Endangered Species: A Population Simulation

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Abstract

This article describes an activity which incorporates biology and mathematics at the secondary level. A hands-on simulation of a decreasing animal population is provided. Students collect their data, record it in a table, and analyze it using technological tools. The mathematics used in this activity includes rates; fitting functions to data; creating and interpreting linear, quadratic, and exponential functions; and using functions to solve real-world problems.

Scientists continually aim to preserve animal populations that are nearing extinction. In this activity, we simulate the work of a biologist in determining whether a species is becoming endangered. Multiple factors cause a species' population to decline, including destruction of its natural habitat, introduction of exotic species, illegal hunting that is not controlled, legal exploitation, and natural causes. For example, the Indian tiger is nearing extinction due to illegal hunting such that more tigers are dying than are being born (Shukla, 2014).

Common Core State Standards Addressed

Based on the Common Core State Standards for Mathematical Practice MP4: Modeling with Mathematics (CCSSI, 2010), we developed this activity to simulate the decrease in a species' population assuming that the species' death rate is higher than its birth rate. This activity also addresses MP5: Using appropriate tools strategically, as students have the choice of using computers or graphing calculators to analyze their collected data. We have used this activity as an example of science, technology, engineering and mathematics (STEM) instruction in a graduate course for in-service middle and secondary mathematics teachers and in undergraduate courses for pre-service middle and secondary mathematics and science teachers. This activity could also be used in Algebra 1, Algebra 2, or in AP Statistics courses.

Preparing for the activity

The following topics should be reviewed in preparation for this activity (corresponding Common Core State Standards are in parenthesis): Finding a percent of a quantity as a rate per hundred (6.RP.A.3.c); creating equations in one variable (HAS.CED.A.1); and fitting a function to data and using such functions to solve problems (HSS.ID.B.6.A).

The Activity

Scientists have identified five categories by which they classify the percentage changes in an endangered species' population over time, from highest threatened level to lowest threatened levels: critically endangered, endangered, vulnerable, near threatened and least concern (IUCN, 2013). Table 1 explains the percentages considered when determining how to classify a species in the described level of endangerment.

Table 1: Threatened Levels Based on Population Reduction Percentage

	Classification Criteria
Critically Endangered (CR)	≥ 80% population reduction over a 10 year period
Endangered (EN)	≥ 50% population reduction over a 10 year period
Vulnerable (V)	≥ 30% population reduction over a 10 year period
Near Threatened (NT)	≥ 25% population reduction over a 10 year period.
Least Concern (LC)	Does not qualify for any of the above categories.

You will be simulating drops in population of a species using beans. Each bean represents one animal.

Materials:

- Plastic container labeled "Living Population" filled with 300 or fewer beans (roughly 4-5 handfuls of beans)
- Empty plastic container labeled "Deceased Population"
- Optional use of TI-84 graphing calculator, spreadsheet software, such as Microsoft Excel.

Procedure (referring to Table 2):

1. Count your beans in the "Living Population" pile. Fill in C4. This represents the "Living Population" of the animal in year 0.
2. Use your entry from E4 to fill in C5.
3. From the "Living Population" pile of beans, pull out two handfuls of beans **and count the number of beans that you took**. Record your results in D5. Place these beans in the "Deceased Population" pile.
   a. Use your results from columns D5 to fill in E5.
4. Calculate the percent remaining of the living population and the percent deceased of the living population. Fill in F5 and G5.
5. Using Table 1, identify the species' threatened level classification in H5.
6. Repeat steps 2-5 four more times, working your way down the table.
7. Respond to the questions listed following the table.

Table 2: Population Simulation Data

A/1	B	C	D	E	F	G	H
2	Year	Living Population	Deceased Population	Remaining Population	% Remaining of Living Population	% Deceased of Living Population	Threatened Level
3		All Beans	Beans You Pulled	C - D	E / C	100% - F	Reference Table 1
4	0		0		100.0%	0.0%	N/A
5	10						
6	20						
7	30						
8	40						
9	50						
10	60						
11	70						
12	80						
13	90						
14	100						
15	110						
16	120						
17	130						
18	140						
19	150						

(An electronic version is available at http://tinyurl.com/p673fr7)

Questions Regarding the Experiment:

