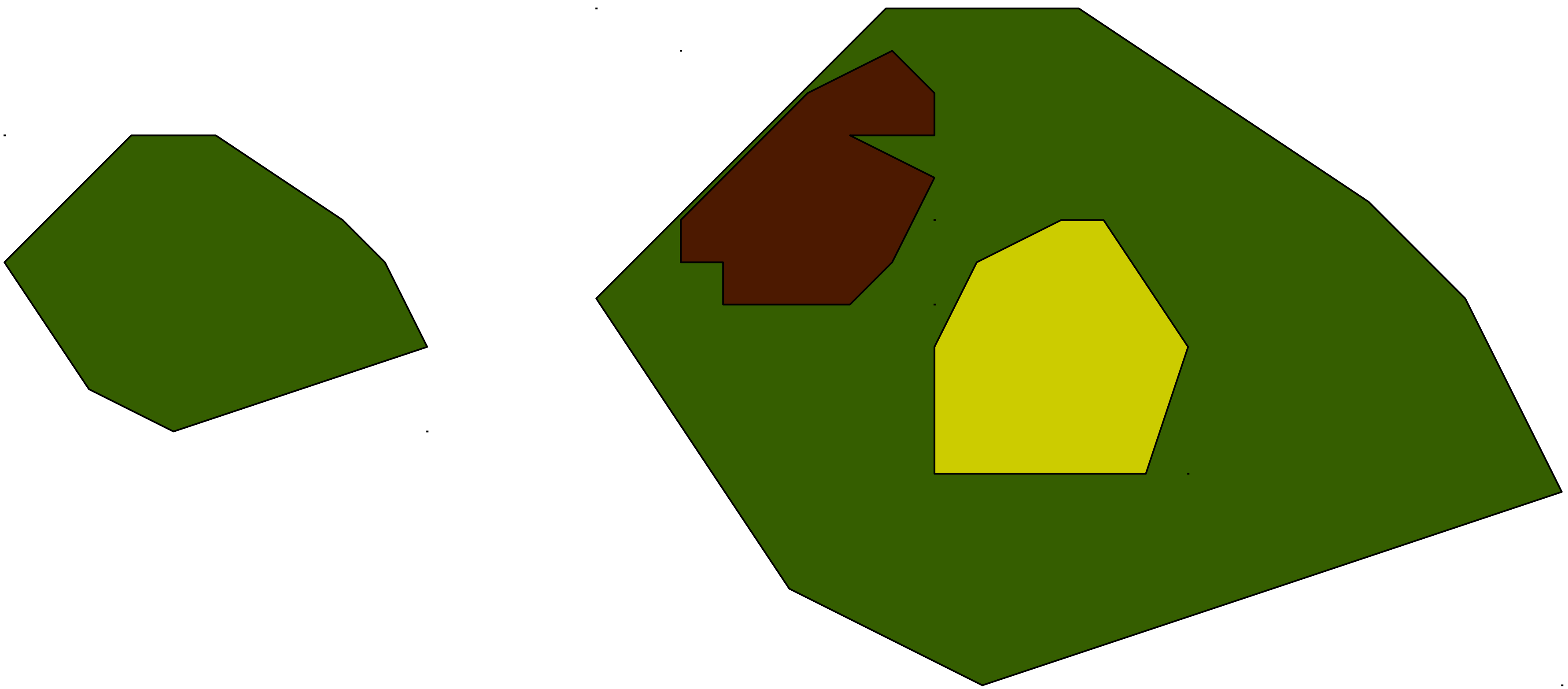


"*Ceteris paribus*"

- The theory assumes that apart from island size all other things are equal.
- This is both a strength and weakness of the theory.
- Strength
  - Generality (can be applied to any situation)
  - Tractability (mathematics can be fully worked out)
  - Can be the starting point for more refined theories
- Weakness
  - Lack of realism (very easy to find exceptions)
  - Low predictive power in real situations (other variables can hide the effect)
  - Can be accepted uncritically and applied inappropriately

