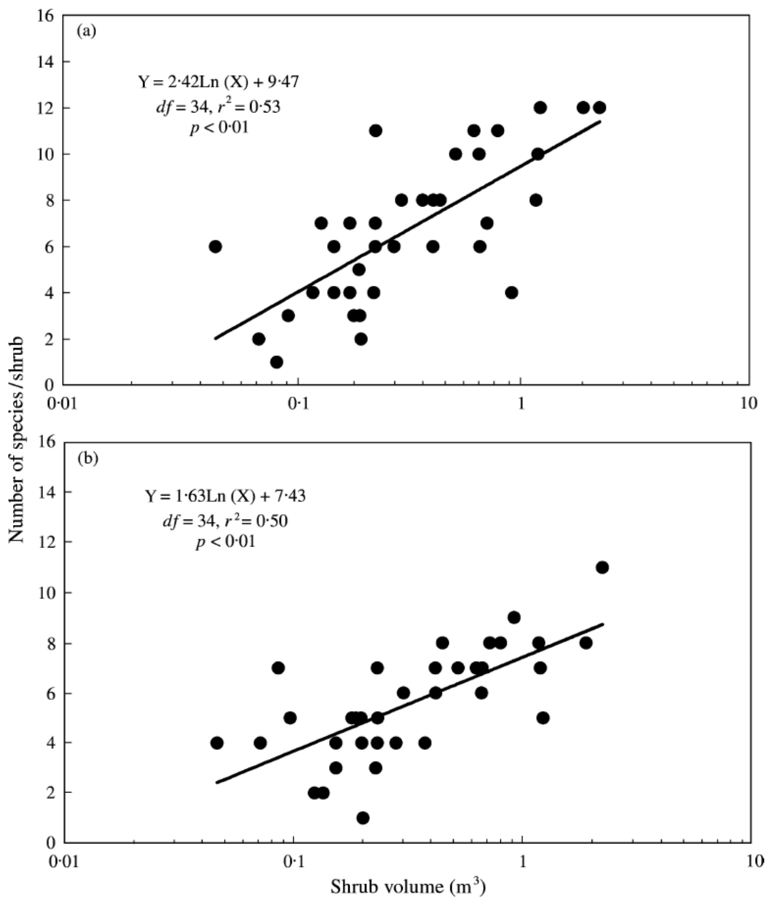
## HOW TO USE THIS RESOURCE

Show the following figure and caption to your students. The accompanying "Student Handout" provides space below the caption for "Observations, Notes, and Questions" and space next to the "Background Information" for "Big Ideas, Notes, and Questions." The "Interpreting the Figure" and "Discussion Questions" sections of the "Educator Materials" provide additional information and suggested questions that you can use to prompt student thinking, increase engagement, or guide a class discussion about the characteristics of the figure and what it shows.

Additional information related to pedagogy and implementation can be found on this resource's webpage, including suggested audience, estimated time, and curriculum connections.




***Caption:*** *Numbers of specialist herbivore arthropod species found on isolated shrubs of different sizes. The top graph* ***(a)*** *shows the number of species before all arthropods were removed by fumigation. The bottom graph* ***(b)*** *shows the number of species two weeks after fumigation. Results from linear regression analyses are displayed on each graph.*

## BACKGROUND INFORMATION

How many different species will be found in a habitat of a certain size? Answering this question could help us better understand patterns in where species are found. It could also help us predict how many species will be lost from damaged habitats and design protected areas to save Earth's remaining wildlife.

To investigate the relationship between species number and habitat size, scientists studied species of **arthropods** — such as beetles, grasshoppers, flies, and moths — in a desert in central New Mexico, USA. They focused on arthropods that live on desert shrubs. Some of these arthropod species are **specialist herbivores** that feed and live only on these shrubs. The sand and grasses between the shrubs do not provide the food or shelter that these specialist species need to survive for long periods.

The scientists counted the number of specialist herbivore arthropod species on individual, isolated shrubs. They also calculated the volume of each shrub, which can be used as a measure of habitat size for the arthropods. The scientists then used an insecticide to **fumigate**, or kill all the arthropods on, these shrubs. Two weeks after fumigation, they counted the arthropod species that had returned to each shrub. These arthropods came from other places in the environment, including shrubs that had not been fumigated.

## INTERPRETING THE FIGURE

The shrubs in this study were creosote bushes (*Larrea tridentata*), which grow in desert shrublands and grasslands in southwestern North America. Creosote bushes are inhabited by many species of specialist and generalist arthropods, and dense clumps of creosote bushes can support large, species-rich communities. These shrubs can be colonized by arthropods living on other vegetation and experience **species turnover**: one species might be found in a shrub for some time before dying out/being displaced and is then replaced by a different species.

One goal of this study was to test whether the creosote bush system was consistent with the principles of island biogeography. **Island biogeography** is a theory that explains how the number of species in an "island" (habitat patch) is affected by the size and degree of isolation of that island — from actual islands surrounded by water to "islands" of natural habitat surrounded by inhospitable areas, such as human farms or cities. In this case, the isolated shrubs act as "islands" of essential habitat and resources for specialist herbivore arthropods. They are surrounded by an inhospitable "sea" of grass and sand where the specialists cannot survive as easily.

