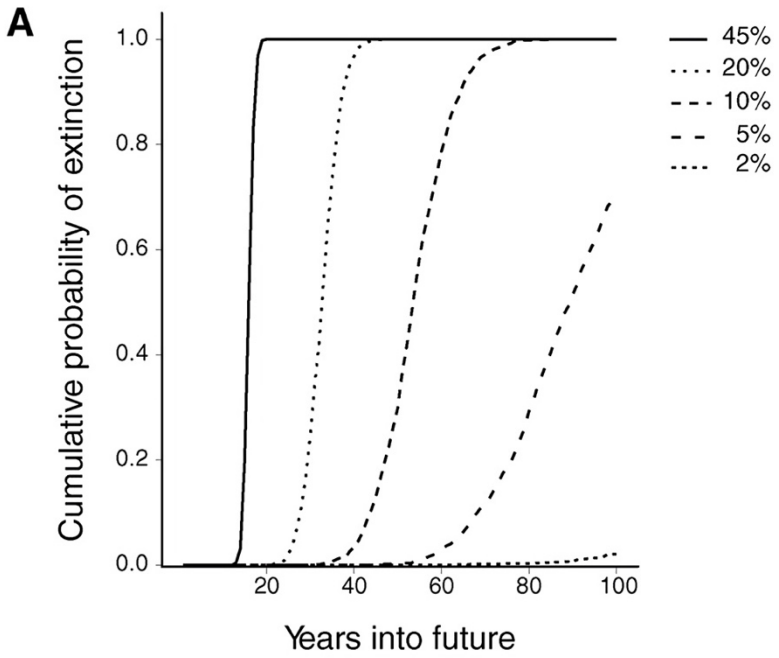
HOW TO USE THIS RESOURCE

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, increase engagement, or guide a class discussion about the characteristics of the graph and what it shows.



Caption: Estimated cumulative probabilities of extinction for the little brown bat population in the northeastern United States. These probabilities were projected for five annual rates of population decline (45%, 20%, 10%, 5%, or 2%) under an infectious disease called white-nose syndrome (WNS). Each projection was simulated for up to 100 years after the disease emerged in the population.

BACKGROUND INFORMATION

In 2006, an infectious disease called white-nose syndrome (WNS) began wiping out bat populations in North America. WNS is caused by a fungus known as *Pseudogymnoascus destructans* (formerly *Geomyces destructans*). Although the fungus does not harm bat populations in Europe, where it is thought to have originated, it kills about 73% of the bats it infects in North America. In North America, the fungus grows on the skin of hibernating bats. This skin infection often makes the bats wake up from hibernation too early, leading them to use too much energy during the winter and eventually starve to death. By killing large numbers of North American bats, many of which eat insect pests, WNS may devastate ecosystems and increase pest control costs.

Scientists investigated how WNS may impact one major North American bat population: the little brown bat (*Myotis lucifugus*) population in the northeastern United States. The scientists created a mathematical model based on the population's observed survival and breeding rates with and without WNS. They used this model to project the probabilities that the population will go extinct within 100 years. The scientists also considered the possibility that the population of bats could eventually evolve resistance to WNS, which would slow the

population's decline. To account for different levels of resistance, the scientists ran the model under five different annual rates of population decline: 45%, 20%, 10%, 5%, and 2%.

INTERPRETING THE GRAPH

The graph shows cumulative extinction probabilities for the little brown bat population in the northeastern United States. The "cumulative" extinction probability for a given year is the probability that extinction occurred during *or* prior to that year. To estimate extinction probabilities, the scientists used their model to perform 1000 simulations, each showing 100 years of the population's growth after WNS emerged. They defined the probability of extinction for each year as the proportion of the 1000 simulations in which the population fell below an extinction threshold (0.01% of the starting population of 6.5 million bats, or 650 bats) during that year.

The model was run under five possible rates of annual population decline (45%, 20%, 10%, 5%, and 2%), which can correspond to different levels of resistance or other adaptations to WNS. As shown in the figure, only the lowest decline rates (5% and 2%) do not lead to a 100% chance of extinction within 100 years. A decline rate of 45%, the worst-case scenario, results in a 99% chance of extinction within just 16 years. Even at medium decline rates of 20% and 10%, the chance of extinction within 65 years is greater than 90%. These results suggest that the population's annual decline rate would need to fall below 5% to significantly reduce the chance of extinction within 100 years.

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

- Graph type: Line graph
- *X*-axis: Number of years after 2006, the year when WNS emerged in the northeastern United States.
- *Y*-axis: Cumulative probability of extinction for the little brown bat population in the northeastern United States (the probability that extinction occurred during *or* prior to that year).

DISCUSSION QUESTIONS

- The extinction of the little brown bat in the northeastern United States would be an example of a regional extinction. What is meant by a "regional extinction"? How is this distinct from what is normally meant by extinction?
- What is a "cumulative" probability? Explain your answer using an example from the figure.
- Why did the scientists consider five different rates of population decline?
- Which rate(s) of decline lead to a 100% chance of extinction within 100 years?
- Which rate of decline would probably cause the population to go extinct the soonest? For this rate, within how many years would the population most likely be extinct?
- How low would the population's rate of decline need to be to reduce the chance of extinction within 100 years below 100%? Below 50%?
- What are some changes that could reduce the population's chances of extinction? Your answer may include both potential adaptations in the population and actions by wildlife managers.
- Is this population guaranteed to evolve resistance to WNS? Explain your answer using the process of natural selection.
- In their model, the scientists assumed that the population would be extinct if it fell below 0.01% of its starting size. However, people often think that extinction means that there are *no* organisms of a species left. Why do you think the scientists deemed very low population numbers to be "an extinction"?
- What are some advantages of using mathematical models in addition to field observations or experiments? Why do you think the scientists chose to use a model in this particular study?
- What might be some limitations of population models like this one?
- Could this model be used to estimate extinction probabilities for a different population or species? Why or why not?

- The fungus that causes WNS is believed to have come from Europe and does not cause high mortality in European bat populations. Why do you think this fungus affects European bats and North American bats so differently?
- This figure was published in 2010. Do some research to see what has happened to North American bat populations since then and compare what you find to the projections in the figure. Are there any differences between the more recent findings and the model's projections? If so, what might explain these differences?

KEY TERMS

bats, cumulative probability, extinction, fungus, infectious disease, population model, white-nose syndrome

SOURCE

Figure 4A from:

Frick, Winifred F., Jacob F. Pollock, Alan C. Hicks, Katie E. Langwig, D. Scott Reynolds, Gregory G. Turner, Calvin M. Butchkoski, and Thomas H. Kunz. "An emerging disease causes regional population collapse of a common North American bat species." *Science* 329*,* 5992 (2010), 679–682. https://doi.org/10.1126/science.1188594.

AUTHOR

Bob Kuhn, Centennial High School, Roswell, Georgia
Edited by Winifred Frick, University of California, Santa Cruz; Sydney Bergman, Esther Shyu, and Jessica Johnson, HHMI