Drawing Connections: The Parallels Between the End-Permian Mass Extinction and Current Climate Change

An undergraduate of East Tennessee State University explains that humans' current effects on the biosphere are disturbingly similar to the circumstances that caused the worst mass extinction in biologic history.

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Introduction

Imagine living in a world with dinosaurs. All the directors, writers, and various actors of the Jurassic Park movies series would agree—life would be survival of the fittest. And the fittest would not be the humans.

Most people are familiar with what happened to the dinosaurs. A 6-mile-wide asteroid struck Earth near what is now the Yucatan Peninsula. Its impact made enough energy to power over 500 nuclear weapons. The resulting cloud of debris blocked the sun for months and polluted the atmosphere. All the chemicals in the air and the lack of light brought an end to the dinosaurs' reign.

The End-Cretaceous Extinction event that destroyed the dinosaurs gave an advantage to some species—those that could tolerate the environmental changes were given the opportunity to grow and evolve. Thus, this extinction trend eventually allowed for the rise of man.

Ironically, some extinctions have benefits that allow humans to flourish; however, a new extinction is upon us. Humans threaten not only themselves, but also every other species living on Earth. Except the rats. The rats will flourish, as one scientist will say. Humans have affected the globe so greatly; scientists have proposed assigning a new name to describe our current geological epoch. According to two scientists, Paul Cruzten and Eugene Stoermer, instead of the *Holocene*, we are now living in the "Anthropocene", meaning human impacted.

The proposed name change is a result of scientific observations that dictate humans' involvement in changing the earth. Humans are affecting earth's topography, animals, and atmosphere. The scope of our effect is so significant we could be dawning on another mass extinction similar to the End-Permian Mass Extinction event, which up until now has been the worst mass extinction in recorded biologic, geologic, and paleologic history.

Brief Geologic Timeline

The history of Earth is separated into four eras: Pre-Cambrian, Paleozoic, Mesozoic, and Cenozoic. During the Pre-Cambrian era, life was just beginning, and our atmosphere just started to accumulate oxygen to support life. The Paleozoic era, which means "old life", included some animals, fungi, and plants, who all began evolving from simple protists. It was during this time that vertebrates, fishes, and amphibians began to evolve. The End-Permian Extinction, which occurred around 250 million years ago, marks the end of the Paleozoic Era. It destroyed over 96% of all life on Earth and defines the border from "old life" to "middle life", or the Mesozoic Era.

The Mesozoic era began the reign of the dinosaurs with the remnants of the Permian Mass Extinction. The end of the Mesozoic era is defined by the End-Cretaceous Mass Extinction, the most well-known massacre where the dinosaurs died from the asteroid impact I mentioned before. The asteroid ushered in the "modern life".

The Cenozoic era marks the beginning of "modern life". In geologic terms, this began almost 65.5 million years ago. Most of the geologic era and periods are defined by fossil evidence scientists can find; as a result, paleontologists and geologists are able to define more precise timelines and divide fossils into more accurate time periods called epochs.

The most modern epoch is the Holocene, which began at the end of the Ice Age (one-hundred thousand years ago). This was also the beginning of the dominant human species.

All the eras, periods, and epochs are defined by specific events that ushered in new species or wiped out old ones. With this in mind, the scientific community is currently reviewing a proposal to change our current epoch (Kolbert). Paul Cruzten, a Nobel Prize winner, and the late Eugene Stoermer, an expert in diatoms[1], believe humans have changed the Earth so

[1] One of the first protists and predecessor to current life.

greatly that we need to change the epoch from Holocene, meaning "recent whole" (because of the rise of humans), to Anthropocene, meaning "human effected".

The Anthropocene

Paul Cruzten and Eugene Stoermer, along with other scientists, agree—humans have affected the globe immensely, beginning at the Age of the Industrial Revolution, or before. The two proposed the International Commission on Stratigraphy[2] rename the epoch and redefine the line at the beginning of the Industrial Age in the late eighteenth century. More specifically, Cruzten and Stoermer suggest 1784, the year James Watt invented the steam engine. Evidence in ice cores[3] shows that this event marks the beginning of elevated carbon dioxide and methane levels that led to the imminent global warming—the greatest effect humans produce (Gore).

Humans are effecting more than just the atmosphere. Although the gases and pollutions industries release cause global warming, people also destroy biodiversity. Human activities lead to transformation of lands and waterways, disturbed animal interactions, and overexploitation of earth's resources—all leading to a biodiversity crisis.

Biodiversity Crisis

Biodiversity is plummeting. Scientists have measured that "human activity has increased the species extinction rate by one thousand to ten-thousand-fold" (Cruzten and Stoermer). The increase in extinction rate means a decrease in biodiversity. The biodiversity crisis is caused by several factors—all human based. According to my college biology textbook these include: habitat loss, invasive species, overharvesting, pollution, and global climate change (Reece 764).

Habitat Loss

Habitat destruction is the number one cause of species loss. Without a home to live in, species cannot survive. They do not have shelters, food stamps, or government care. Humans

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[2] The group responsible for maintaining the official timetable of earth's history.

[3] Ice Cores are used to measure atmospheric gases, such as carbon dioxide and methane, predating current times. They are more reliable than weather balloons because there are less variables. The gases get trapped in the ice and form bubbles when they freeze. This allows for a more accurate measurement of concentration.

are destroying the habitats per their advancement. Deforestation occurs because of “agriculture, urban development, forestry, mining, and environmental pollution” (Reece 764). In addition to deforestation, fragmentation separates habitats and makes it difficult for species to reproduce, thus lowering biodiversity. Fragmentation is the separation of habitats via forest fires, roadways, erosion from agriculture practices, farmland, etc. Deforestation and fragmentation of habitats cut animals resources for shelter and food.