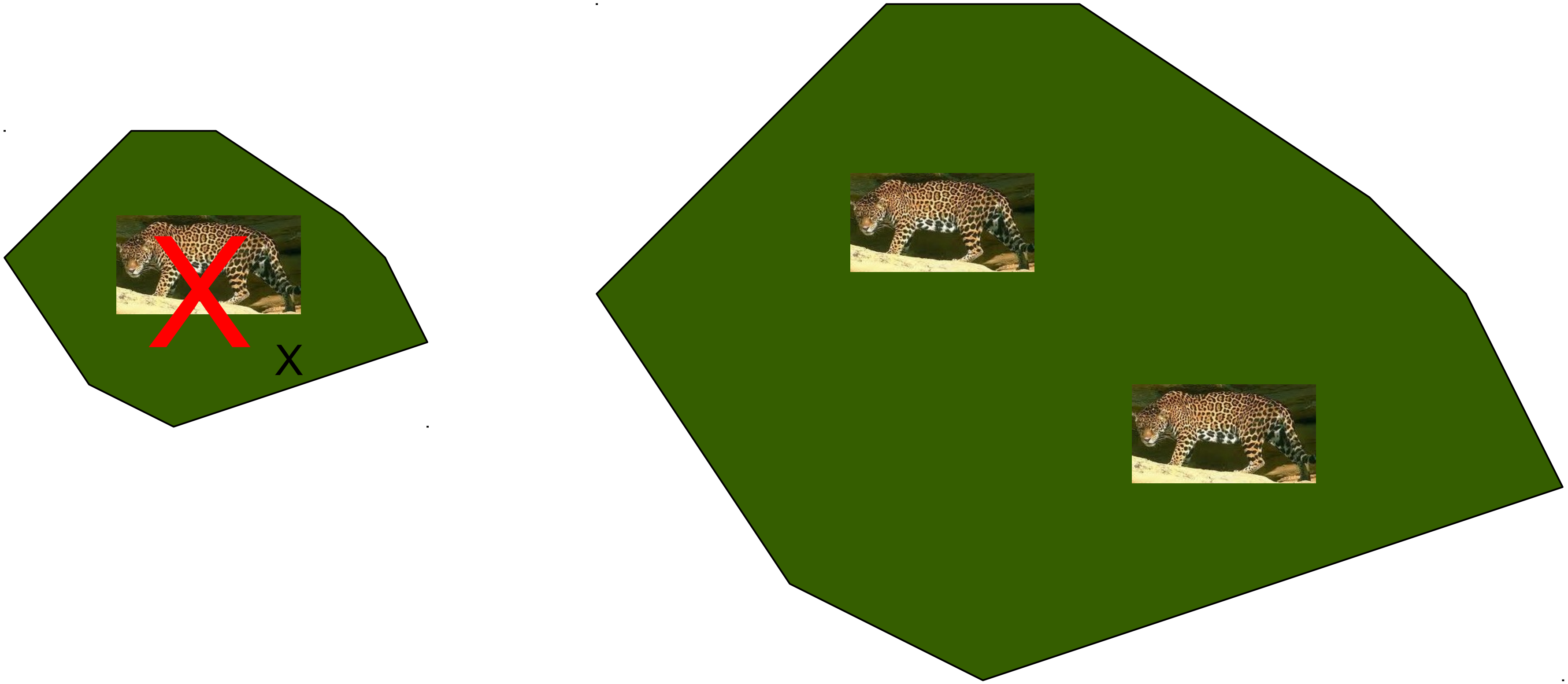
Other effects

- Habitat diversity: The number of species may be a function of the number of habitats. Larger islands → more habitats.



