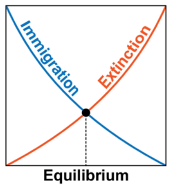


Exploring Island Biogeography through Data

OVERVIEW

In this activity, you'll analyze data from published scientific studies to discover factors that influence the number of species found in a habitat. The concepts you'll explore are from a theory called **island biogeography**, which has helped guide efforts to protect wildlife. Principles of island biogeography apply to *any* isolated habitat, ranging from islands in the sea to **habitat fragments**: "islands" of natural habitat on land surrounded by a "sea" of human roads, farms, or cities.

In the first part of this activity, you'll explore a pattern in island biogeography called the **species-area relationship** and how it relates to the number of species on an island in the long run. You'll then explore two important processes, called **immigration** and **extinction**, that drive the species-area relationship.

During this activity, you'll work in groups to analyze a specific study/topic, then join new groups to share your knowledge with classmates who analyzed different studies/topics. At the end, you'll use what you've learned to explain other important patterns in island biogeography, which apply to the conservation of many species and habitats.

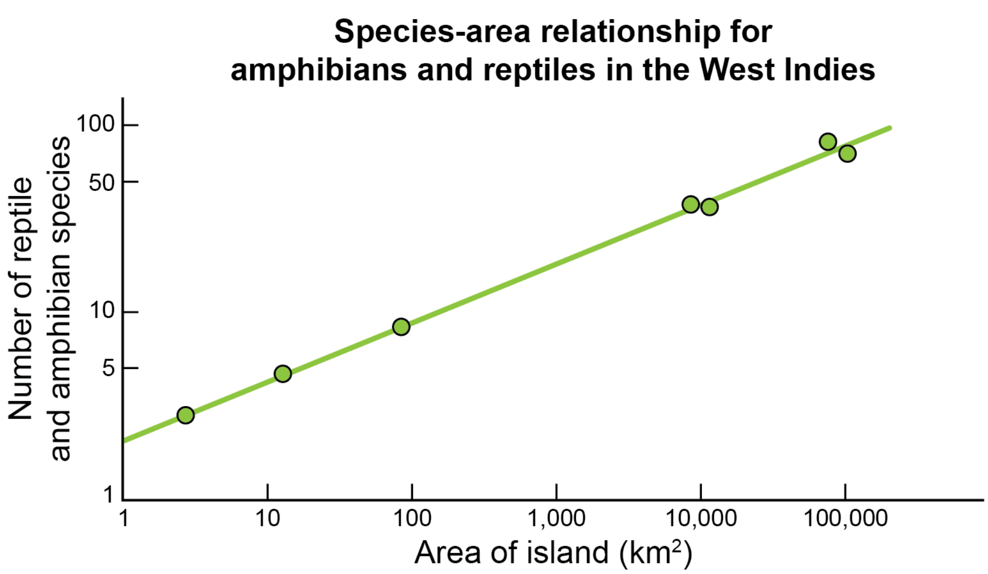
PROCEDURE

PART 1: The Species-Area Relationship and Equilibrium Species Number

You instructor will give you a profile for **Figure A**, which shows data from a real study related to island biogeography.

1. Read the profile to learn about the study in Figure A. What were the "islands" (the habitats where the species live)? What was the "sea" (the surrounding habitat where the species are less likely to survive)?

Figure 1 below shows data from a different study.



2. Complete the following table to compare the studies in Figure 1 and Figure A. The first row has been filled out as an example.

Characteristic	**Figure 1**	**Figure A**
Location	Islands in the West Indies	A desert in New Mexico
Types of species		
Study type/design		
Figure type and axis scales		

3. Both Figure 1 and Figure A demonstrate a pattern in island biogeography called the **species-area relationship**. Describe the species-area relationship based on your observations of both figures.

4. Figure A shows data on the species-area relationship before and after a fumigation.
   a. Suggest **three** specific ways that arthropod species could have traveled to the shrubs after the fumigation.

   b. What information about the species-area relationship does having data from both before and after the fumigation reveal?

   c. Figure A shows the numbers, but not types, of species before and after the fumigation. Do you think the *types* of species after the fumigation were the same as those before the fumigation? Why or why not?