Additionally, humans have altered 50% of Earth’s land and water already (Cruzten and Stoermer). Humans use over half fresh water habitats and most of the worlds’ rivers have been altered as a result of dams. For example, in 1962, the Kissimmee River in Florida was drained from its natural water path and forced into a canal. Engineers constructed the plan as a way to convert the floodplain to useable land for progress. The project, however, drained 31,000 acres of wetlands (Reece 776). The new canal led to a 92% decline in waterfowl and 70% decline of bald eagle territories. Because the wetland marsh is a natural filter of agricultural pollution, such as nitrogen and phosphorus, the lack of floodplain made all the pollution flow straight to Lake Okeechobee. The influx of additional chemicals further disrupted the Everglades ecosystem. Eventually, all these negative effects were recognized and the Kissimmee River was restored, but sadly that is not the fate of all misdirected rivers.

Invasive Species

Not only have humans transformed over half of the Earth’s land, but they have also altered the fate of many animals. Most of the species are dying from invasive species, foreign species introduced to new lands by humans.

For example, in 1859, English colonists introduced a new species of rabbits to Australia. These rabbits became a pest, destroying farm land and monopolizing marsupials’ main food sources. They devastated the land and native species (Reece 749).

Overexploitation

Furthermore, humans are overexploiting wildlife. Humans cut down trees for paper, houses, and luxuries without regard to the rarity of the wood or the threatened species. In addition to tree species, humans are drastically reducing animal species via excessive commercial harvest and poaching. One example includes overexploiting marine fish and seafood. Human's fisheries remove more than a quarter of primary production in the oceans (Cruzten and Stoermer). This means there are fewer populations of species present, demonstrating additional loss in biodiversity.

Pollution

The fourth cause of plummeting biodiversity is pollution. Pollution is ubiquitous. Humans pollute the earth, water, air, and animals. People cause oil spills, acid rain, "dead" zones[4], and ozone depletion[5]. Humans are also responsible for the Bald Eagle's endangerment in 1963.

After congress banned the hunting of eagles due to only 400 nesting eagles populating America, the population struggled to make a comeback. The population struggled because of the widely used, now banned, pesticide called DDT. The pesticide was used to wipe out mosquito populations on farmlands in attempt to eliminate the pest and the deadly disease, malaria, they carry. DDT failed to wipe out the mosquitos, but succeeded in devastating the eagle population.

The DDT polluted the soil and travelled to the oceans through runoff from the water cycle. In a process called biological magnification, the diluted version of DDT travelled through the food chain and multiplied in concentration. At elevated levels, DDT is poisonous—its effect: the eagles that ate DDT-ingested fish produced soft-shelled eggs, so that when the mother

[4] A "dead" zone is an aquatic habitat overrun by algal growth because of excess nutrients such as nitrogen and phosphorus. The algae block sunlight from travelling through the water and absorb much of the oxygen, depriving any life below of essential resources and killing them. The most famous dead zone is located in the Gulf of Mexico.

[5] Ozone is an essential chemical in our atmosphere that keeps an extra layer of protection from the sun's harmful rays. When certain chemical, such as CDCs, interact with ozone, they tear it apart. In the 1970s, humans created a hole in the atmosphere known as the Ozone hole. It is currently under reconstruction.

incubated her eggs, she crushed them. Once DDT was banned, the eagle population finally recovered in 2007 (Fact Sheet).

In addition to pesticide pollution, human industries, such as urbanization and agricultural practices are changing the composition of gases in the atmosphere. In the last 300 years, cattle populations have grown to 1.4 billion; and in the last 100 years, urbanization increased tenfold. An increase in cattle population leads to an increase in methane exhaustion, and the increase in urbanization means increases in carbon dioxide. As a result, these greenhouse gases, carbon dioxide and methane, have substantially increased—carbon dioxide by thirty percent and methane by more than one hundred percent. More nitrogen and phosphorus have been added to the environment by industrial fertilizers than natural inputs (McDowell). This proves that "greenhouse gases are accumulating in Earth's atmosphere as a result of human activities" (Oreskes), and are changing the composition of the atmosphere.

The greenhouse gases mentioned above include carbon dioxide, methane, and nitrous oxide. These gases occur naturally in the atmosphere and contribute to the greenhouse gas effect, the natural heating of the biosphere.

Greenhouse Gas Effect

The greenhouse gas effect is how the biosphere stays at a habitable temperature. If greenhouse gases did not insulate earth, we would not be able to live. The effect is so sensitive that even a little bit of warming alters the system.

The greenhouse gases (carbon dioxide, methane, and nitrogen oxides) are considered greenhouse gases because their ion arrangement allows for infrared absorption. This effect is a natural occurrence where earth absorbs light from the sun. The light energy Earth takes in is called visible light, which means the energy is coming in at a high frequency because the sun is warm. No energy can be destroyed according to the second law of thermodynamics; therefore, once the biosphere (Earth and its atmosphere) has used and absorbed the light waves, it must release the energy as well. Because Earth is cooler than the sun, the biosphere emits a lower frequency of energy known as infrared light. This infrared light gets absorbed by greenhouse gases on its way out. The longer the infrared light stays in the atmosphere; the more heat the biosphere retains. Because of this effect the earth is warm enough to live on.

