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Friend or Foe: Human Impact on the Earth's Ecosystems

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Introduction

Movies, books, and toys expose children to dinosaurs, wooly mammoths, and saber-toothed tigers. They amaze, frighten, fascinate, and ultimately lead children understand that these creatures were once alive, but no longer exist on Earth. Most elementary school curricula do not cover the concept of extinction, even though it is a natural and expected part of the Earth's history and Earth's future. Extinction is so common that between 99% of life on Earth has already disappeared from existence.[12] There is currently a sixth mass extinction at work unique from the five previous mass extinctions Earth has experienced. The past mass extinctions, known as the Big 5, are believed to have by been caused by slow global climate change or natural catastrophes. No one species has caused any of these mass extinctions. However, the ever-increasing human population has sent us into an era known as the Anthropocene, in which the extent of human impact is altering ecosystems and biodiversity at a rate that no other species has done in the past. This impact is causing biodiversity losses that are hurdling us towards an entirely human-caused sixth mass extinction.

However, humans are becoming increasingly aware of our own impact. We have not stopped the exploitation of earth's natural resources and biodiversity, but some efforts are taking place around the world to promote a beneficial "caretaker" role towards ecosystems. These methods are conserving the biodiversity left on our planet, while building a better livelihood for local communities and preserving indigenous cultures. This approach of community-based conservation and recognition of indigenous practices provide us with strategies to replenish and preserve biodiversity with an ecosystem. Since humans as a species can so heavily impact the Earth, prioritizing basic human needs over strict conservation legislation provides a pathway forward for a more positive role that humans can take in an ecosystem.

Rationale

I teach at a public school in the city of Richmond, Virginia. Each year, my students are asked to draw a picture of an ecosystem as a pre-survey to my unit. The illustrations show a diversity of organisms from trees and flowers to birds and bees, all commonly found in parks or urban neighborhoods where my students live.

However, rarely do my students include themselves or other humans in their representations of an ecosystem. Despite the abundance of green spaces and public parks within city limits, it is clear my students do not see themselves as part of the ecosystem they live within.

Public education is constantly trying to better adopt its standards for more modern classrooms. New curricula is designed to better reflect current events and global issues our students will face as they grow older. However, I rarely see elementary science curriculum units highlighting the true extent of human impact on the environment. In addition, Virginia's science standards changed, removing the subcategory "human impact on ecosystems." Without this substandard, I fear the misconception that students believe they exist outside of their surrounding ecosystem will only grow.

Due to the fact that human presence has spread to every corner of the globe, students cannot be educated on ecosystems in isolation from humans. Sadly, that separation no longer exists. I believe it is vital that the human role in the recent mass extinction of species and increasing list of endangered species must be discussed in the classroom if we are to create a community of ecosystem caregivers, rather than future exploiters.

Learning Objective

Within Virginia's 4th grade science curriculum standards, students must understand how organisms, including humans, interact with living and nonliving things. The nature of this relationship is broken down into three sub-standards. First, students are required to understand and identify the differences between an organism, population, community, and ecosystem. Second, students must also understand the interdependencies of species within an ecosystem by studying energy flow through a food web. Third, students will need to understand how species live within specific habitats and have specific roles, or niches.[3]

Because my school is an International Baccalaureate (IB) school, I am required to approach our curriculum taught through the lens of global citizenship. Therefore, my class will focus on five major ecosystems seen throughout the world: oceans, rainforests, grasslands, mountains, and deserts. Although my state's curriculum altered the ecosystem unit standards to not include a sub-standard solely dedicated to human impact, I intend to make the majority of my unit about how humans are impacting the environment.

Content Background

Mass Extinctions

The Big Five

Extinction is a natural, biological phenomenon. It is so common that between 99% of all life that has ever existed on Earth has already gone extinct.[4][5] The normal rate of extinction is known as background extinction. Typically, species last on our planet for only 1 to 10 million years.[6][7] However, at certain points in our planet's

history, the rate of extinction has far exceeded the background extinction rate. Scientists refer to this phenomenon as a mass extinction.

