THE SIXTH EXTINCTION

EARTH matters
Studies For Our Global Future

introduction

Species go extinct all the time. In fact, over 99 percent of all species in the history of the Earth are now extinct. Most of this loss happened slowly and without fanfare through what is known as **background extinction**. What is much less common is a period of high species loss over a relatively short period of time, or a **mass extinction**. Throughout the history of the planet, there have been five identified periods of mass extinction and all five have deeply influenced the history of life on Earth.

Many scientists contend that we are now experiencing a sixth mass extinction due to the impacts of the human species. Paleobiologist Dr. Alex Dunhill from The University of Leeds writes: "The similarities between today and the past are uncanny. The majority of past extinctions are associated with carbon dioxide from volcanoes causing rapid global warming, which led to a number of environmental cascade effects. The cause may be different, but the results will be the same."[1] It is now humans that are emitting carbon dioxide and manipulating the environment and Earth's systems.

Conservation biologists are calling this sixth mass extinction a **biodiversity** crisis due to the abnormally large number of species dying out. And while the demise of well-known and well-loved creatures make headlines – such as the extinction of the western black rhinoceros and Pinta Island tortoise (one of which was the famed Lonesome George) – many other lesser-known species, such as the sea mink, acorn pearly mussel, and golden toad, are lost with little or no fanfare. In all cases, we're altering the delicate web of life that not only adds to the beauty and richness of the planet, but is also critical to our own existence.

Vocabulary: background extinction, biodiversity, mass extinction, observed extinction rate

materials

Part 1

- Article excerpts: "The Sixth Extinction?" (provided)
- Chart: "Mass Extinctions – Losses and Causes" (provided)
- Student Worksheet 1

Part 2

- Student Worksheet 2 (Version A or B)

concept

Human activities have caused a mass extinction of species, which threatens the rich biodiversity on Earth.

objectives

Students will be able to:

- Read and respond to questions from an article and chart on mass extinction.
- Describe the geologic history of extinction and past causes.
- Calculate the current extinction rate using observed extinction data, and interpret plot and line graphs displaying observed extinction statistics.
- Compare current extinction levels to background extinction levels and use the information to discuss the validity of a modern sixth extinction.

subjects

Environmental Science (General and AP), Biology, Algebra, English Language Arts

skills

Reading comprehension, critical thinking, writing and solving proportions, analyzing scatterplot and line graphs, creating bar graphs

method

Students read and discuss an article about the current mass extinction of species, then calculate extinction rates and analyze data to compare modern rates to the background extinction rate.

Part 1: The Past "Big Five"

procedure

1. Distribute the excerpted article "The Sixth Extinction?" and Student Worksheet 1 to each student.

2. Display the chart, "Mass Extinctions – Losses and Causes," and provide students time to answer the content and extension questions. (They will need both the chart and the article to answer all of the questions.) You may either pose the questions for class discussion, have the students discuss the questions in small groups, or have students complete written answers to the questions individually.

Answers to Student Worksheet 1

See Answer Key

Part 2: Extinction Rates, Then and Now

procedure

1. Introduce the concept of background extinction: Throughout all of Earth's history, there has been a continuous, low-level extinction of species – this is known as background extinction. When working with extinction data, E/MSY (extinctions per million species per year) is a widely-used metric referring to the number of extinctions per 10,000 species per 100 years.

   A recent estimate asserts the natural, or 'background,' extinction rate is 2 E/MSY. This means that if there was no outside influence from humans, we would expect to see 2 extinctions per 10,000 species per 100 years.

2. Distribute copies of Student Worksheet 2 and allow students time to work through the problems. Instruct students to round their answers to the hundredths decimal place. The worksheet is differentiated so you can distribute Versions A or B accordingly:

   - For advanced students, use Student Worksheet 2 – Version A. Students will need to fully determine the mathematic processes on their own.
   - To provide more support, use Student Worksheet 2 – Version B which offers scaffolding on the mathematic processes.

   Notes:
   - Be sure students understand the difference between the terms background extinction rate (the expected or "natural" rate) and **observed extinction rate** (what you could consider the "actual" rate).
   - Questions #1, #2, and #3 on the Worksheet are comparing the *numbers* of extinct species: background vs. observed; Questions #4 and #5 are comparing the *rates* of extinction: background vs. observed.

3. Review the answers to Student Worksheet 2.

Answers to Student Worksheet 2

See Answer Key

discussion questions

1. Reflect on the data covered in Student Worksheet 2. Based on that information, do you agree with the claim that the Earth is in the midst of a mass extinction?

   Answers will vary but most students would agree, based on the data showing exceptionally high modern extinction rates, that the Earth is experiencing a mass extinction.

2. The data provided on Student Worksheet 2 came from a study that provided two estimates on extinctions. One number is the count of extinctions directly observed by scientists. The other number includes species that are "on the brink" of extinction (meaning they will likely become extinct by 2050) in addition to the directly observed extinctions. Do you agree with using the broader number (that includes species "on the brink") to serve as extinction data? Explain.

   Some students might disagree because it means including species that are still living, even if there are only a few hundred individuals, within the number of observed extinctions. Other students might agree with including the "on the brink" species because it is unlikely that the species will make a comeback in the wild, and their impact on the ecosystem is severely limited.

