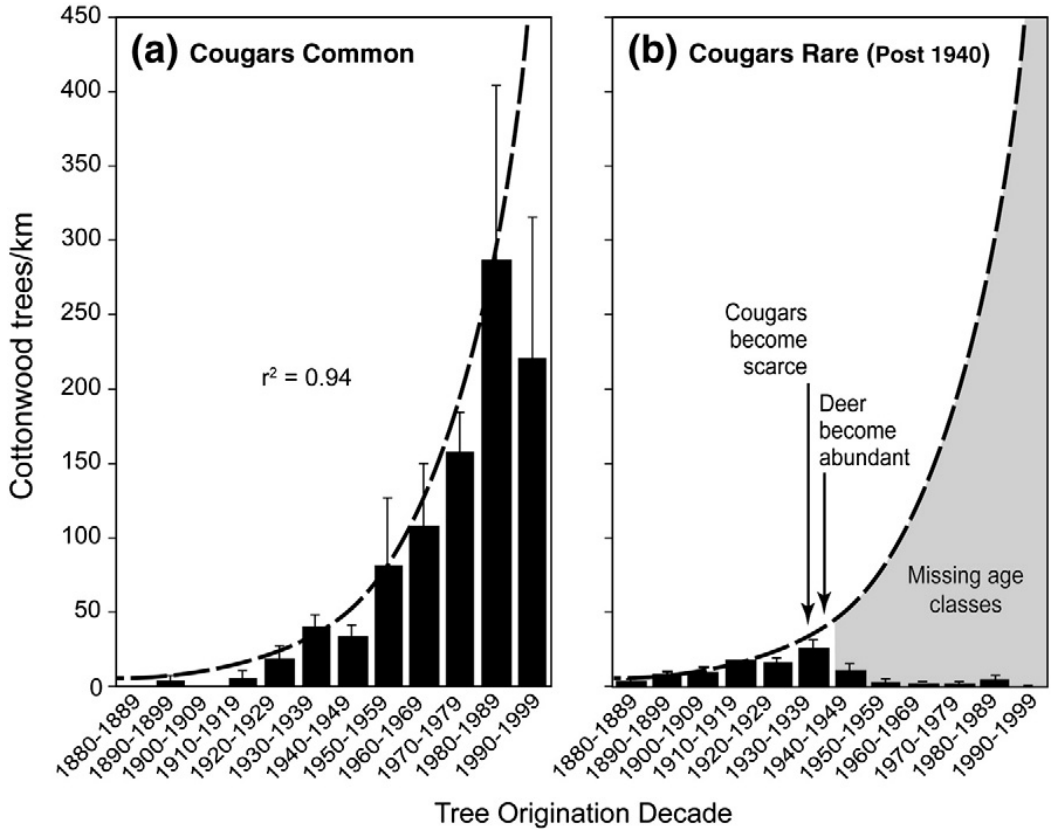
HOW TO USE THIS RESOURCE

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



Caption: A comparison of the age structure of cottonwood trees growing in two different riparian areas within Zion National Park in 2005. (a) North Creek, an area where cougars are common, and (b) the North Fork of the Virgin River in Zion Canyon, an area where cougars are rare. The dashed line in the left figure represents the best fit for the data. This same line is shown in the right figure for easier comparison of the two data sets.

BACKGROUND INFORMATION

Utah's Zion National Park is famous for its desert landscape and canyons, but forests cover the riverbanks (also called riparian areas). Under normal conditions, riparian areas are home to cottonwood trees, shrubs (such as willows), wildflowers, aquatic plants, fish, tree frogs, toads, lizards, butterflies, mule deer, coyotes, black bears, and cougars. However, human activity over the last 150 years has impacted the plants and wildlife in some areas.

Historically, healthy riparian forests would have been common along the Virgin River in Zion Canyon. However, beginning around 1862, European-American farmers settled in the canyon, and by 1915 they had destroyed much of the canyon's native vegetation. In 1918, the government created Zion National Park to protect Zion Canyon and surrounding areas from human impacts, and soon the natural ecosystems began to recover. During the late 1920s and early 1930s, park managers built new roads and trails in the park. With new access, the number of visitors increased in the area along the Virgin River in Zion Canyon, and cougars were displaced from high-use

areas. As cougars were displaced, the population of mule deer grew rapidly, which in turn affected the vegetation that deer consume.
To determine how the loss of a top predator like the cougar affects riparian vegetation, researchers examined canyon regions in Zion National Park with and without cougars. In 2005, they counted and measured the sizes of cottonwood trees along riparian areas within these canyons. Tree size is an indicator of tree age. Figure (a) shows cottonwood data collected in North Creek, an area where visitors are rare and cougars are plentiful. Figure (b) shows cottonwood data collected along the Virgin River in Zion Canyon, which has few cougars.