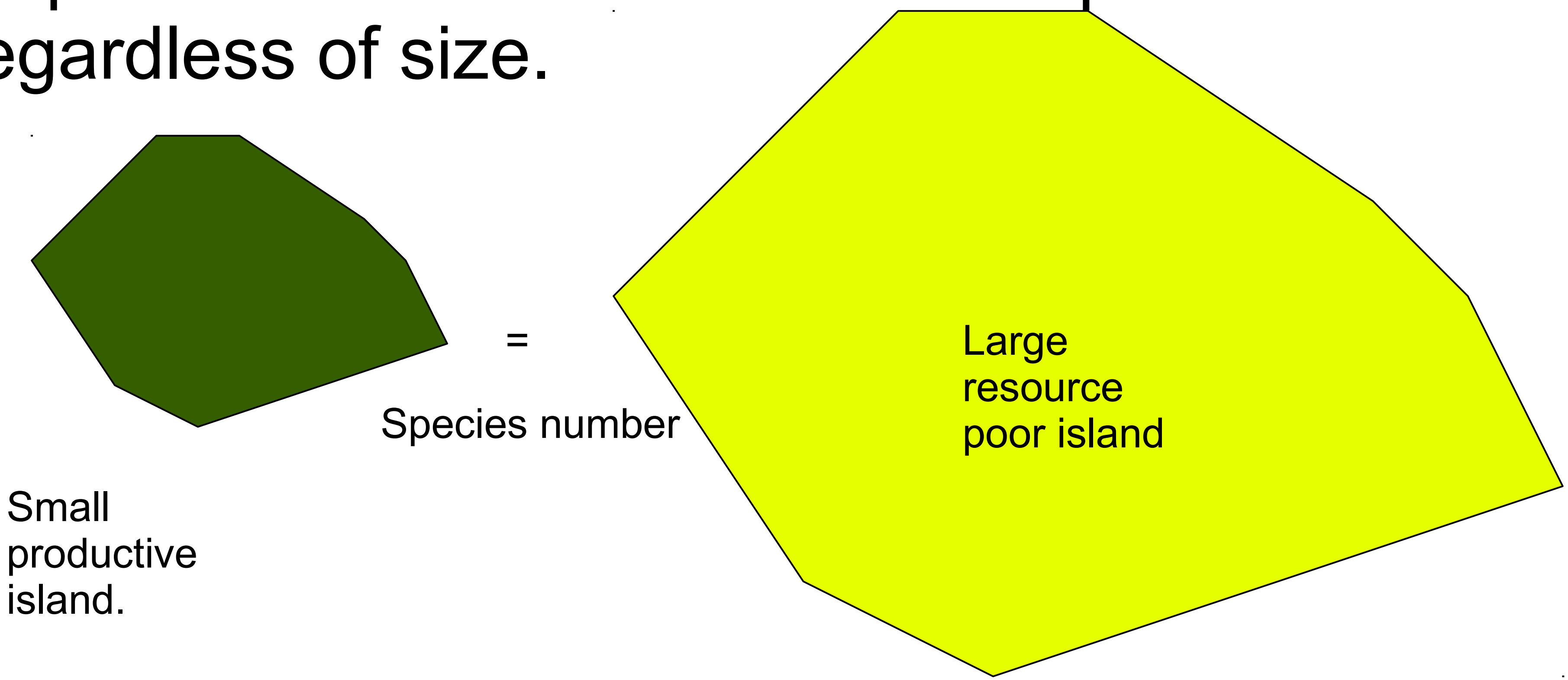
Other effects

- Incidence functions: Some species can only exist on large islands as they need large territories.