   Note: Students might be interested to know that until recently, the background extinction rate was assumed to be between 0.1 and 1 E/MSY, reflecting what could be inferred from the fossil record in the 1990s. Had we used a rate in this range rather than 2 E/MSY, current extinctions would have appeared even more dramatic.

3. Consider the graph of human population over time. What type of relationship (direct or inverse) is there between human population growth and vertebrate extinction?

   There is a direct relationship. As the number of humans increased, the percentage of species gone extinct also increased.

4. What accounts for the increase in species extinction over the past 500 years?

   The actions of humans have increased the number of species going extinct. The largest threats species currently face are 1) habitat loss due to expansion of agriculture and development, as well as climate change, 2) competition with invasive species, 3) air, water, and land pollution, and 4) overexploitation for economic gain. All of these stressors are related to human population growth as well as increases in consumption.

5. What, if any, additional data would you like to explore to more strongly make the case of a sixth mass extinction?

   Answers will vary.

assessment

Students complete an exit ticket identifying one way the current loss of species is similar to past extinction events and one way the current loss of species is different from past extinction events.

follow-up activity

Have students write an essay on one of the following topics:

- Biologist and paleontologist Niles Eldredge writes that "agriculture represents the single most profound ecological change in the entire 3.5 billion-year history of life," and that "to develop agriculture is essentially to declare war on ecosystems." He goes on to write that agriculture "had the effect of removing the natural local-ecosystem upper limit of the size of human populations." Write an essay linking agricultural development, human population growth, and species loss. How did the mechanization of farming methods change the relationship between agriculture and species loss? Include at least one example of a country or region where agricultural expansion has been the cause of insufficient species habitat.

- The decline of species has several causes. These factors are summarized by conservation biologists under the acronym HIPPO (Habitat destruction, Invasive species, Pollution, Population, and Overharvesting/hunting). Write an essay explaining how these factors can be interrelated in causing a species' decline or extinction. Also describe and give examples of how these factors relate to two or three specific species. How do you think the importance of each of the HIPPO factors has changed over the course of human history, from hunter gatherers in Paleolithic times to today?

---

[1] Dunhill, A. (2017, June 29). Five mass extinctions - and what we can learn from them about the planet today. *The Conversation*. Retrieved from https://theconversation.com/five-mass-extinctions-and-what-we-can-learn-from-them-about-the-planet-today-79971

[2] Ceballos, G., Ehrlich, P.R., and Raven, P. (2020, June). Vertebrates on the brink as indicators of biological annihilation and the sixth mass extinction. *Proceedings of the National Academy of Sciences*. Retrieved from https://www.pnas.org/content/117/24/13596

Chart: Mass Extinctions – Losses and Causes

	Millions of years ago (mya)	Era	Loss of species	Suspected causes
1st	440	Late Ordovician	84-86%	Advance and retreat of ice sheets caused a short, severe ice age. Only event caused by global cooling.
2nd	360	Late Devonian	70-75%	Rapid fluctuations in sea levels and reduced oxygen levels in the oceans. Possibly caused by volcanic activity; possibly due to newly evolved plant life on land – roots dug into Earth and released nutrients into the ocean.
3rd	250	Late Permian	96%	Gigantic and prolonged eruption of the Siberian Traps rapidly intensified the greenhouse effect and the planet warmed. The ozone layer was partially destroyed, the ocean acidified as oxygen levels in the water were depleted.
4th	200	Late Triassic	80%	Causes are debated. Some point to a large volcanic eruption of the Central Atlantic Magmatic Province (that also split up Pangaea). Others claim an asteroid impact could be the cause.
5th	66	Late Cretaceous	76%	The impact of an asteroid to the Yucatan Peninsula was the final blow to species already under stress due to volcanic activity and climate change. (This extinction wiped out the dinosaurs.)
6th	*0 (today)*	*Anthropocene*	*33-58%**	

Source: Thomas, C. et al. Nature. *Extinction risk from climate change.*

*expected by mid-century

The Sixth Extinction?

By Elizabeth Kolbert

The following are excerpts from the longer article "The Sixth Extinction?" by Elizabeth Kolbert, published in the May 25, 2009 issue of The New Yorker.

The significance of mass extinctions goes beyond the sheer number of organisms involved. In contrast to ordinary, or so-called background, extinctions, which claim species that, for one reason or another, have become unfit, mass extinctions strike down the fit and the unfit at once.

…

Once a mass extinction occurs, it takes millions of years for life to recover, and when it does it generally has a new cast of characters; following the end-Cretaceous event, mammals rose up (or crept out) to replace the departed dinosaurs. In this way, mass extinctions, though missing from the original theory of evolution, have played a determining role in evolution's course; as Richard Leakey has put it, such events "restructure the biosphere" and so "create the pattern of life." It is now generally agreed among biologists that another mass extinction is under way. Though it's difficult to put a precise figure on the losses, it is estimated that, if current trends continue, by the end of this century as many as half of earth's species will be gone.