However, the Earth is warming above natural temperatures because of human impacts. Humans are adding more greenhouse gases, specifically carbon dioxide to the atmosphere than natural processes known as biogeochemical cycles[6] (Crutzen and Stoermer). The added gas molecules of carbon and methane from the carbon cycle and nitrogen oxides from the nitrogen cycle creates more gases in the atmosphere that can absorb infrared light. The more molecules to absorb, the longer it takes for the energy to leave, the warmer the earth becomes. Since the dawn of the Industrial Age, humans have caused large increases in greenhouse gas concentrations—As of 2013, there has been a 40% increase in carbon dioxide and three times as much methane concentrations compared to the levels in the 1800s (HowGlobalWarmingWorks.org).

The rising concentration of greenhouse gases is directly correlated to the rise in global temperatures (Oreskes); thus, humans are causing global warming, an effect that is impacting human civilization as well as biodiversity.

Global Warming

Global warming is a sensitive topic in present-day life because many people are uneducated on the topic, ignore it, or do not believe climate change is happening. But in the scientific community, there is no doubt climate change exists. Naomi Oreskes demonstrated in 2008 that there is a current scientific consensus that global temperatures are rising (Oreskes). “The scientific consensus maybe wrong,” she warrants, but it exists. In the last thirty years, global temperatures have risen 0.2°C, or .32°F (McDowell). This may not seem significant, but keep in mind, the world’s carbon dioxide concentrations have never been higher than 400ppm[7]

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[6] Cycles that connect earth, atmosphere, and life. These cycles include the water, carbon, nitrogen, and phosphorus cycles.

[7] ppm stands for parts per million

(or .04%). None of the mass extinctions contained levels as great as this; but, in May of 2013, scientists recorded the Earth's atmospheric carbon dioxide levels to be 400ppm. Humans have set a record in the Guinness Book of World Records. Carbon dioxide levels are important because they are correlated with global temperature fluctuations (Oreskes).

If the fluctuation increase (as they have been), the warming alters normal weather patterns and causes more intense droughts, and ironically, worse flooding and storms (McKibben). The year 2010 brought in the warmest recorded year in meteorological history—19 countries set all-time records, since then, the subsequent years have been increasingly warmer. In 2010, Northern Europe experienced the Great Russian heat wave, which was recorded as the "most intense, widespread, and long-lasting heat waves in world history" (Masters). It almost matched the European heat wave of 2003 that killed 35,000-50,000 people. In 2011, the Mississippi River experienced its third "100-year-flood[8]" in the last twenty years (McKibben). And in August of 2016, the floods of southern United States displaced tens of thousands of people. These types of floods are predicted to occur 0.2 percent chance in any given year, yet happened eight times in a little over a year (Bromwich).

This change in weather patterns significantly affect humans (as shown in their displacement), animals (because their habitats are being destroyed), and the land (landscapes are being altered). Because of this, global warming is the fifth cause of biodiversity loss and many scientists are convinced it is "likely to become a leading cause" (Reece 765).

Anthropogenic global warming is just one example on how humans effect the biosphere. Human practices also pollute the atmosphere, exploit animals and resources, displace animals, and destroy habitats. As a result, scientists are reviewing a proposal to change the current geologic epoch to the "Anthropocene".

[8] This means the floods' intensity and occurrence are statistically improbably.

Relationships between the Permian Extinction and the Current Extinction

In order to understand the severity of human's impact, other than just a name-change suggestion, it is important to look to the past. Many of the threats humans pose today have been observed in the past, especially during times of mass extinctions.

Extinction Trends

Extinctions are inherently difficult to date and determine the causes. Geological processes, such as tectonic plates (the movement of Earth's thin crustal plates on the Mantle's moving magma), moves and crushes evidence, making it difficult to locate specific fossils from the different time periods.

The movement of the plates causes continents to strike each other, which creates mountains that bring up old sediments and rock. Other processes, such as the biogeochemical cycles, break down this sediment and destroys the fossil evidence. Despite these efforts, paleontologists are still able to date the rocks through radiometric dating. They can study the different chemicals in the soil and determine what time era and period the rock is from. They can also measure other elements to determine what Earth looked like at the time, i.e. the atmosphere, topography, and types of animals. They can also determine what caused major extinctions by measuring the amount of carbon or iridium in the samples.

The five major extinctions—End-Ordovician, Late Devonian, End-Permian, Late Triassic, and End-Cretaceous—each had different main extinction events, but they all are correlated with fluctuations in carbon dioxide levels and global temperature changes.

Scientists found the main cause of the End-Cretaceous extinction to be an asteroid impact, supported by copious amounts of iridium in strata dated to the extinction event time. Scientists also found the crater from the asteroid impact buried at the Yucatan Peninsula. As a result of the impact, volcanic eruptions ensued and caused intense global warming, but the large amounts of pollution from dirt particles and methane gas caused a planet-wide blackout for months, creating the Ice Age.

This global warming trend can be seen in all the major extinctions (Lee). They are all important to note, but perhaps the most influential extinction to understand is the End-Permian Mass Extinction.

The Permian period showed the genesis of land plants and animals, many of which still inhabit Earth, but not as greatly. Many of the animals are similar to those we have today and are thought be have been affected by the same factors humans are experiencing.