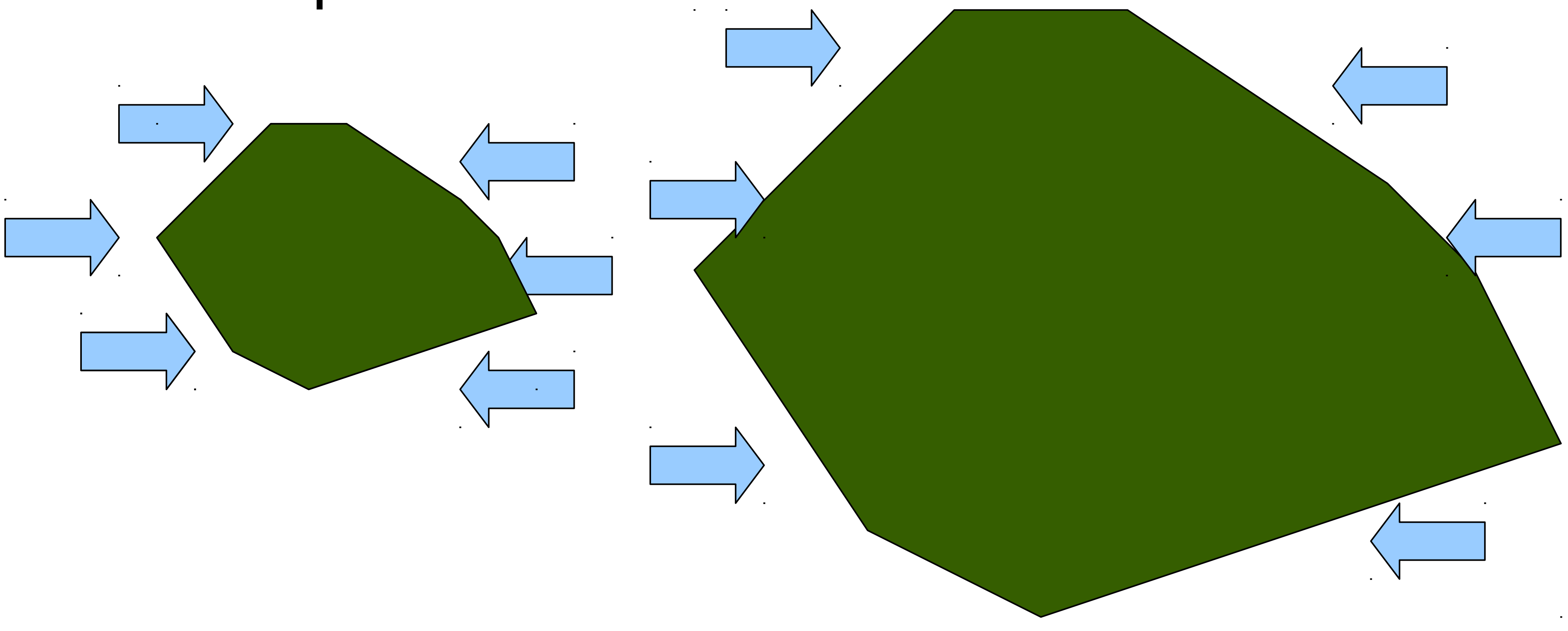
Other effects

- Species-energy theory: Number of species determined by the resource base of the island. Unproductive islands have fewer species regardless of size.