…

It is difficult to say when, exactly, the current extinction event—sometimes called the sixth extinction—began. What might be thought of as its opening phase appears to have started about fifty thousand years ago. At that time, Australia was home to a fantastic assortment of enormous animals; these included a wombatlike creature the size of a hippo, a land tortoise nearly as big as a VW Beetle, and the giant short-faced kangaroo, which grew to be ten feet tall. Then all of the continent's largest animals disappeared. Every species of marsupial weighing more than two hundred pounds—there were nineteen of them—vanished, as did three species of giant reptiles and a flightless bird with stumpy legs known as *Genyornis newtoni*.


Photo Credit: Carl Bento/Australian Museum

Genyornis newtoni.

This die-off roughly coincided with the arrival of the first people on the continent, probably from Southeast Asia. Australia is a big place, and there couldn't have been very many early settlers. For a long time, the coincidence was discounted. Yet, thanks to recent work by geologists and paleontologists, a clear global pattern has emerged. About eleven thousand years ago, three-quarters of North America's largest animals—among them mastodons, mammoths, giant beavers, short-faced bears, and sabre-toothed tigers—began to go extinct. This is right around the time the first humans are believed to have wandered onto the continent across the Bering land bridge. In relatively short order, the first humans settled South America as well. Subsequently, more than thirty species of South American "megamammals," including elephant-size ground sloths and rhino-like creatures known as toxodons, died out.

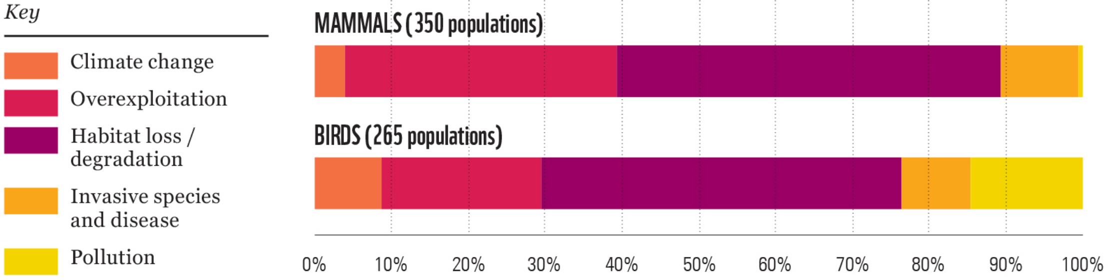
…

“We expect extinction after people arrive on an island,” David Steadman, the curator of ornithology at the Florida Museum of Natural History, has written. “Survival is the exception.”

Why was first contact with humans so catastrophic? Some of the animals may have been hunted to death; thousands of moa bones have been found at Maori archeological sites, and man-made artifacts have been uncovered near mammoth and mastodon remains at more than a dozen sites in North America. Hunting, however, seems insufficient to account for so many losses across so many different taxa in so many parts of the globe. A few years ago, researchers analyzed hundreds of bits of emu and *Genyornis newtoni* eggshell, some dating from long before the first people arrived in Australia and some from after. They found that around forty-five thousand years ago, rather abruptly, emus went from eating all sorts of plants to relying mainly on shrubs. The researchers hypothesized that Australia’s early settlers periodically set the countryside on fire—perhaps to flush out prey—a practice that would have reduced the variety of plant life. Those animals which, like emus, could cope with a changed landscape survived, while those which, like *Genyornis*, could not, died out.

When Australia was first settled, there were maybe half a million people on earth. There are now more than six and a half billion, and it is expected that within the next three years the number will reach seven billion.*

Figure 7: Taxonomic differences in threat frequency for 703 declining terrestrial populations in the LPI database *(WWF/ZSL, 2016).*



Source: WWF

Human impacts on the planet have increased proportionately. Farming, logging, and building have transformed between a third and a half of the world’s land surface, and even these figures probably understate the effect, since land not being actively exploited may still be fragmented. Most of the world’s major waterways have been diverted or dammed or otherwise manipulated—in the United States, only two percent of rivers run unimpeded—and people now use half the world’s readily accessible freshwater runoff. Chemical plants fix more atmospheric nitrogen than all natural terrestrial processes combined, and fisheries remove more than a third of the primary production of the temperate coastal waters of the oceans. Through global trade and international travel, humans have transported countless species into ecosystems that are not prepared for them. We have pumped enough carbon dioxide into the air to alter the climate and to change the chemistry of the oceans.

…

Andrew Knoll, a paleontologist at Harvard, has spent most of his career studying the evolution of early life…. Knoll noted that the world can change a lot without producing huge losses; ice ages, for instance, come and go. “What the geological record tells us is that it’s time to worry when the rate of change is fast,” he told me.

…

“CO_2 is a paleontologist’s dream,” Knoll told me. “It can kill things directly, by physiological effects, of which ocean acidification is the best known, and it can kill things by changing the climate. If it gets warmer faster than you can migrate, you’re in trouble.”

In the end, the most deadly aspect of human activity may simply be the pace of it. Just in the past century, CO_2 levels in the atmosphere have changed by as much—a hundred parts per million—as they normally do in a hundred-thousand-year glacial cycle. Meanwhile, the drop in ocean pH levels that has occurred over the past fifty years may well exceed anything that happened in the seas during the previous fifty million. In a single afternoon, a pathogen like Bd can move, via United or American Airlines, halfway around the world. Before man entered the picture, such a migration would have required hundreds, if not thousands, of years—if, indeed, it could have been completed at all.