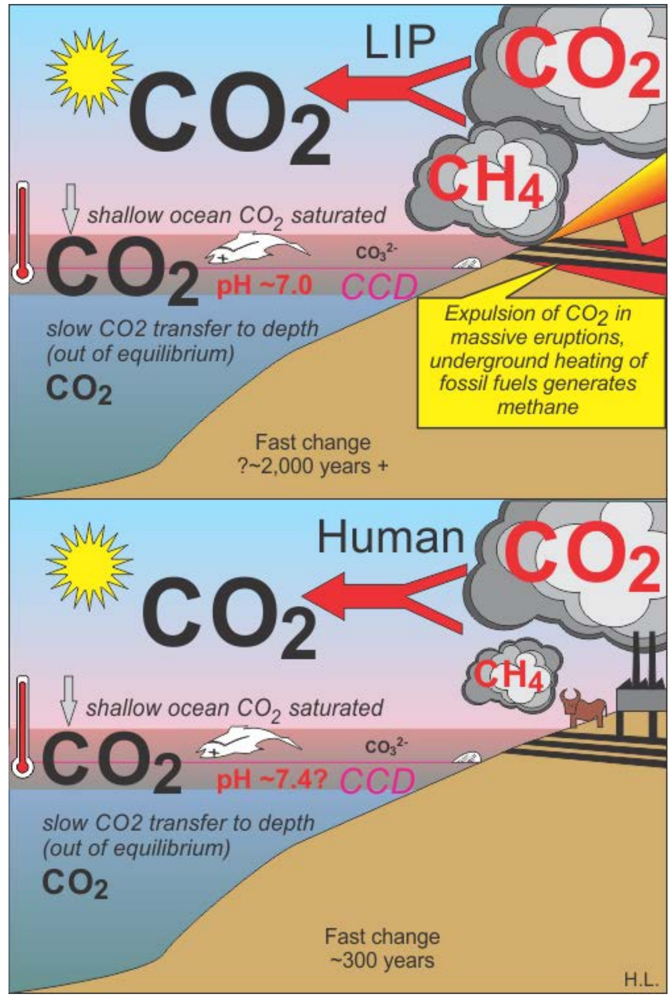
The Permian Extinction

The End-Permian Mass Extinction was the largest extinction of all—losing approximately 96% of all living species—aquatic and terrestrial. If the Earth's history was a book, the Permian Mass Extinction would be the climax. Earth's topography, atmosphere, and biodiversity changed significantly following the main extinction event. It took one-hundred thousand years for the species levels to return to the background levels[9].

During the Permian period, most life lived under water, that is, they were aquatic. Some examples include: crustaceans, echinoderms (starfish and sea cucumbers), cephalopods (octopus and squid), and gastropods (snails). Those living on land were recently acquainted to terrestrial life. Organisms had only colonized land 250 million years before the event. This means mostly arthropods (insects and spiders) and tetrapods[10] (mostly reptilian) inhabited the land at the time (Benton and Twitchett). Plant life consisted mainly of ferns and mosses (Reece).

[9] Term used to refer to a time before an extinction's main event.
[10] A vertebrate with four limbs.

The atmosphere at the time, was much like it is today. It contained the greenhouse gases: carbon dioxide, methane, and nitrogen oxides; and it held almost the same concentrations of nitrogen and oxygen as we have today. Where our methane and carbon dioxide comes from cattle and industrial pollution, the Permian period had LIP, or Large Igneous Province, otherwise known as the Siberian Flood Basalts. The flood basalts are an area of high volcanic activity and are thought to have released copious amounts of carbon dioxide and methane, as well as, some sulfur dioxide. The carbon dioxide levels were not nearly as high as they are today, only reaching about 210ppm; however, the global temperatures rose by ten degrees Celsius (biocab.org).



From: http://www.skepticalscience.com/Lee-commentary-on-Burgess-et-al-PNAS-Permian-Dating.html

Scientists, such as Michael Benton, R.J. Twitchett, and others, believe that this global temperature rise is what caused the extinction event. Or so, is one contributor.

There are many theories as to what caused the End-Permian Mass Extinction, some include: plate tectonics, asteroid impact, volcanic eruptions, and ocean acidification and anoxia. However, one theory is most widely accepted. It is so widely accepted that I learned about in my introductory biology course at ETSU, read about in my biology textbook, and discovered that many scientists, including Michael Benton, believe this theory is the most likely cause of the Permian extinction event. The Siberian Flood Basalts.

Volcanic eruption from the Siberian Flood Basalts is considered the main extinction event for the End-Permian mass extinction. This is an area located in present day Siberia known for its high volcanic activity. In a recent study, Michael Benton and Richard Twitchett discovered large amounts of activity from the volcanoes coincided with the Permian-Triassic boundary.

The volcanoes would have emitted copious amounts of carbon dioxide and methane. So much so that the global temperatures were increased by 6°C, or 10.8°F. This large increase greatly affected the greenhouse gas system. It is difficult to describe the extent of the effect. Imagine the weather effects I described earlier, but on a much larger scale.

Because the entire globe warmed, the temperature in the poles were closer to the temperatures in the tropics. This would have destroyed the temperate and artic habitats. The reduced interval of temperature differences slowed the ability of warm and cool water to mix. Therefore, aquatic biomes lost currents and habitats. Low current means low water mixture, means low oxygen levels. Low oxygen levels lead to hypoxia and anoxia, both meaning a deficit of oxygen levels in tissues. This alone would kill many organisms, but oxygen deficiency was not the end. Because of the low oxygen environment, it was possible for anaerobic bacteria to thrive. These are bacteria who can live and reproduce without oxygen. Anaerobic bacteria emit a poisonous by-product called hydrogen sulfide. This would have "bubbled" out of the oceans and killed land plants and animals (Reece). Hydrogen sulfide would have also reacted with other chemicals in the atmosphere and caused ozone depletion, similar to the effect of CDC in the 1970s.