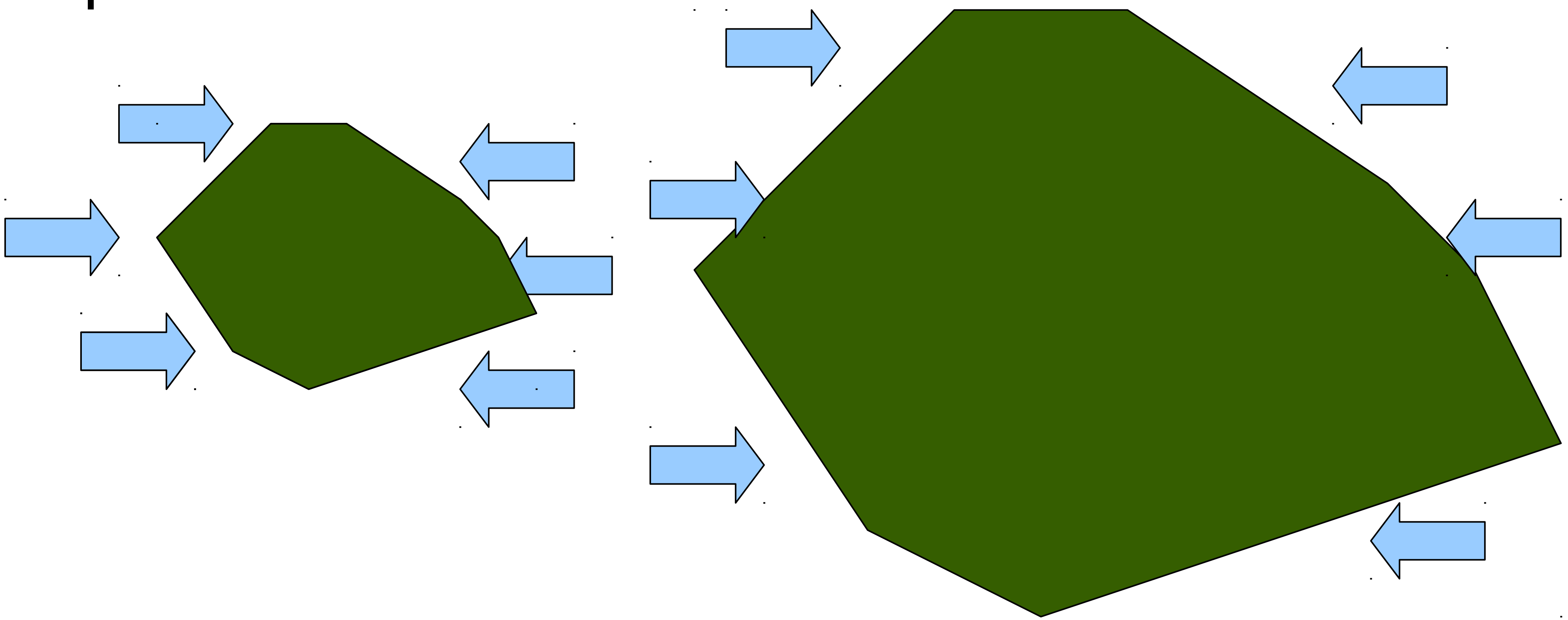
Other effects

- Small island effect. Edge effects greater on small islands making them more extreme. Some species cannot survive.