Currently, a third of all amphibian species, nearly a third of reef-building corals, a quarter of all mammals, and an eighth of all birds are classified as “threatened with extinction.” These estimates do not include the species that humans have already wiped out or the species for which there are insufficient data. Nor do the figures take into account the projected effects of global warming or ocean acidification. Nor, of course, can they anticipate the kinds of sudden, terrible collapses that are becoming almost routine.

I asked Knoll to compare the current situation with past extinction events. He told me that he didn’t want to exaggerate recent losses, or to suggest that an extinction on the order of the end-Cretaceous or end-Permian was imminent. At the same time, he noted, when the asteroid hit the Yucatán “it was one terrible afternoon.” He went on, “But it was a short-term event, and then things started getting better. Today, it’s not like you have a stress and the stress is relieved and recovery starts. It gets bad and then it keeps being bad, because the stress doesn’t go away. Because the stress is us.”

*World population reached 7 billion in 2011 and is expected to grow to 8 billion by 2023.

**As of 2021, 40 percent of all amphibian species, one-third of reef-building corals, over one-fourth of all mammals, and one-seventh of all birds are classified as “threatened with extinction.”

THE SIXTH EXTINCTION | student worksheet 1

Name: ____ **Date:** ________________

Use specific evidence from the chart "Mass Extinctions - Losses and Causes" and the excerpted article "The Sixth Extinction?" by Elizabeth Kolbert to answer the following questions. Use complete sentences.

Content Questions

1. What does the abbreviation mya stand for when talking about events in natural history?

2. What types of events are thought to have caused earlier mass extinctions?

3. Which of the earlier mass extinctions was most devastating?

4. What about the current extinction is different from other major extinctions?

5. How is a mass extinction different from background extinctions?

6. What is the main feature of the opening phase of the current extinction? Describe the impact this had on species at that time.

7. Since reaching a global human population of over 7 billion, "human impacts on the planet have increased proportionately." What parts of the planet do humans impact and how?

8. How much (in parts per million) has CO_2 levels in the atmosphere increased in the last 100 years? How long did it normally take CO_2 levels to increase that amount?

9. What is one consequence of our global interconnectedness (our ability to easily move from one place to another)?

Extension Questions

10. What does Kolbert surmise is the most deadly aspect of human activity, and how does this impact ecosystems and extinction?

11. The author quotes paleontologist Andrew Kroll saying “the stress is us” when referring to the stress on the planet. How do humans put stress on the Earth?

12. Biologist and paleontologist Niles Eldredge once stated, “We can continue on the path to our own extinction, or... modify our behavior.” What does he mean?

13. What roles does CO_2 play in mass extinction events?

14. How do you imagine an extinction event “restructures the biosphere?” Hint: Consider that it wasn’t until the dinosaurs went extinct that mammals, such as humans, flourished.

THE SIXTH EXTINCTION | student worksheet 2 - version A

Name: ______________________________ **Date:** ____________

Number of Expected Extinctions

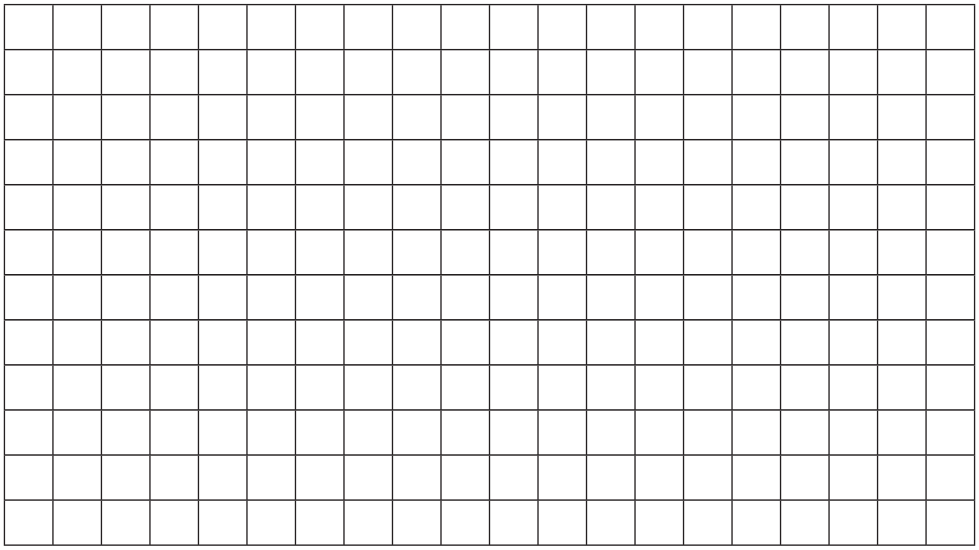
1. Question: 29,400 vertebrate species were evaluated. The background (expected) extinction rate is 2 E/MSY, which means that if there was no outside influence from humans, we would expect to see 2 extinctions per 10,000 species per 100 years. Based on this information, how many vertebrate species would you expect to go extinct in 100 years? Show your work.

   Answer: In 100 years, we'd expect ____________ out of 29,400 vertebrate species to go extinct.

2. Question: Using the same number of evaluated species (29,400) and background extinction rate (2 per 10,000 species per 100 years), how many vertebrate species do you expect to go extinct in 119 years? Show your work.