In addition to the anoxia, ocean acidification would have occurred. Because of the rising carbon dioxide levels in the atmosphere, more carbon dioxide dissolved in the oceans. When dissolved in water, particles of carbon dioxide disassociate and reattach to water molecules to form carbonic acid. This is the acid that makes sodas fizz and gives it the bubbly taste. The added acid raised the pH levels of the ocean which naturally stays around 8.1, a slight basic concentration above the neutral level of 7. The new acid levels destroyed coral reefs who were home to numerous species, as they are today, and the carbonic acid reacted to chemicals in crustaceous shells, killing 59% of the living species (Clapham and Payne). Ninety-seven to one hundred percent of soft-bodied animals, like the starfish and squid, died, most likely because of hypoxia and anoxia (Payne and Clapham).

Seventy percent of all terrestrial life was destroyed.

The arthropods and tetrapods were the only families acquainted with terrestrial life. Only one species of tetrapods survived (Huey and Ward). Many of the insect species did not survive either. Cockroaches are the prime example of the type of arthropods that survived. The most-likely source for the drop in terrestrial life is the hydrogen sulfide by-product, yet, we can also attribute habitat loss as a secondary cause. Because of the lava from the volcanoes, many habitats were lost, leaving many animals without a home. Many of the insects living at the time, did not have wings, and therefore, could not take off to the air (Reece).

The loss of habitats would have also led to the increase in carbon dioxide. With less plants to absorb carbon dioxide through a process called photosynthesis[11], more carbon dioxide remained in the air to contribute to ocean acidification and rising global temperatures.

The End-Permian Extinction was the end of an era, literally. The geologic time scale transitioned from the Paleozoic Era (meaning old life) to the Mesozoic Era (meaning middle life). The evidence and theories for the causes of the event are numerous. Because the extinction occurred almost 250 million years ago, many geologic processes have destroyed much evidence, but the latest scientific technologies and methods are encouraging more definite arguments in the field. Despite the uncertainty of what caused the event, scientists agree that the End-Permian Mass Extinction was ultimately the worst extinction of biodiversity in biological history.

[11] Photosynthesis the how a plant breathes. They take in carbon dioxide and water and produce oxygen and sugars for food.

A Sixth Extinction

Many of the conditions scientists have hypothesized from the Permian Extinction are being observed in the “Anthropocene”. Today, we have ocean acidification, anoxia, and global warming, to name a few obvious conditions. We also have habitat destruction and invasive species. The difference, however, between the Permian extinction and the Anthropocene is the largest contributor. Where the Permian extinction had the Siberian Flood Basalts, the Anthropocene has *Homo sapiens.*

The human species has changed the Earth’s atmosphere, topography, and biodiversity, so greatly that we are dawning a possible extinction to close the Anthropocene epoch, or maybe the Quaternary Period, or possibly the Cenozoic Era—that is how severe humans are devastating the Earth.

All the conditions previously described have led to a major loss in biodiversity. In the last one hundred years, the extinction rate has increased to above 1000 times its normal rate (Cruzten and Stoermer). By scientists’ definition of an extinction, where the biodiversity loss is 75% greater than the background rate, we are amidst an extinction. Whether or not this leads us into a new epoch, period, or era, is yet to be seen.

In addition to the extinction rate, the global conditions (i.e. global warming) do not provide the ideal environment for humans to prosper. The increases in global temperature leads to severe weather changes that devastate human cities and populations. The elevated carbon dioxide levels not only increase the temperatures, but are creating hypoxia and ocean acidification. Scientists are currently seeing these effects in coral bleaching[12]—the most important example is that 20% of the Great Barrier reef has been pronounced dead, leading to a greater drop in biodiversity.

[12] When corals are under physiological stress (change in warmth, acid levels, etc.) they stop reactions with their symbiotic algae and temporarily shut down. If corals bleach too long, they die.

Biodiversity is also plummeting because of human causes—habitat destruction, invasive species, overharvesting, and pollution. Major biodiversity loss is only one boundary of defining an extinction. Scientists look at fossil records for 1) the disappearance of fossil species (meaning biodiversity loss), and 2) the appearance of new species ("Extinction Event"). Thus, we will not know whether we are living in an extinction until we are able to look back at this time in the future. However, a sixth extinction is a valid argument regarding the biodiversity loss and the carbon dioxide levels, each of which correspond to previous extinction trends.

Conclusion

Humans are endangering the earth of a sixth extinction. They are causing severe biodiversity loss and global warming that rivals the statistics of the largest mass extinction in biologic history—the End Permian Mass Extinction. Humans are decreasing biodiversity via destroying habitats, introducing invasive species to new lands, overusing natural resources, creating pollution, and increasing the global temperatures. Humans have affected the globe so much so that scientists are considering renaming our geologic epoch from Holocene to Anthropocene.

Imagine a world where humans no longer existed. Jan Zalasiewicz did, and he believes rats will become the new humans (Kolbert). After the Cretaceous extinction removed the dinosaurs, humans evolved and thrived; after the Anthropocene extinction, rats will evolve and thrive. Zalasiewicz believes rats would dominate because they are able to live under any conditions and scavenge for food and burrow in the ground. They can feast on the remains of humans and hide in the rubble and dirt to avoid the poisonous atmosphere and waters.

What if humans became the dinosaurs and the rats become the humans?

Imagine the world then?