Another study on island biogeography, which also counted arthropod species before and after a fumigation, was a famous experiment done in the Florida Keys. Watch 6:36–7:46 of the short film *From Ants to Grizzlies: A General Rule for Saving Biodiversity* to learn more about the Florida Keys experiment.

5. Compare the Florida Keys experiment, based on what is shown in the film, with the experiment for Figure A. How are the experimental designs and results similar?

Now consider some additional data from the Florida Keys experiment, shown in Figure 2.

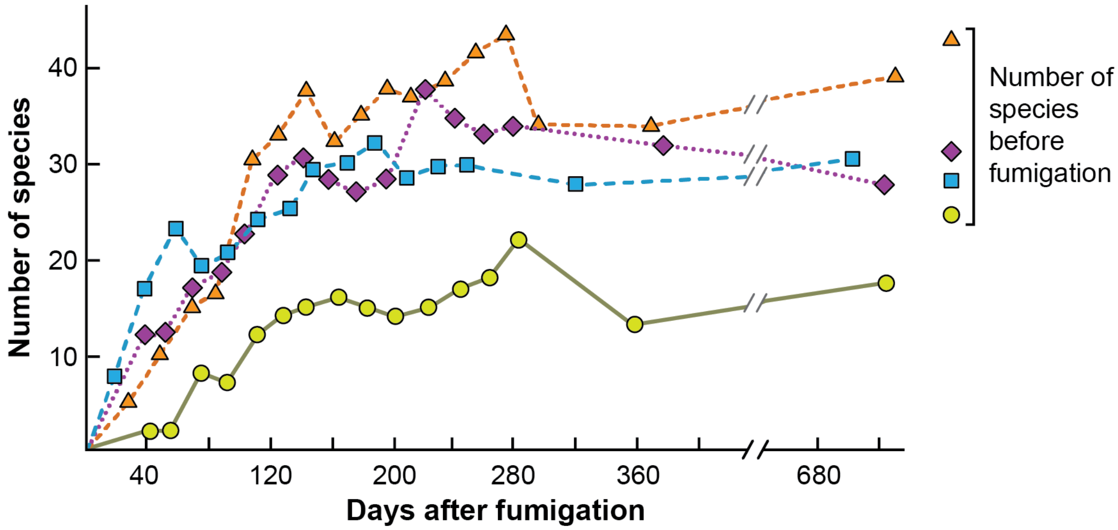


Figure 2. Number of species over time after the fumigation in the Florida Keys experiment; the number of species *before* fumigation are shown on the right. Each type of symbol represents data from a different island.

6. Both Figure 2 and Figure A demonstrate the concept of an **equilibrium** number of species. Describe what the term "equilibrium" means based on the patterns you observed in both figures.

7. New species will keep arriving on an island even after the equilibrium species number is reached. Why do you think the *total* number of species on an island stays at an equilibrium species number, instead of just growing bigger and bigger?

PART 2: Immigration/Extinction Rate and Island Area

In Part 1, you saw examples of the **species-area relationship**, a pattern in which the number of species on an island increases with island area. This pattern persists even after a major disturbance, such as fumigation. Even after species are removed through fumigation, the number of species will return to a similar number as before: the **equilibrium** species number.

How is the equilibrium species number determined, and why does it increase with area? The theory of island biogeography describes how the equilibrium is maintained by a balance between two rates: the **immigration rate**, which is the rate at which species enter and establish on an island, and the local **extinction rate**, which is the rate at which species die out and are no longer found on the island.

Figure 3 shows a graphical model of how the immigration and extinction rates depend on the number of species currently on an island. The two curves in Figure 3 represent the relationships between each rate, immigration and extinction, and the number of species.

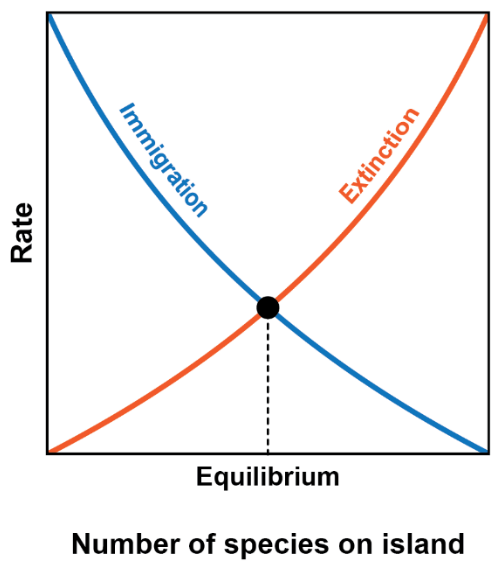


Figure 3. The equilibrium model based on the immigration and extinction rates for a single island.