   Answer: In 119 years, we'd expect ____________ out of 29,400 vertebrates to go extinct.

3. Scientists directly observed that 543 vertebrate species went extinct between 1900 and 2019. On the grid below, create a graph that compares the expected number of extinct vertebrate species (your answer from #2) with the observed number of extinct vertebrate species, for the 119-year period. You'll need to decide what type of graph you'll use, determine an appropriate scale, and include all necessary labels.



Current Rate of Extinctions

4. <u>Question</u>: In Question #2, you determined how many vertebrate species, out of 29,400, were expected to go extinct in a 119-year period assuming the background extinction *rate* of 2 E/MSY. In reality, 543 vertebrate species went extinct during that time period. What was the actual observed extinction rate for this 119-year period? Answer should be given in E/MSY. (Remember that E/MSY = the number of species going extinct out of 10,000 studied over 100 years.)

   <u>Answer</u>: During this 119-year period, the observed extinction rate in E/MSY: ______________________________

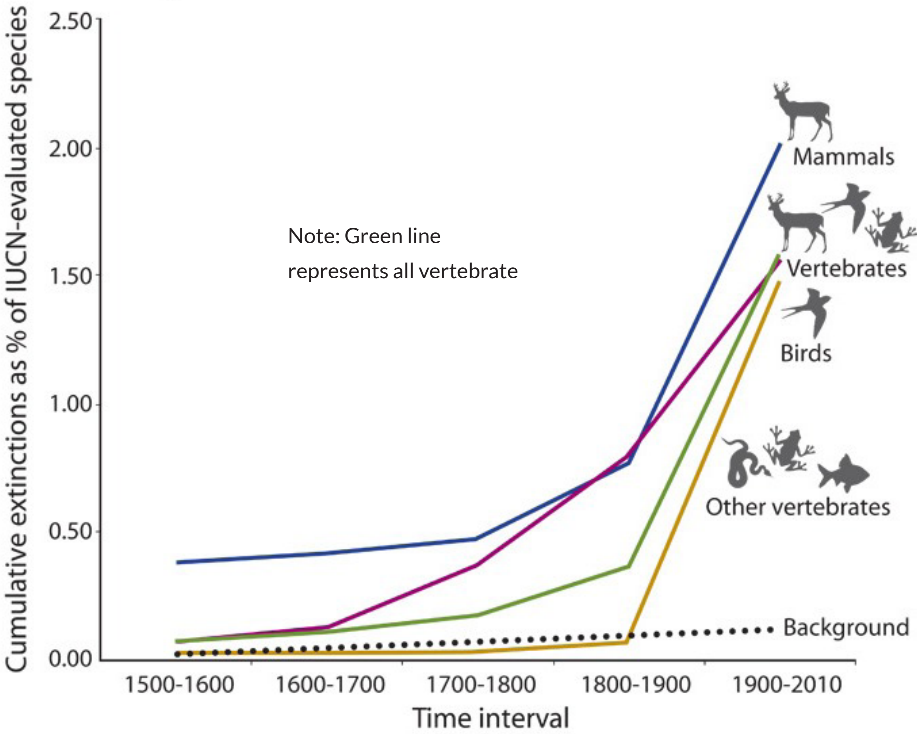
Years Needed for Recent Extinctions

5. It has been observed that 543 vertebrate species went extinct between 1900 and 2019, a 119-year period. At the rate of 2 E/MSY, one could expect it to take 9,235 years for 543 species to go extinct.

   Use adding machine paper to display the actual number of years (119) and the expected number of years based on the background extinction rate (9,235). Represent time, in years, using length by implementing the scale 100 years = 1 cm. You should end with two strips of paper, cut to the appropriate length.

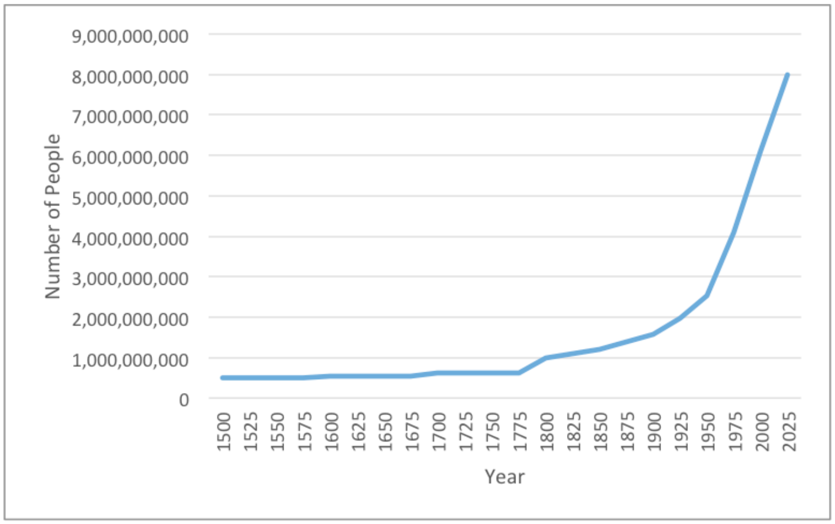
Further Evidence for Discussion

Percentage of Species Gone Extinct Over Time



Source: Ceballos, G., Ehrlich, P. R., Barnosky, A. D., García, A., Pringle, R. M., & Palmer, T. M. (2015, June 1). Accelerated modern human-induced species losses: Entering the sixth mass extinction. *Science Advances*. Retrieved from https://advances.sciencemag.org/content/advances/1/5/e1400253.full.pdf