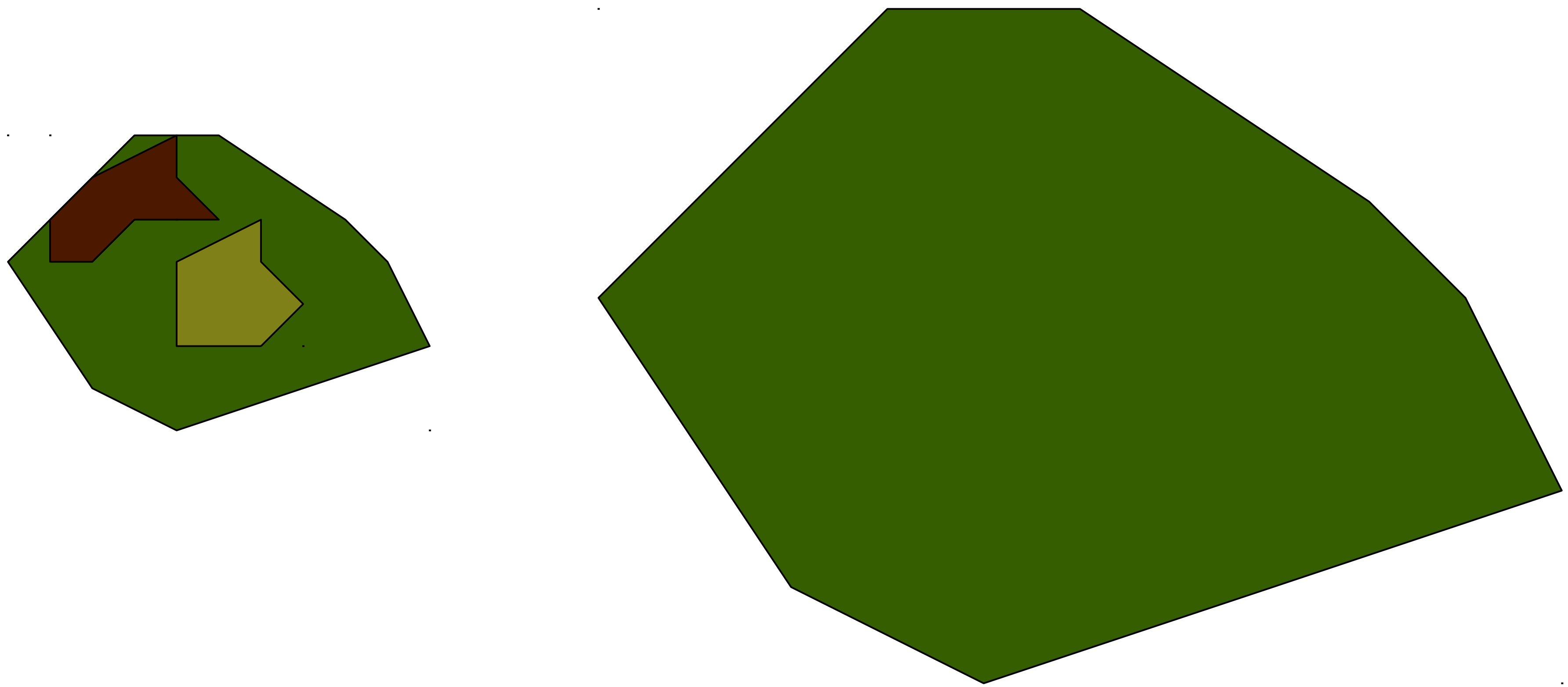
Other effects

- TARGET effect. Large islands offer an easier target for immigration as they have more perimeter to aim for.



Other effects

- Small-island **habitat** effect. Small islands may in fact have special **habitats** not found on large islands, so **more** species than expected.