8. For each of the following statements, fill in the blanks to describe the patterns shown in Figure 3. After each statement, propose a general biological reason for why this pattern occurs.
   a. The immigration rate ________ as the number of species on an island increases.
   Reason for this pattern:

   b. The extinction rate ________ as the number of species on an island increases.
   Reason for this pattern:

   c. The equilibrium number of species occurs when the curves for immigration and extinction rates ________________.
   Reason for this pattern:

9. As you saw in Figure A and Figure 2 in Part 1, an island will return to its equilibrium species number even after a disturbance. Use Figure 3 to describe how an island returns to its equilibrium species number in the

following two scenarios. In each scenario, consider what happens to the immigration and extinction rates to bring the species number back to equilibrium.

a. An island *loses* species, which causes the species number to *decrease* and move to the *left* of the equilibrium point.

b. An island *gains* species, which causes the species number to *increase* and move to the *right* of the equilibrium point.

We can extend the equilibrium model in Figure 3 to explain the species-area relationship — that is, why the equilibrium species number increases with area. First, we need to determine how area affects immigration and extinction rates.

For the next part of this activity, your instructor will assign you, in groups, to examine the profile for either **Figure C** or **Figure D**. Like Figure A, these figures show data from published studies related to island biogeography.

Work together with your group to answer the questions for your assigned figure on the following pages. **Only complete the questions for the figure that you were assigned. You can skip the other questions.**

Questions for Figure C

10. Read the profile to learn about the study in Figure C.
    a. What types of species were investigated in this study?

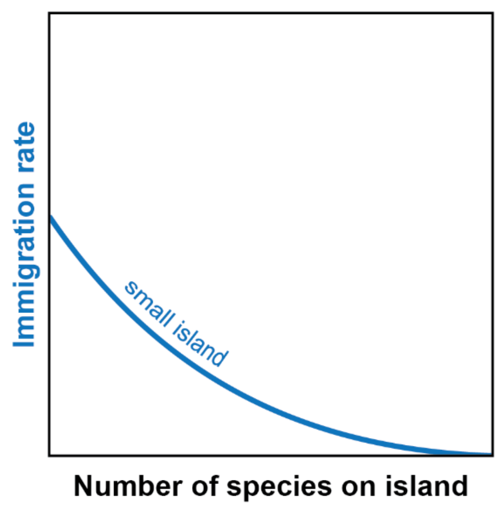
    b. What were the "islands"? What was the "sea"?

11. Summarize the main pattern or relationship that Figure C shows between island **area** and **visitation rate**, which is used to indicate the potential immigration rate.

12. Propose a biological reason for why this pattern occurs.

Let's explore the "immigration curve" in Figure 3, which shows the relationship between immigration rate and the number of species currently on an island. We will examine how this curve changes for islands of different areas.

13. The graph below shows the immigration curve for a theoretical island that is **small**. Based on what you learned from Figure C, draw and label a second immigration curve for an island that is **large** in comparison.



Questions for Figure D

14. Read the profile to learn about the study in Figure D.
    a. What types of species were investigated in this study?

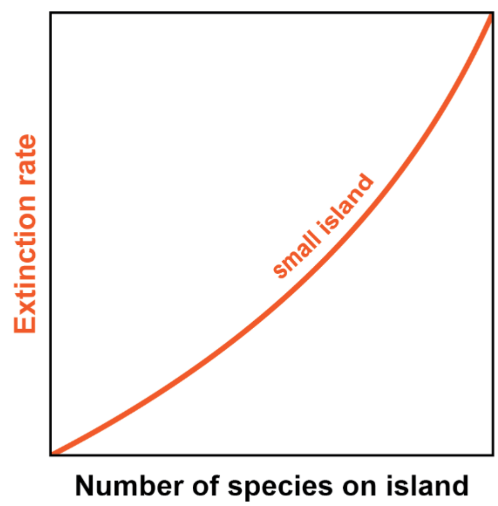
    b. What were the "islands"? What was the "sea"?