Human Population Growth



THE SIXTH EXTINCTION | student worksheet 2 - version B

Name: ____ **Date:** ______________

Number of Expected Extinctions

1. Question: 29,400 vertebrate species were evaluated. The background (expected) extinction rate is 2 E/MSY, which means that if there was no outside influence from humans, we would expect to see 2 extinctions per 10,000 species per 100 years. Based on this information, how many of the 29,400 evaluated vertebrate species would you expect to go extinct in 100 years?

   a. Express the background rate as a fraction showing number of extinct species out of 10,000. Use that to create a proportion to determine the number of extinct species (x) out of 29,400.

   $$\_\_\_\_\_\_ = \frac{x \text{ extinct species}}{29{,}400 \text{ evaluated species}}$$

   b. Cross multiply the equivalent fractions. Write your new equation below.

   ____________ • ____________ = ____________ x

   c. Simplify your equation. Then isolate the variable using inverse operations. Remember to do the same thing to both sides.

   ____________ = ____________ x

   x = ____________

   Answer: In 100 years, we'd expect ____________ out of 29,400 vertebrate species to go extinct.

2. Now that you know the number of species that we would expect to go extinct in a 100-year period (x from #1), use that ratio to determine how many species you would expect to go extinct in a 119-year period by solving for z.

   Set up a proportion to calculate the answer.

   $$\frac{x \text{ species}}{100 \text{ years}} = \frac{z \text{ species}}{119 \text{ years}}$$

   z = ____________

   Answer: In 119 years, we'd expect ____________ out of 29,400 vertebrate species to go extinct.

3. Scientists directly observed that 543 vertebrate species went extinct between 1900 and 2019. Create a bar graph that compares the expected number of extinct vertebrate species (your answer from #2) with the observed number of extinct vertebrate species. The scale for the y-axis should range from 0 to 600. Be sure to include all necessary labels.

Current Rate of Extinctions

4. <u>Question</u>: In Question #2, you determined how many vertebrate species, out of 29,400, were expected to go extinct in a 119-year period assuming the background extinction *rate* of 2 E/MSY. In reality, 543 vertebrate species went extinct during that time period. What was the actual observed extinction rate for this 119-year period? Answer should be given in E/MSY. (Remember that E/MSY = the number of species going extinct out of 10,000 studied species over 100 years.)

   a. Because the rate is given per 100 years, you'll need to first determine how many species went extinct in 100 years. The following proportion has been set up for you. Cross-multiply and isolate the variable to solve for x. Refer back to problem #1 if you need reminders on this process.

$$\frac{\text{543 species}}{\text{119 years}} = \frac{\text{x species}}{\text{100 years}}$$

x = ______________

b. Now that you know how many species out of 29,400 species went extinct (in 100 years), use that ratio to determine how many species out of 10,000 species would go extinct. Set up another proportion, or use another method, to calculate the answer.

<u>Answer</u>: During this 119-year period, the observed extinction rate in E/MSY: _______________

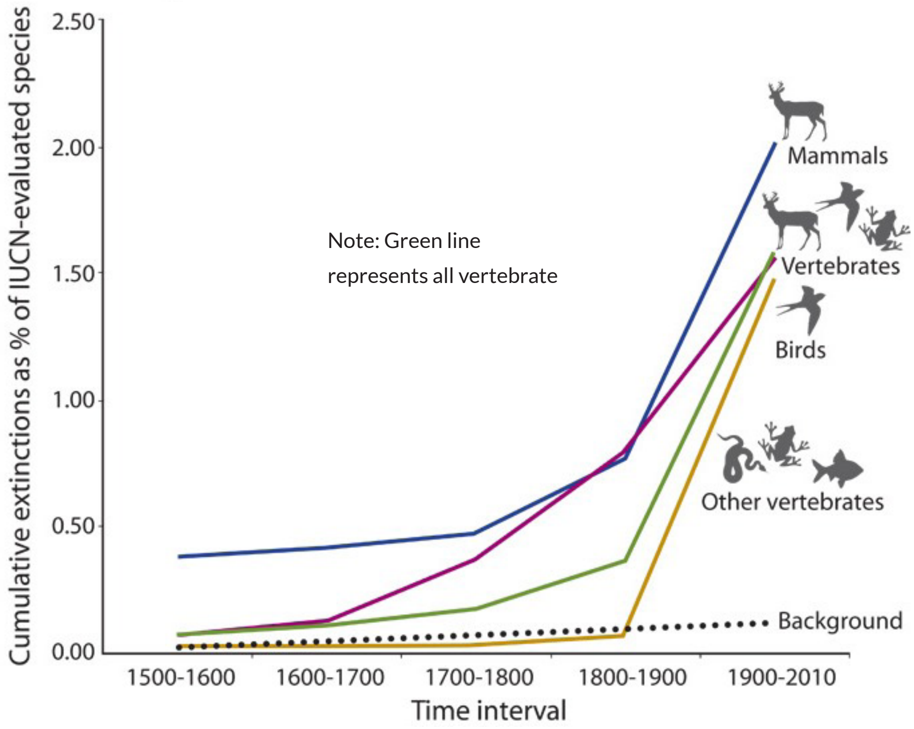
Years Needed for Recent Extinctions

5. It has been observed that 543 vertebrate species went extinct between 1900 and 2019, a 119 year period. At the rate of 2 E/MSY, one could expect it to take 9,235 years for 543 species to go extinct.