A major pattern in island biogeography, called the **species-area relationship**, predicts that the number of different species on an island increases with island area. In other words, there are generally more species on large islands than on small ones. This study looked at the number of specialist arthropod species found on different shrubs, with "island area" corresponding to shrub volume.

In the figure, each dot represents a different shrub. Each graph compares the volume (size) of the shrubs to the number of specialist species found on the shrubs. Both before fumigation (a) and after fumigation (b), larger shrubs generally supported more species of specialists than the smaller shrubs did. The linear regression analyses reported on the graphs indicate that the relationship between species number and shrub volume is statistically significant both before and after fumigation. These results suggest that the number of species per shrub is *positively* associated with shrub volume — similar to the species-area relationship in island biogeography, which predicts that the number of species in a habitat is positively related to habitat area.

## TEACHING TIPS

**Prompt students to explain the parts of the figure as applicable:**

- Graph type: Semilog scatterplots with trendlines
  - "Semilog" (semilogarithmic) refers to the fact that the graphs have a logarithmic scale on one axis (in this case, the *x*-axis) and a linear scale on the other.
- *X*-axis: Shrub volume in cubic meters, shown on a logarithmic scale (log-10)

- The use of a logarithmic scale makes it easier to compare values and visualize trends across a large range.
- *Y*-axis: Number of specialist herbivore arthropod species per shrub, shown on a linear scale
- Trendline: Lines fitted to the data in each graph using linear regression analyses. In both graphs, the trendline indicates a *positive* association between the number of species and shrub volume. Additional information from the linear regression analyses is also displayed on the graphs, including:
  - *df* (degrees of freedom): Sample size (36) minus the number of parameters being estimated (2)
  - $r^2$ (coefficient of determination): Proportion of the variation in the dependent variable (number of specialist herbivore arthropod species) that is directly associated with variation in the independent variable (shrub volume). Values of $r^2$ vary from 0 to 1, with larger values indicating a better fit of the data to the trendline.
  - *p* (*p* value): The probability that the independent and dependent variables are not associated. For both graphs, $p < 0.01$, which indicates a significant relationship between the number of species and shrub volume.

**Complement this Data Point with the following related resources:**

- The Data Point "Habitat Isolation Impacts Arthropod Species" presents a similar figure from the same study. It explores another pattern in island biogeography known as the **distance effect**, which describes the relationship between species number and the distance from a major source of species.
- The Data Point "Habitat Fragmentation Impacts Arthropod Species" presents a figure from another study that looked at species loss following experimental fragmentation of a moss habitat. The results of this study are related to key principles in island biogeography, including the species-area relationship explored in this Data Point.
- The activity "Exploring Island Biogeography through Data" has students use multiple scientific figures, including the one presented in this Data Point, to explore and synthesize the key patterns in island biogeography.
- The short film *From Ants to Grizzlies: A General Rule for Saving Biodiversity* and its accompanying film activity can be used to introduce students to island biogeography concepts, with an emphasis on the species-area relationship. The film features the original fumigation experiment that inspired the theory of island biogeography.

**DISCUSSION QUESTIONS**

- Based on these graphs, what is the overall relationship between the number of specialist herbivore species and shrub volume?
  - Is this relationship statistically significant? How can you tell?
  - Propose a biological reason for why this relationship occurs.
- Why don't the data points lie exactly on the line? Why doesn't the line connect all the points?
- What type of scale is the *x*-axis using? Why do you think this type of scale was used?
- Why do you think the scientists checked the species on the shrubs both before and after fumigation?
  - Would you expect the exact same types of species to be present both before and after fumigation? Why or why not?
  - How might shrub volume affect how quickly the species returned after fumigation?
- Why do you think these graphs show specialist herbivores only and don't include other types of species?
  - The scientists also looked at the relationship between shrub volume and the number of generalist predator species: species that eat other insects and that can live on plants other than shrubs. How might the results of the generalist predators have differed from those of the specialist herbivores?
- What other types of species and habitats might the patterns found in this study apply to?

- How might the results of this study apply to designing protected areas, such as wildlife refuges?

- One goal for this study was to test whether the desert shrub system was consistent with island biogeography theory. **Island biogeography** is a field of science that looks at species distribution and dynamics in isolated habitats — from actual islands surrounded by water to "islands" of natural habitat surrounded by a "sea" of inhospitable areas, such as human farms and cities.
  - What are the "islands" in the desert shrub system? What is the "sea"?
  - Why might we want to test whether the patterns observed for islands in the ocean also apply to "islands" on land, such as shrubs?
  - One major pattern in island biogeography is that there are more species on large islands than on small ones. Does the desert shrub system follow this pattern? Support your answer with evidence from the figure.
  - The short film *From Ants to Grizzlies: A General Rule for Saving Biodiversity* (6:36–7:46 in particular) describes a fumigation experiment in the Florida Keys, which was a famous experiment in island biogeography. Compare and contrast the Florida Keys experiment with the desert shrub experiment. How do the experimental designs and results compare?

## SOURCE

Figure 2 from:

Sanchez, Brian C., and Robert R. Parmenter. "Patterns of shrub-dwelling arthropod diversity across a desert shrubland-grassland ecotone: a test of island biogeographic theory." *Journal of Arid Environments* 50, 2 (2002): 247–265. https://doi.org/10.1006/jare.2001.0920.

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