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An Annotated Bibliography

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Crutzen, P. J., and Stoermer E.F. (2000, May). The "Anthropocene". *International Geosphere-Biosphere Programme Newsletter 41. Global Change News Letter*. *Vol. 41.* pp. 17-18.

This four-page article proposes changing our current geological epoch from "Holocene" (meaning "current whole") to "Anthropocene" (meaning human impact). Crutzen proposes the term in his essay as he provides many examples concerning humans' impact on the globe, and specifically, on the future geological record. The proposal is well organized and easy for non-scientists to understand.

Paul Crutzen is well established in the science community; among other awards, he won the Nobel Prize in Chemistry in 1995. The late Eugene Stoermer was known for his work with diatoms (a type of algae), but he became a large influence when he coined the term "Anthropocene" in the 1980s. Although, Stoermer coined "Anthropocene", Crutzen is known for applying it to the current geologic epoch and bringing it to the public's attention.

Gore, Al, narrator. *An Inconvenient Truth.* Davis Guggenheim, director. Paramount Home Entertainment, 2006. Run time: 96 minutes.

This climate change documentary stars Al Gore as he gives a PowerPoint presentation. Gore uses numerous statistics from various sources, one including a study from one of his old professors. Intermittently throughout the film, we learn more about Gore as a politician and family man from flashbacks of his life. Although the film promotes Al Gore's political career, it concerns global climate change more than Gore's life. Davis Guggenheim wanted to educate people on global warming and used Al Gore's presentation to do so.

The presentation is easy to follow and cites many studies, experiments, statistics, and quotes from scientists and essayists. Gore connects with the audience with humor and myriad visual aids. It is comprehensible and interesting.

Kolbert, E. (2014). Welcome to the Anthropocene. In E. Kolbert, *The Sixth Exinction: An Unnatural History* (pp. pp. 92-110). New York: Picador.

Elizabeth Kolbert is a well-known author in both the news world and the science world. For this book, she traveled the world and was privileged to meet with various scientists to learn about numerous events in geological, paleontological, and biological history that related to the idea of a sixth extinction. Kolbert has earned many awards, one including a Pulitzer Prize in the General Nonfiction Category for *The Sixth Extinction.*

She writes in a manner that translates scientific studies into laypeople language. She also uses different modes throughout the book to keep the reader interested. In one mode she writes about science and history, and during the other mode she recalls travel adventures and reporting. Her transitions are smooth and easily connect.

In the chapter, “Welcome to the Anthropocene,” Kolbert recalls meeting with Jan Zalasiewicz, a stratigraphic scientist who specializes in graptolites, or a species of animals used as index fossils. She explains the history of the Ordovician Period, the burst of life and the quick end caused by climate change that cooled the planet, and the first mass extinction. She then transitions to the Permian Period, which ended with the largest drop in biodiversity of all the mass extinctions. This period ended with climate change that warmed the planet. And finally she introduces the “Anthropocene”, a term made famous by Paul Crutzen, used to describe the current epoch we live in.

McDowell, Timothy, Assistant Professor of Biological Sciences, Department of Biological Sciences, East Tennessee State University, Johnson City. Fall 2016 Lectures for section 001 of Biology 1010.

Dr. Timothy McDowell is a professor at East Tennessee State University. He specializes in taxonomy and phylogeny of certain plants; however, he also teaches Biology I for non-majors. As part of the curriculum, he explains broad concepts of biology in depth using a textbook and his PowerPoint lectures. His lectures are cursory compared the textbook, but they highlight the main ideas he wishes to cover. The lectures are comprehensible and fluid. His anecdotes and examples make the material easier to learn.

“Lecture 3—Biomes.” 29 and 31 Aug. 2016.

Dr. McDowell introduces the lecture using various visual aids to show the diversity of biomes on Earth. He then begins by explaining the hierarchy ecologists use to study interactions. He shows how ecosystems include biotic and abiotic factors. He expands on the physical and chemical factors in the biosphere and gives examples of how animals adapted. He then explains weather patterns and biomes patterns as a result of the Earth’s rotation, the sun’s position, precipitation and wind patterns. He employs multiple visual aids to help the audience to understand how uneven heating of the Earth causes the formation of lands and habitats for animals. Lastly, Dr. McDowell introduces the aquatic and terrestrial biomes and the corresponding influencing factors. He closes with connecting the two types of biomes via the water cycle.

The water cycle connects land and water, thus what happens on land affects the earth and vice versa. When humans pollute either land or water, that pollution will spread everywhere leading to larger impacts. The weather patterns, including precipitation in the water cycle, help explain why global warming is as severe and widespread as it is.

"Lecture 5—Communities and Ecosystems". 12-16 Sept. 2016.

This lecture follows the required book for the class (*Campbell Biology: Concepts and Connections)* and adds several visual materials. Dr. McDowell provides many examples of species interactions, going into depth of specific adaptations and keystone species. He also uses several visual aids to explain how energy moves through a community and an ecosystem. He then explains, step by step, each cycle of nitrogen, phosphorus, and carbon. He illustrates with a picture of each, and explains humans impact as he cycles through each.

Understanding the biogeochemical cycles is crucial in understanding the connection between humans and the Earth. With every tree we cut down, gas we burn, fertilizer we use, et cetera, humans significantly change one or all of the cycles, and this effect is demonstrated in larger proportions in, for example, global warming and ocean acidification.

"Lecture 6—Conservation Biology." 19-23 Sept. 2016.