   Use adding machine paper to display the actual number of years (119) and the expected number of years based on the background extinction rate (9,235). Represent time, in years, using length by implementing the scale 100 years = 1 cm. You should end with two strips of paper, cut to the appropriate length.

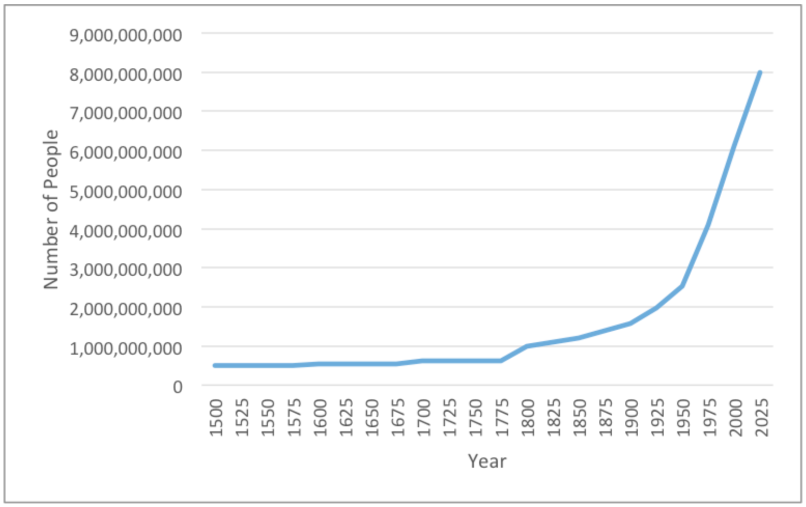
Further Evidence for Discussion

Percentage of Species Gone Extinct Over Time



Source: Ceballos, G., Ehrlich, P. R., Barnosky, A. D., García, A., Pringle, R. M., & Palmer, T. M. (2015, June 1). Accelerated modern human-induced species losses: Entering the sixth mass extinction. *Science Advances*. Retrieved from https://advances.sciencemag.org/content/advances/1/5/e1400253.full.pdf

Human Population Growth



THE SIXTH EXTINCTION | student worksheet 1 answer key

Content Questions

1. What does the abbreviation mya stand for when talking about events in natural history?

   Millions of years ago.

2. What types of events are thought to have caused earlier mass extinctions?

   The earlier mass extinctions are thought to be caused by volcanic eruptions, changes in the oceans' chemistry, and in one case, asteroid impact. The former are all climate and temperature related causes.

3. Which of the earlier mass extinctions was most devastating?

   The Late Permian was the most devastating – 96 percent of species were lost.

4. What about the current extinction is different from other major extinctions?

   The cause of the current extinction is human activity; the causes of past extinctions were naturally occurring phenomenon.

5. How is a mass extinction different from background extinctions?

   During a mass extinction event, species are lost at a greatly increased rate and species that are both fit and unfit for survival are lost. Background extinction happens at a much slower pace and only claims species that have become unfit for survival.

6. What is the main feature of the opening phase of the current extinction? Describe the impact this had on species at that time.

   The arrival of humans to new areas was the main feature of the opening phase, and coincided with an abnormal amount of large land animals going extinct in these areas.

7. Since reaching a global human population of over 7 billion, "human impacts on the planet have increased proportionately." What parts of the planet do humans impact and how?

   Humans impact land through farming, logging, and building; waterways have been diverted or dammed; the atmosphere has higher levels of nitrogen due to chemical plants and CO_2 emissions; we have altered the oceans with fisheries and CO_2 emissions.

8. How much (in parts per million) has CO_2 levels in the atmosphere increased in the last 100 years? How long did it normally take CO_2 levels to increase that amount?

   CO_2 levels have increased one hundred parts per million. Throughout most of natural history, it took 100,000 years for CO_2 levels to increase by this amount.

9. What is one consequence of our global interconnectedness (our ability to easily move from one place to another)?

   Global interconnectedness means that species can be transported into ecosystems which are not able to survive their arrival. It also means harmful pathogens can easily spread throughout the world and infect far-reaching species.

Extension Questions

10. What does Kolbert surmise is the most deadly aspect of human activity, and how does this impact ecosystems and extinction?

    Kolbert states that "the most deadly aspect of human activity may simply be the pace of it." Humans are manipulating the environment – from clearing land for agriculture and building pens for fisheries to constructing highways and causing fragmentation – and thus changing ecosystems. When a species' habitat, food source, predators, etc. change quickly, as we see happening today, any species that cannot adapt will not survive.

11. The author quotes paleontologist Andrew Kroll saying "the stress is us" when referring to the stress on the planet. How do humans put stress on the Earth?

    Humans inhabit or travel over much of the Earth, so we directly affect many areas. In addition, we indirectly affect ecosystems everywhere as a result of actions that may take place far away. For example, humans overharvesting of fish then affects their food sources and the organisms that feed on them, setting off a chain reaction and impacting even the depths of the ocean that are not immediately touched by humans.