Fossil records indicate there have been five major mass extinction events on Earth.[8][9][10][11] The first, known as the Ordovician extinction, occurred about 440 million years ago (MA). It is thought that this was caused by global cooling and glaciation, causing sea levels to lower and mass amounts of marine invertebrates to go extinct. The second mass extinction occurred 365 MA and was known as the Late Devonian extinction. Similarly, it is believed global cooling led to the extinction of a vast marine communities. Other theories claim an extraterrestrial impact may have occurred, as well. The third mass extinction, the Permian extinction, which occurred about 252 MA, is believed to be the largest extinction wherein between 77% and 96% of life on Earth was wiped out. Like the others, the cause of the Permian extinction is debated. Some believe volcanic eruptions caused an increase in greenhouse gases and a toxic environment for life on Earth. Other theories link the extinction event to climate change or a potential asteroid impact. The fourth extinction, the Triassic extinction is also believed to be caused by global cooling, volcanic activity, or asteroid impact. Finally, the fifth mass extinction, the Late Cretaceous extinction, occurred 66 MA. It is the event well known for wiping out the dinosaurs. Like the other mass extinctions before it, the cause of this extinction has been debated for years, causes ranging from catastrophic asteroid impact to slow environmental changes.[12][13][14][15]

Our First Victims

It was long after the fifth mass extinction that early humans finally arrived on the scene. So, exactly how long was it before humans evolved into a species with ecosystems altering abilities? Many believe the first signs of human influence over the environment began around 100,000 to 200,000 years ago, when early humans began to migrate across the globe. By 13,000 years ago, humans had inhabited every continent except Antarctica.[16] During this time, early humans adapted well to a variety of habitats, geography, and climates. While this was occurring, fossil records indicate that a rapid die off of megafauna species occurred. The alarming rate of this die off exceeds average background extinction rates. While there is evidence that points to climate change and global warming taking place at that time, many paleontologists are uncovering more evidence that suggests humans' migratory patterns and hunting practices may have sparked the megafauna mass extinction event.[17][18][19]

One such example of evidence comes from the alignment of human arrival on each continent with the disappearance of that continent's megafauna. The first "pulse" of extinctions occurred in Australia around 40,000 years ago, with North and South American extinctions following some 25,000 years ago. However, Madagascar's megafauna survived until the Middle Ages and moas, a group of large flightless bird species, did not disappear in New Zealand until the Renaissance period. [20] As science writer Elizabeth Kolbert states in her book, *The Sixth Extinction,* "It's hard to see how such a sequence could be squared with a single climate change event. The sequence of the pulses and the sequence of human settlement, meanwhile line up almost exactly."[21]

Yet, many scientists do not believe this correlation is enough to point a finger solely at humans. Labs have begun studying fossilized herbivores droppings for traces of *Sporomiella* counts, a common fungus at the time. By doing so, researchers expected to see a decline in the vegetation population before the decline in megafauna herbivore population. If the change in climate was affecting the ecosystem as a whole, the loss of vegetation should have occurred first, consequently causing the mass die off of large herbivores after. However, that was not the case, suggesting something else was killing off these large creatures before the

climate did. [22] Again, many scientists are not completely convinced in this correlation as well. These doubts are warranted, as each continent possessed different ecosystems and vastly different rates of extinction. [23] Regardless, the studies show that early humans had the capability of contributing to the mass extinction of megafauna. As biologist Telmo Pievani states, “Every time that *Homo sapiens* came somewhere, for someone else the death bell rang”[24]

The Sixth Extinction – The Human Role

We are currently living in a time known as the Anthropocene. The Oxford English dictionary defines this as “the current geological age, viewed as the period during which human activity has been the dominant influence on climate and the environment.” A drastic increase in the rate of changes to Earth’s natural systems began to occur after the Industrial Revolution, sparking an accelerated rate in which humans impact the Earth.[25] At our current rates, it is speculated that humans are causing an average of one species to go extinct every 20 minutes.[26] Some of these species are being killed off before we have a chance to discover or classify them.