Dr. McDowell explains the importance of the biodiversity crisis using examples from the book. He explains factors encompassing biodiversity and human impacts, employing statistics of each. He proves how humans affect the environment. He then explains the importance of the water cycle in transporting pollutants and the drastic effects of pollution through the food chain (i.e. biological magnification). Next he demonstrates and proves global warming exists. He endorses the debate is over and climate change is occurring. He provides examples in statistics, visual aids, and shows where global warming is most evident: the arctic. He shows how climate change is affecting biomes. Lastly, he explores the various ways ecologists are trying to conserve the planet.

The largest problem, and biggest parallel to the End-Permian extinction, is loss in biodiversity. We must understand the causes of biodiversity decrease (mostly human causes) to be able to fix it.

Reece, Jane B. et al. *Campbell Biology: Concepts and Connections.* Boston: Pearson. Ed. 8 (2015). Accessed 2016. Biology 1010 textbook, East Tennessee State University, Johnson City.

"The Biosphere: An Introduction to Earth's Diverse Environment." (pp.678-695).

This chapter discusses three big ideas: the biosphere, aquatic biomes, and terrestrial biomes. In the first few sections, the book shows that many biotic and abiotic factors influence the biosphere such as, energy sources, temperature, water, and inorganic nutrients. It explains how regional climate influences the distribution of terrestrial communities. It goes into further detail to explain the position of the sun, the trade winds, westerlies, and ocean currents, all influence the weather. The next section is the aquatic biomes. The chapter explains how current, sunlight and nutrients are important factors for these habitats. Certain nutrients, including nitrogen and phosphorus control the amount of phytoplankton populations, and if too much nutrients are exposed to the environment, they cause an algal bloom that will absorb the oxygen and suffocate life below. The following section describes the nine different terrestrial biomes and the varying temperature ranges and precipitation that influence the landscape. The chapter ends by linking the aquatic and terrestrial biomes via the water cycle, how water travels through land and water, and how pollution travels fast and far.

The abiotic factors in the environment connect directly with climate change effects on the environment. When we learn about the factors that define a biome (i.e. temperature and precipitation), we observe the differences in these factors over time and predict what will happen if global climate change continues to disrupt their influences. For example, a change in a biome will change the biodiversity of the environment.

"Communities and Ecosystems." (pp.738-757).

The chapter is divided into two main ideas of Community Structure and Dynamics and Ecosystem Structure and Dynamics, and each main idea is separated into mini sections.

Sections 37.19-37.22 explore the processes of the carbon, phosphorus, and nitrogen cycles, as well as human's impact on each, including: the burning of fossils fuels on the carbon cycle, man-made fertilizer on the phosphorus cycle, and synthetic nitrogen fertilizer on the nitrogen cycle. In addition to the cycles, the sections explain how human activities destroy aquatic systems via eutrophication and fertilizer pollution run-off leading to “dead zones”.

Understanding the biogeochemical cycles is crucial to understanding human’s impact of the earth and why the current geological epoch may be renamed to the “Anthropocene”. Humans affect the earth on a small scale, but the cycles turn it into a large scale problem.

“Conservation Biology.” (pp.760-777).

This chapter encompasses two main ideas: the loss of biodiversity, and conservation biology and restoration ecology. It defines different types of diversity and gives examples causing the decreases of biodiversity. The major threats are habitat loss, invasive species, overharvesting, pollution, and global climate change—all factors caused by humans. The chapter then goes into further detail of how human activities are changing the environment i.e. the rising concentrations of greenhouse gases. It explains how climate change is warming the planet and affecting biomes, ecosystems, communities, and populations. To counteract the negativity of human destruction, the chapter segues into what humans are doing to reverse their impacts, such as, protecting endangered populations, sustaining ecosystems, establishing protected areas and zoned reserves.

There are two sides to understanding this as a source: 1) the “Anthropocene”: we must realize that all the factors reducing biodiversity are human-caused; 2) the biodiversity crisis: it is the greatest correlation between present-day problems to the End-Permian mass extinction. A mass extinction by definition would imply a large amount of lost life, but the causes of the extinction parallel to the causes humans are accumulating today.

Benton, Michael J. *When Life Nearly Died: The Greatest Mass Extinction of All Time.* Thames & Hudson Ltd: London, 2003.

Michael J. Benton is a well-established British Paleontologist. He earned his PhD from Newcastle University and researches in the fields of paleontology, palaeobiology, and macroevolution. He has consulted on many documentaries and written many textbooks and children’s books.

In his book, *When Life Nearly Died*, Benton documents the theory of catastrophism (the idea that mass extinctions occur periodically by a sudden event) and describes the most common theories as to what caused the End-Permian mass extinction. He addresses all the accumulating evidence and theories (i.e. tectonic plates, volcanic eruption, meteorite impact, etc.) and proposes the accuracy of each. He vividly describes and explains several scientists’ studies in a manor easy for laypeople to understand.

Lastly, he explains the possible sixth extinction and recognizes the need to understand the biodiversity crises of the past to apply those lessons to the present-day crisis.

Benton, M. J., & Twitchett, R. J. (2003, July). How to Kill (almost) All Life: The End-Permian Extinction Event. *Trends in Ecology and Evolution, vol. 18, issue no. 7,* pp. 358-365.

Benton and Twitchett, two colleagues at the University of Bristol, describe four major discoveries about the End-Permian extinction—one, The Permian-Triassic boundary has been positively dated to 251 million years ago; two, The Siberian Traps, suspected to be a contributing cause of the extinction, have been found to have peaked at the Permian-Triassic boundary; three, the rocks observed at and around the boundary show a pattern of environmental changes; and four, the isotopes dated in the rocks reveal an environmental turmoil where normal feedback processes (natural processes where a change in one affects the other, and the corresponding change returns to change the first process) could not cope.