12. Biologist and paleontologist Niles Eldredge once stated, "We can continue on the path to our own extinction, or... modify our behavior." What does he mean?

    The Earth can only recover from harm when the source of that destruction ceases to be present. If we continue hurting the existence of other species on such a large scale, we will lose the ability to support ourselves and eventually die out. The Earth will then have a chance to recover from our harm. Alternatively, we can find ways to cooperate with nature that will allow us to live sustainably, so that we can continue to pursue our lifestyles without destroying the Earth.

13. What roles does CO_2 play in mass extinction events?

    When CO_2, a greenhouse gas, is added to the atmosphere, it can have far reaching effects. Some are direct, such as ocean acidification, while others are indirect, like climate change, but both impact the environment. And by impacting the environment, they impact all of the plants, animals, and organisms that call these impacted places homes. As ocean water acidifies, some species cannot cope with the lower pH levels. As the climate changes, species must try to adapt to the new climate or migrate to an area where they can survive. But the fast speed at which climate is changing regional environments makes both of these strategies difficult, and some species will not survive.

14. How do you imagine an extinction event "restructures the biosphere?"

    When extinction events occur, it's more than just the loss of many living things. The loss leaves space open in ecosystems for other, or new, creatures to fill. This was in fact the case with the fourth extinction which, because of the massive loss of terrestrial reptiles and amphibians, paved the way for the dinosaurs. The fifth extinction in which the dinosaurs went extinct made it possible for the more recent mammals to thrive.

THE SIXTH EXTINCTION | student worksheet 2 answer key

1. Question: How many vertebrate species would you expect to go extinct in 100 years?

$$\frac{2}{10{,}000} = \frac{x}{29{,}400}$$

$2 \cdot 29{,}400 = 10{,}000x$

$58{,}800 = 10{,}000x$

$x = 5.88$

Answer: In 100 years, we'd expect 5.88 out of 29,400 species to go extinct.

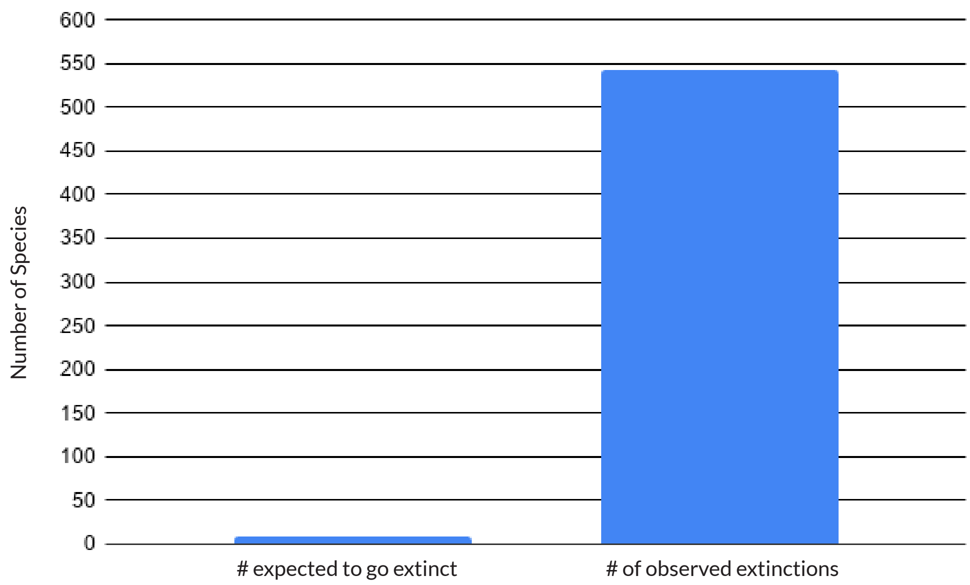
2. Question: How many vertebrate species do you expect to go extinct in 119 years?

$$\frac{5.88 \text{ species}}{100 \text{ years}} = \frac{z}{119 \text{ years}}$$

$z = 7.00$

Answer: In 119 years, we'd expect 7.00 out of 29,400 species to go extinct.

3. Create a graph that compares the expected number of extinct vertebrate species (answer from #2) with the observed number of extinct vertebrate species for the 119-year period.



4. What was the actual observed extinction rate for this 119-year period?

$$\frac{543 \text{ species}}{119 \text{ years}} = \frac{x}{100 \text{ years}} \qquad x = 456.3$$

$$\frac{456.3 \text{ species}}{29{,}400 \text{ species}} = \frac{z}{10{,}000 \text{ species}} \qquad z = 155.2$$

Answer: During this 119-year period, the observed extinction rate in E/MSY: 155.2

5. It has been observed that 543 vertebrate species went extinct between 1900 and 2019, a 119 year period. At the rate of 2 E/MSY, one could expect it to take 9,235 years for 543 species to go extinct.

Use adding machine paper to display the actual number of years (119) and the expected number of years based on the background extinction rate (9,235). Represent time, in years, using length by implementing the scale 100 years = 1 cm.

The two strips of adding machine paper should be cut to the following lengths:

Actual number of years = 1.19 cm

Expected number of years based on 2 E/MSY = 92.35 cm