15. Summarize the main pattern or relationship that Figure D shows between island **area** and local **extinction rate**.

16. Propose a biological reason for why you think this pattern occurs.

Let's explore the "extinction curve" in Figure 3, which shows the relationship between extinction rate and the number of species currently on an island. We will examine how this curve changes for islands of different areas.

17. The graph below shows the extinction curve for a theoretical island that is **small**. Based on what you learned from Figure D, draw and label a second extinction curve for an island that is **large** in comparison.

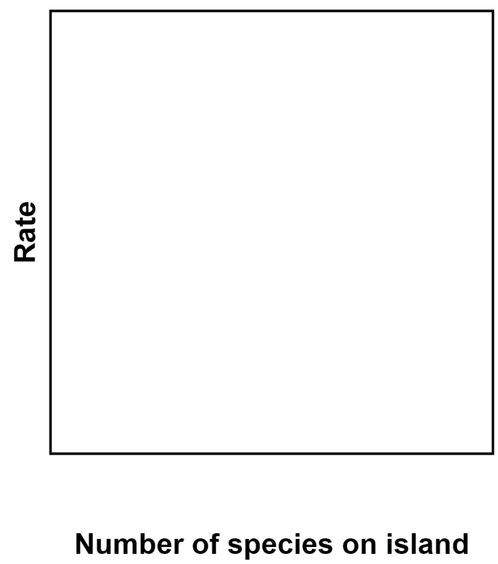


PART 3: Synthesizing the Effects of Area

You will now combine your curves from Part 2 to expand the equilibrium model in Figure 3. Your expanded model will demonstrate how island **area** affects **immigration/extinction rates** (and thus, the equilibrium species number).

Your instructor will assign you to a new group with at least one person who analyzed Figure C and one who analyzed Figure D. Share information about the study, the pattern you examined, and your answers from Part 2 with your group. Revise your answers if needed based on your discussion.

18. Fill in Figure 6 with the immigration and extinction curves for large and small islands, based on your group's answers for Figures 4 and 5. Your figure should have four clearly labeled curves: a curve for **immigration on a small island**, a curve for **immigration on a large island**, a curve for **extinction on a small island**, and a curve for **extinction on a large island**.



19. In Figure 6, label the **equilibrium number of species for a small island** and the **equilibrium number of species for a large island**. You will need to use the intersections of your curves for small and large islands.

20. How can the model you built in Figure 6 be used to explain the species-area relationship?

PART 4: Island Isolation and Equilibrium Species Number

According to island biogeography theory, area is not the only factor that affects the equilibrium number of species on an island. Another important factor is an island's **isolation**: distance from a main habitat, or **source**, that species can come from. For islands in an ocean, isolation can be measured as the distance to the mainland (the nearest large landform, such as a continent). For "islands" of isolated habitat on land, such as habitat fragments, isolation can be measured as the distance to a larger, more continuous area of habitat.

You will now expand the equilibrium model again to show how *isolation* affects equilibrium species number, similar to the model for *area* in Part 3. First, your instructor will give you a profile for **Figure B**. Figure B is from the same study as Figure A, which you examined in Part 1 of this activity.

21. What is the "continent," or source of immigrating species in the study?

22. Summarize the main pattern or relationship that Figure B shows between **number of species** and **isolation** (measured as distance to the "continent").

23. Propose a biological reason for why this pattern occurs.

As you learned in Part 2, immigration and extinction are two processes that affect the equilibrium number of species on an island. In Part 3, you saw how immigration and extinction rates changed with island *area* by examining Figures C and D. You will now consider how immigration and extinction rates could vary with island *isolation*.

For the rest of Part 4, your instructor will assign your group to focus on either the immigration rate or the extinction rate. Work together with your group to answer the questions for your assigned rate on the following pages. **Only complete the questions for the rate (immigration or extinction) that you were assigned. You can skip the other questions.**

Questions for Immigration Rate

24. Figure C showed how the immigration rate (indicated by visitation rate) changes as *area* increases or decreases. How might the immigration rate change as an island's *distance* from a major source of species increases or decreases? Sketch your predicted relationship on the graph below.