They also address the need to understand how certain species survived and recovered so that we may understand the resulting evolution of earth after the mass extinction. They detail the differences in survival of animals in aquatic settings and terrestrial settings.

Lastly, they describe the runaway greenhouse model, which indicates a breakdown in environmental mechanisms. The model shows how the combination of global warming and anoxia from gas hydrate release causes turmoil and they propose that this combination can be applied to other mass extinctions and smaller extinctions. They believe further research into the Permian extinction will reveal differences in local and global patterns of destruction.

It is important to understand the causes and effects of the Permian extinction because it gives us a snapshot of what may happen in our future.

Clapham, M. E., & Payne, J.L. (2011, October) Acidification, anoxia, and extinction: A multiple logistic regression analysis of extinction selectivity during the Middle and Late Permian. *Geology*. *Vol. 39, issue no. 11*, pp. 1059-1062.

This study focuses on the survivorship of certain marine animals during the Permian mass extinction. The scientists studied physiological characteristics of the organisms to determine why they either lived or died. They found that the extinction selected against animals that had a poorly buffered respiratory physiology and calcareous shells. This means that the animals had a poor ventilation system in their respiratory system that caused them to be unable to survive in an oxygen deprived environment. A calcareous shell is made of calcium carbonate. When it reacts to heat, as it would have when temperatures rose, the calcium carbonate breaks down into calcium oxide and carbon dioxide, which would kill the animals with calcareous shells.

In addition, the leading causes of the extinction—warming, hypercapnia, ocean acidification, and hypoxia—all correlate between animal physiology and their survivorship.

The article connects the environmental conditions from the Permian era to current ocean conditions. Clapham and Payne predict that because of the correlation between physiological traits and the causes of the extinction, that animals, like the coral reefs, with similar selected physiological traits to those creatures existing during the Permian Extinction will be at great risk, considering the increasing human effects on Earth.

Huey, R. B., & Ward, P.D. (2005, April). Hypoxia, Global Warming, and Terrestrial Late Permian Extinctions. *Science. Vol. 308, issue no. 5720,* pp. 398-401.

This study analyzes and graphs three main causes of the End-Permian mass extinction: restricted supply of oxygen, climate warming, and the increased metabolic demand for oxygen. These three factors play a major role in the inevitable hypoxia (a deficiency in the supply of oxygen to tissues). In addition to the hypoxia, another leading role in the extinction is a protracted environmental degradation. According to their simulation the process would have forced extinctions because of reduced habitat diversity and fragmentation of habitats. The combined efforts of the hypoxia and habitat destruction led to the extinction of almost all terrestrial species. In relation to this study, Huey and Ward found that hypoxia, although was not the main contributor to the primary mass extinction event, it did play a role in smaller extinction events before the end, during the catastrophe, and helped delay the biodiversity recovery after the event. Hypoxia could be the reason it took 100 million years to recover from the End-Permian Mass extinction.

Understanding what hypoxia is and what causes it is crucial to understanding how terrestrial organisms died during the extinction. The causes, low oxygen and high carbon dioxide concentrations, can be found today as a result of global warming. This connection further links the Permian environment to present-day features.

Payne, J. L., & Clapham, M. E. (2012, May). End-Permian Mass Extinction in the Oceans: An Ancient Analog for the Twenty-First Century. *Earth and Planetary Sciences, vol. 40*, pp. 89-111.

Jonathan L. Payne of Stanford University and Matthew E. Clapham of the University of California, Santa Cruz collaborated on an essay published in *Earth and Planetary Science Letters*, a weekly peer-reviewed scientific journal. They aggregated several studies of the End-Permian Mass Extinction to create an essay accounting for all the elemental causes of the extinction, focusing primarily on the effects of the ocean and its life. Their main accession shows how recent studies of the extinction demonstrate its importance in relation to twenty-first century oceans. They believe that the leading cause of the extinction (a rapid release of carbon dioxide in Earth's atmosphere) parallels with recent events provoked by human impacts and reminds the reader that the outcome of today's problems can be predicted by Earth's past.

Shu-Zhong Shen et al. "Calibrating the End-Permian Mass Extinction," Science 334 (2011): 1367-72. Accessed 27 Sept. 2016. https://www.researchgate.net/publications/51808192_Calibrating_the_End-Permian_Mass_Extinction

This research project was led by Shu-Zhong Shen, a professor at the Chinese Academy of Sciences in Beijing. He is a PhD in paleontology, geology, and geochemistry. He published the paper in *Science*, a peer-reviewed journal that has been publishing since 1880. Both Chinese and American scholars collaborated during the project.

The study took place in South China and surrounding areas, including: Tibet, Kashmir, and Pakistan. The scientists took samples from several biomes, including: aquatic, terrestrial-aquatic, and terrestrial. They used Uranium-Lead dating to analyze the sediment samples; they wanted to narrow the time span of the End-Permian mass extinction, and hoped to provide additional evidence for their theory—the Siberian flood basalts caused the extinction. They hypothesize that the volcanic structures exploded a combination of carbon dioxide, methane, and nitrogen sulfides. This influx of greenhouse gases contributed to heating the Earth above sustainable inhabitation. Overall, this incident occurred abruptly in geographic terms; it lasted a span of a hundred thousand years. They found the mass extinction could not have started earlier than 252.08 million years ago and the transition from the Permian era to the Triassic era was exactly 252.17 million years ago.