Additional complications

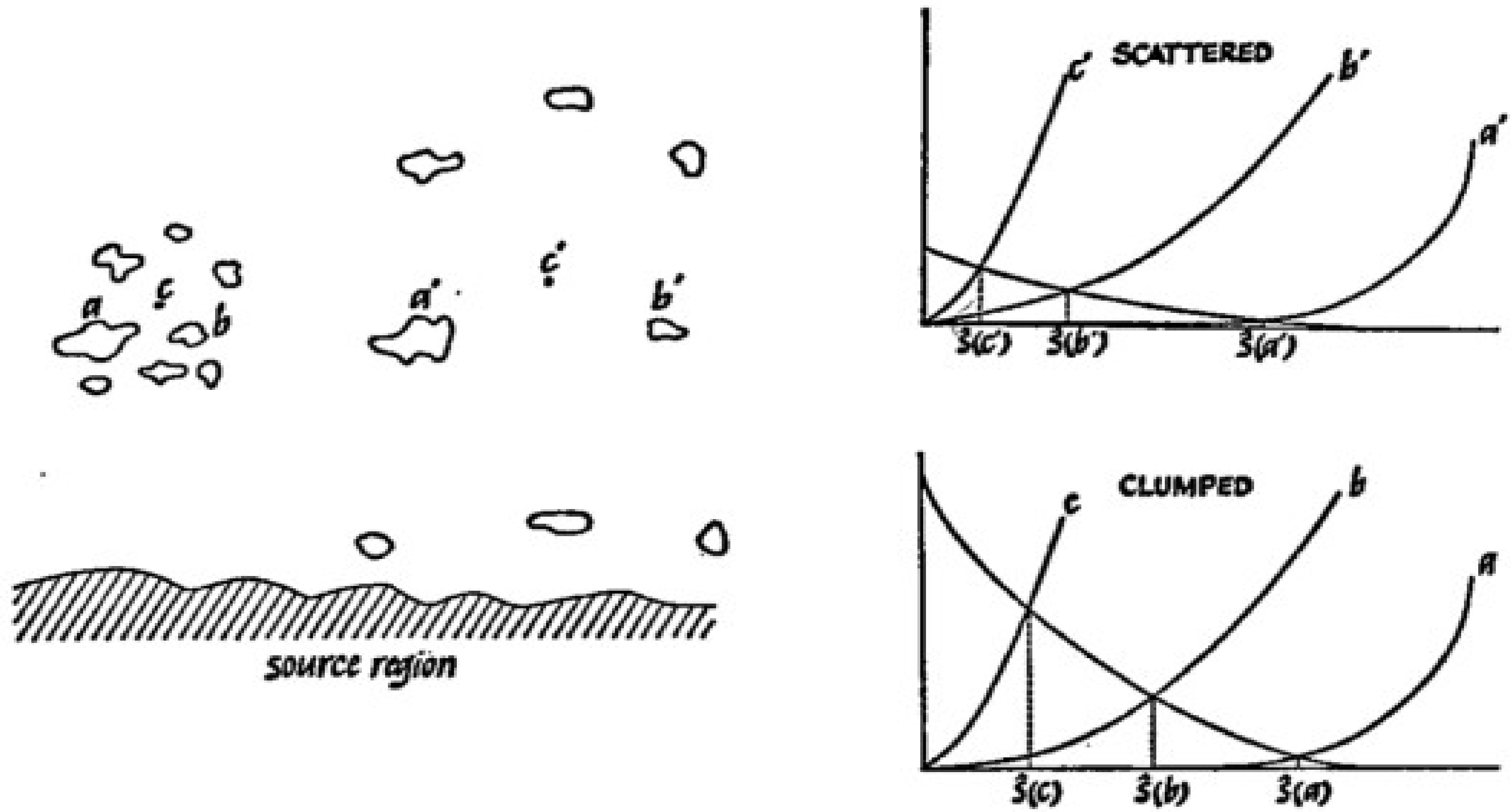


FIGURE 15. Predicted effect of increased clumping of islands. When clustered together, the islands raise each others' immigration rate, which in turn reduces the slope of the overall area-species curve.

Implications for reserve design

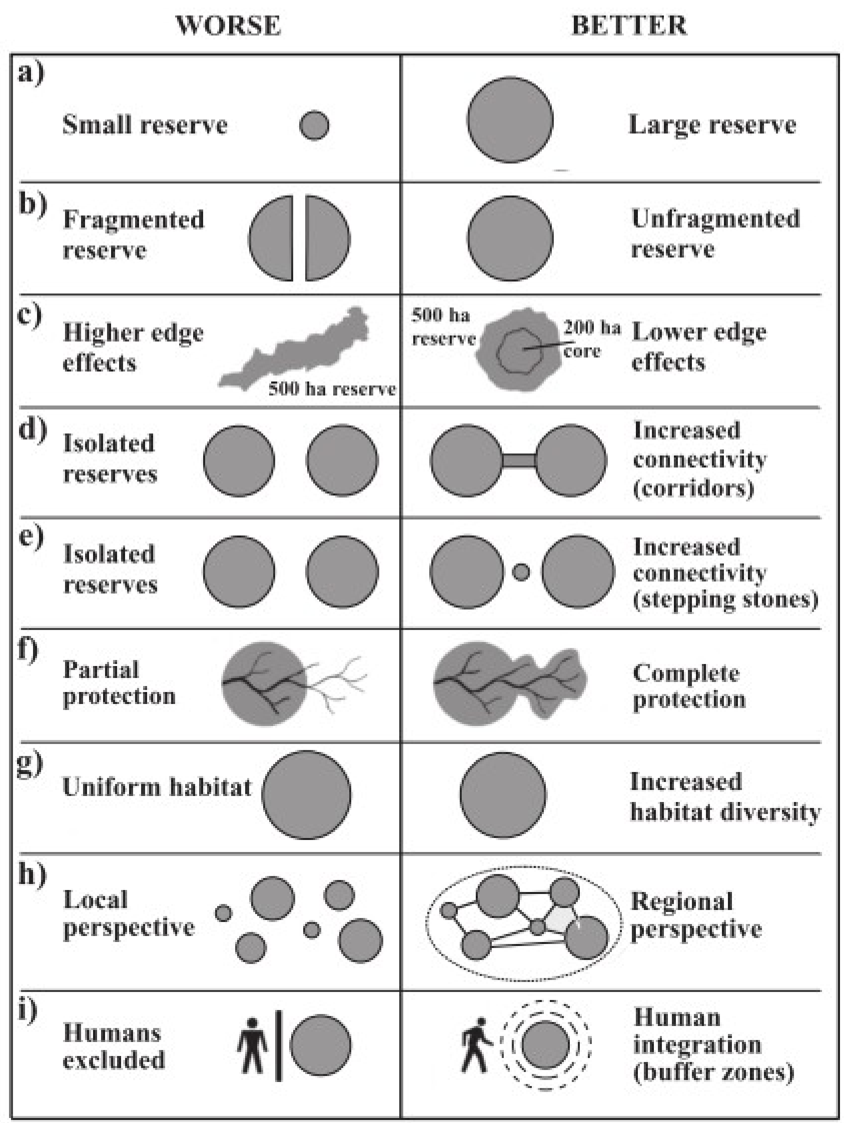


Figure 8.2 Design guidelines for reserves, as derived initially from the theory of island biogeography and extended by subsequent contributions to theory (e.g. see Harris, 1984; Shafer, 1997). Re-drawn from Huggett (2004, Figure 18.3, p. 362).