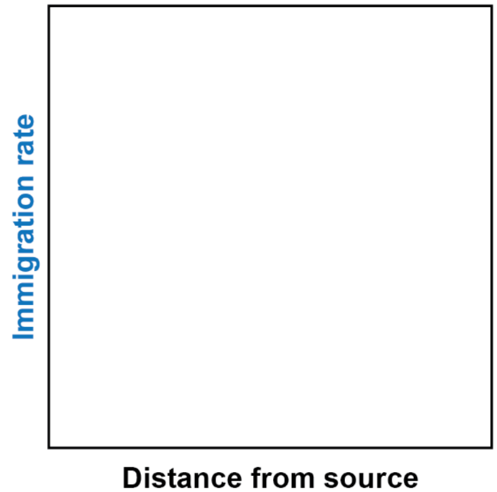


Figure 7. Expected relationship between immigration rate and island isolation (measured as distance from a major source of species).

25. Explain your reasoning behind the relationship you drew in Figure 7.

26. Figure 4 showed how you expected the immigration rate to shift based on island *area.* On the graph below, draw two curves showing how you expect the immigration rate to shift based on island *isolation*. Draw one curve for a less isolated island that is **near** the source of species and one curve for a more isolated island that is **far** from the source.

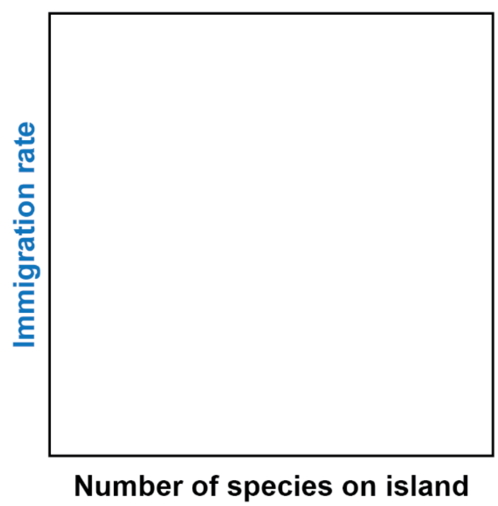


Figure 8. Model of immigration rates for islands with different levels of *isolation* (near vs. far).

Questions for Extinction Rate

27. Figure D showed how the extinction rate changes as *area* increases or decreases. How might the extinction rate change as an island's *distance* from a major source of species increases or decreases? Sketch your predicted relationship on the graph below.

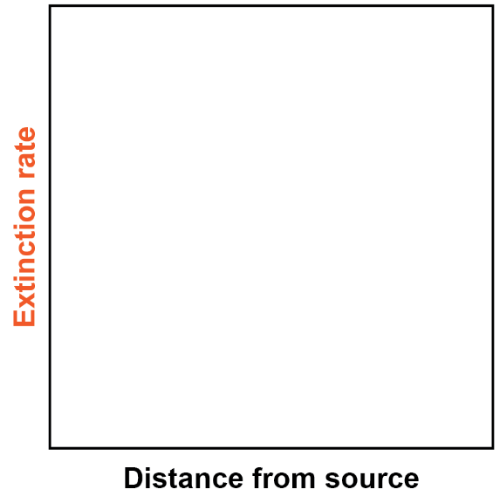


Figure 9. Expected relationship between extinction rate and island isolation (measured as distance from a major source of species).

28. Explain your reasoning behind the relationship you drew in Figure 9.

29. Figure 5 showed how you expected the extinction rate to shift based on island *area.* On the graph below, draw two curves showing how you expect the extinction rate to shift based on island *isolation*. Draw one curve for a less isolated island that is **near** the source of species and one curve for a more isolated island that is **far** from the source.

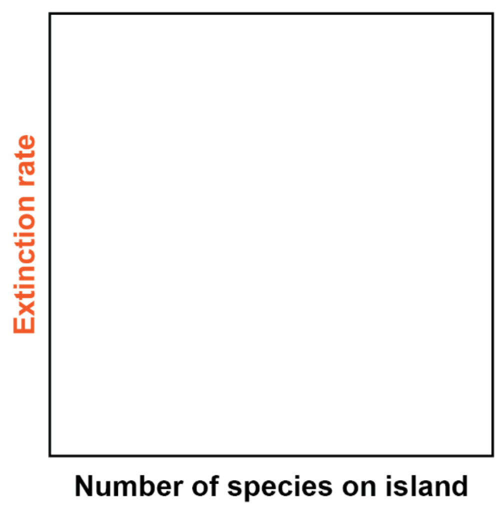


Figure 10. Model of immigration and extinction rates for islands with different levels of *isolation* (near vs. far).