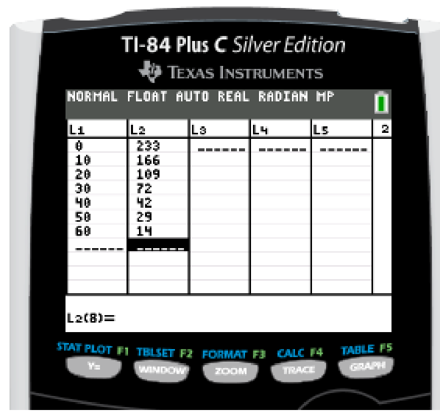
1. Based on your experiment, will your species become extinct? If so, how long will it take for this to happen?
2. Graph the year (independent variable, column B of Table 2 – L1 in a graphing calculator) and the remaining population (dependent variable, column C of Table 2 – L2 in a graphing calculator). What kind of curve seems to fit the data the best? Find the equation for the curve.
3. Continue the experiment until the species becomes extinct. Record the data in the table. Does this match your prediction from your experiment? Your equation? Explain.
4. If the initial population size were doubled, would that double the amount of time that it takes for the population to become extinct? Why or why not?
5. Create three additional questions that you can answer using your data. Answer these questions.

Extension Questions

Table 3 is data produced by a group of students in Mr. Gonzalez's class.

Table 3: Sample Data

A/1	B	C	D	E	F	G	H
2	Year	Living Population	Deceased Population	Remaining Population	% Remaining of Living Population	% Deceased of Living Population	Threatened Level
3		All Beans	Beans You Pulled	C - D	E / C	100% - F	Reference Table 1
4	0	233	0	233	100.0%	0.0%	NT
5	10	233	67	166	71.2%	28.8%	NT
6	20	166	57	109	65.7%	34.3%	V
7	30	109	37	72	66.1%	33.9%	V
8	40	72	30	42	58.3%	41.7%	V
9	50	42	13	29	69.0%	31.0%	V
10	60	29	15	14	48.3%	51.7%	EN



1. Using the data in Table 3 and the exponential regression feature on her graphing calculator, Sally got $y = 2260.35 \times (.96)^x$ as the equation of best fit, with $R^2 = 0.9897$. Tom used the same data and did exponential regression in Excel and obtained the equation, $y = 260.35 \times e^{-0.046x}$ and obtained the same R^2 value, 0.9897. Tina asks, "How can it be that we obtained different exponential functions but still got the same R^2 value?" Respond to Tina's question.

2. Lillian is trying to determine when the animal population will become 0. She plugs the expression $y = 283.82 \times (.95)^x$ into her graphing calculator and she receives an error message when she tries to analyze the zeroes of the function. Why is she getting this error message?

3. In the experiment, the results of the regressions we perform on our sample data are the following:
   a. Linear regression: $y = -3.5643x + 201.93$ with $R^2 = 0.9231$
   b. Quadratic regression: $y = 0.588x^2 - 7.0929x + 231.33$ with $R^2 = 0.9985$
   c. Exponential regression: $y = 260.35 \times e^{-0.046x}$ with $R^2 = 0.9897$

4. Mr. Gonzalez asks the students to determine which curve is the best fit for the data. Bob says he thinks that the quadratic equation is the best fit because it has the greatest R^2 value. Jane disagrees and prefers to use the exponential equation. What are some reasons why Jane might not prefer the exponential equation?

Conclusion

In this simulation, students simulate a species' strictly decreasing population. As a further extension of the activity, students can explore parameters which allow a species to increase its population, namely, have a birth rate that is higher than its death rate over a long period of time. An example of such an extension activity is published in *The Oregon Mathematics Teacher Journal* (Thompson & Cheng, 2014).

References

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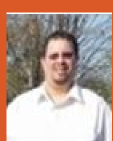
Diana Cheng is an assistant professor in the Department of Mathematics at Towson University. She prepares in-service and pre-service teachers to teach mathematics at all grade levels. She is interested in using STEM topics to motivate students to learn mathematics.



David Thompson is a mathematics and science teacher at Bayard Middle School in Wilmington, DE, and is a mathematics education graduate student at Towson University. He formerly taught secondary mathematics in Baltimore City Public Schools. He enjoys incorporating real-world scenarios in mathematics instruction.

"The classroom is a domain; real life is another. We react to a piece of information not on its logical merit, but on the basis of which framework surrounds it, and how it registers with our social-emotional system. Logical problems approached one way in the classroom might be treated differently in daily life. Indeed they *are* treated differently in daily life."

Taleb, N. N. (2010). *The black swan: The impact of the highly improbable*, 53. New York, NY: Random House.

"Alas, we are not manufactured, in our current edition of the human race, to understand abstract matters-we need context."

Taleb, N. N. (2010). *The black swan: The impact of the highly improbable*, 132. New York, NY: Random House.