INTERPRETING THE GRAPH

This figure provides evidence of a trophic cascade, in which the removal of a top predator (cougars) led to the uncontrolled population of mule deer, which depleted a primary producer (cottonwoods).

Figure (a) represents an area within Zion National Park with an intact cougar (top predator) population. After a period of intense farming and ranching by early pioneers, the park was established in 1918 and the riparian vegetation, deer, and cougar populations began to recover. This resulted in a population structure with many more young trees than older trees. The resulting exponential trend is typical of healthy riparian forests.

The data for Figure (a) was collected by counting cottonwood trees along three different 200-m stretches of North Creek, which is rarely visited by tourists. In addition, the diameter of each tree was measured and compared to selected tree core samples to estimate the age. The age of each tree is represented in the figure by the decade in which the tree likely germinated. Standard error (represented by error bars) was calculated using the three different sampling transects along North Creek. An exponential curve was then fitted to the data (dotted line), resulting in a correlation coefficient of 0.94. The researchers also conducted species counts of important floral and faunal indicator species and found high biodiversity (data not shown).

In contrast to North Creek, the Zion Canyon area, shown in Figure (b), saw major increases in human visitors during the 1930s and 1940s (4.5 million in 2017). As visitations increased, much of the Zion Canyon cougar population was displaced, as confirmed by counting scat (data not shown). Cottonwood age data was collected from three different stretches along the heavily trafficked Virgin River in Zion Canyon. Figure (b) also includes two events from historical records in the 1930s. These events mark the general disappearance of cougars (due to an increasing human presence) and the subsequent increase in the mule deer population (due to the displacement of their primary predator). These events coincided with a decline in cottonwood recruitment (i.e., growth of seedlings/sprouts into tall saplings and trees). These results suggest that human displacement of cougars led to an increase in the mule deer population, which fed increasingly on cottonwood seedlings and greatly reduced the normal rate of cottonwood recruitment. Additionally, surveys of indicator species in this area confirmed reduced biodiversity and population numbers within various categories of plant and animal species.

Teacher Tip: Prompt your students to explain the parts of the graph as applicable:

- Graph type: Bar graphs
- Error bars: Standard error
- Trend line: Exponential function fitted to the frequency of different tree age categories in (a), with an r^2 = 0.94. A copy of this line was reproduced in (b) for comparison only; the trend line is not a fit to the data in (b).
- X-axis: Tree origination decade. This is the estimated decade in which a tree originated (germinated) based on tree diameter.
- Y-axis: Density of cottonwood trees. This is the number of cottonwood trees of a certain age per kilometer within each riparian area.

DISCUSSION QUESTIONS

- What are some similarities between these two bar graphs? What are some differences?

- What impacts did the European-American pioneers have on the riparian ecosystems of Zion National Park?
- In which decade do the trends in tree recruitment begin to differ between the two graphs? What happened during this time?
- Why does the figure not include data on trees that germinated before 1880?
- Draw a food chain that includes cottonwood trees, mule deer, and cougars.
- Draw a model of direct and indirect effects between these three species. What effect do cougars have on cottonwood trees?
- In Figure (b), what caused cougars to become scarce and deer to become abundant?
- Which other plant and wildlife species might be affected by the different events that occurred in the two riparian areas? Why?
- Which area do you think contains higher biodiversity, North Creek (with cougars) or the Virgin River in Zion Canyon (without cougars)? What is the rationale for your claim?
- What trend in cottonwood tree population sizes would you expect to see over the next few decades if Zion Canyon were closed to human visitors? Provide evidence that supports your prediction.
- If you were a wildlife management consultant for Zion National Park, what recommendations would you make to help increase the cottonwood population in the Virgin River area of Zion Canyon? Why?

KEY TERMS

age class, biodiversity, germination, herbivory, predator, prey, trophic cascade

SOURCE

Figure 7 in:
R. Beschta and W. Ripple. (2012) The Role of Large Predators in Maintaining Riparian Plant Communities and River Morphology. *Geomorphology* 157-158, 88-98. doi:10.1016/j.geomorph.2011.04.042.

AUTHOR

Natalie Dutrow, PhD, Salt Lake City School District, Utah
Edited by Robert Beschta, PhD, Oregon State University, Corvallis; Mark Nielsen, PhD, Bridget Conneely, and Jessica Johnson, HHMI