PART 5: Synthesizing the Effects of Isolation

Your instructor will now assign you to a group with at least one person who focused on the immigration rate and one who focused on the extinction rate. Share information about your rate with your new group. Revise your answers if needed based on your discussion, then work together to answer the questions below.

30. Similar to what you did for Figure 6, fill in Figure 11 with immigration and extinction curves for near and far islands. Your figure should have four clearly labeled curves: a curve for **immigration on a near island**, a curve for **immigration on a far island**, a curve for **extinction on a near island**, and a curve for **extinction on a far island**.

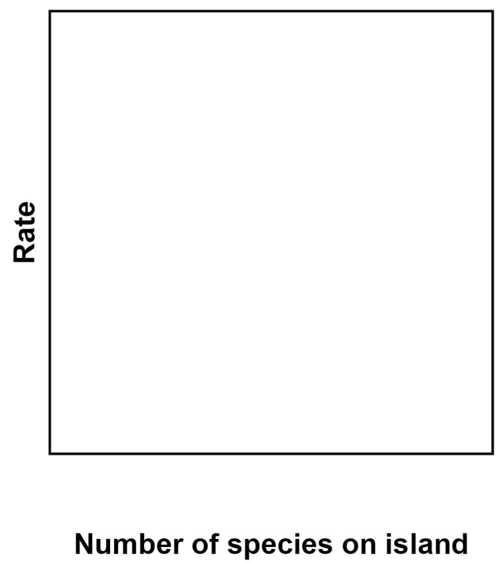


Figure 11. Model of immigration and extinction rates for islands with different levels of *isolation* (near vs. far).

31. In Figure 11, label the **equilibrium for a near island** and the **equilibrium for a far island**.

32. How can the model you built in Figure 11 be used to explain the relationship between **isolation** and **species number**? This is the relationship that you observed in Figure B and that you proposed an initial reason for in Question 23.

You have now built the equilibrium models that form the basis for the theory of island biogeography. These models demonstrate how immigration and extinction rates change with island area and isolation, ultimately determining the equilibrium number of species that a habitat can support.

33. Conservationists around the world have used concepts from island biogeography to design protected areas for wildlife. Suggest at least **one** specific guideline for protected area design based on what you have learned from your models.

EXTENSION: Habitat Fragmentation

You will now examine Figure E, which shows the results of a study related to island biogeography and **habitat fragmentation:** the process of habitats being broken into smaller, separated pieces called fragments.

1. Read the profile to learn about the study in Figure E.
   a. What types of species were investigated in this study?

   b. What were the "islands"? What was the "sea"?

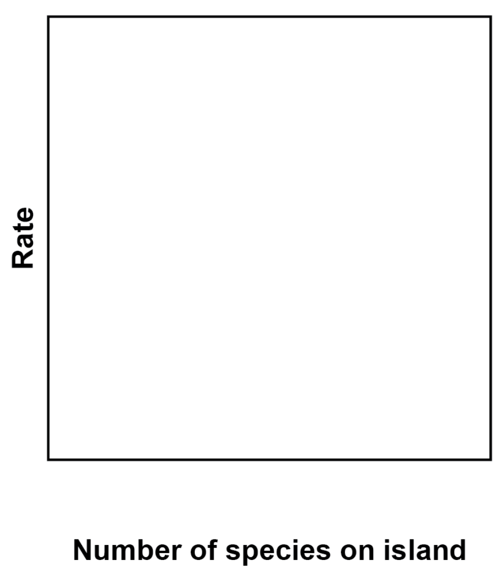
2. Parts of this experiment examined the effects of both fragment area and isolation on species number.
   a. What was the effect of *area* on species number? Support your answer by comparing specific treatments in Figure E.

   b. What was the effect of *isolation* on species number? Support your answer by comparing specific treatments in Figure E.

   c. Imagine that isolation had *no* effect on species number. Sketch or describe what the bar graph in Figure E would look like in this case.

3. How do these results align with the model of island biogeography that you investigated? Support your answer based on evidence from Figure 6 (in Part 3) and Figure 8 (in Part 4) of this activity.

   a. mainland vs. insular



   b. broken vs. corridor