According to evolutionary scientists Norman Myers and Niles Eldredge, this rate of mass extinction cannot be categorized as “catastrophism” or changes in the earth's crust from sudden violent and unusual events.[27] Instead, they describe these rates of extinction as very realistic consequences of human actions. They continue to describe that it is never one single cause that threatens an ecosystem or biodiversity. Instead, threats to species and mass extinction rates are caused by a combination of factors.[28]

With such a high rate of extinction taking place, it is not hard to find examples of species already lost to the Earth. For example, the passenger pigeon no longer can be seen flying over America’s forests and fields in its massive flocks (see Figure 1).[29] As the human population of the United States doubled between 1870 and 1900, so did the deforestation of much of the Northeastern and Midwestern forests. Our need for timber as fuel and the construction of homes, businesses, and infrastructure caused an extraordinary amount of passenger pigeon habitat loss. With these deforestation practices, passenger pigeons also lost their source of food. Although a law was passed to protect the birds in the 1880s, it did not restrict netting and was rarely enforced. Hunting and netting practices began to deplete what little population of passenger pigeons was left.[30] By the early 1900s passenger pigeons had gone from “being one of the most abundant birds ever to extinction in less than a century.”[31]

Figure 1. Massive passenger pigeon flocks seen flying over field.

There are more examples of extinction caused by humans’ tendency to over hunt and fish, destroy habitats,

and selfishly harvest natural resources. The great auk, Caribbean monk seal, Carolina parakeet, and Tasmanian tiger (thylacine) all fell victim to extinction in a fashion similar to the passenger pigeon. Today, amphibians are considered the class of animal most at risk of extinction. According to background extinction rates, typically, one amphibian goes extinct every thousand years. The current extinction rate of amphibians is forty-five thousand times higher than the background rate, leaving most herpetologists to witness multiple extinctions within their career.[32]

The extinction of one such amphibian, the golden toad, I found particularly interesting due to the circumstances of its demise. "More than 1,500 toads were observed in 1987, but only a single toad was observed at the main known breeding site in 1988 and 1989, while seven adult males and two adult females were recorded 4-5 km away in 1988."[33] The biologists who struggled to track the disappearance of the toad throughout the hills of El Valle, Panama were not racing against the bulldozers of deforestation. Instead, these students, biologists, and toads were fighting against a unique species of chytrid fungus known as *Batrachochytrium dendrobatidis,* or Bd.[34]

The earliest cases of chytrid fungus exist in South Africa. The second case of chytrid, outside of South Africa, was discovered on a green frog species in Québec, Canada.[35] Since then, chytrid fungus has been found in vast regions of the Americas, Europe, and Australia, far from its continent of origin, Africa.[3637] Amphibians from different regions are reacting differently to the fungus, and in the case of the golden toad, some are completely wiped out. What is so remarkable about the particular case of the golden toad's extinction is that on paper the finger can be pointed at the Bd fungus and the fungus alone. However, on closer examination studies have shown that "no geographic spreading pattern could be observed over time," meaning that chytrid could not have jumped over oceans from continent to continent on its own.[38] Rather, the spread of chytrid is linked to international trade, being passed along between continents by boat or plane[3940] This information asks us to once again look inward at ourselves as the reason the golden toad was victim to Bd in the first place.

Current Threats to Biodiversity

In this section, I explain the human imposed threats to Earth's biodiversity by ecosystem. The specific threats to one ecosystem can be different from its neighbors' threats. However, through years of research, scientists have developed a list of negative human's impacts. Edward O. Wilson, a leading evolutionary biologist, proposed the HIPPO model to categorize our current threats to biodiversity:

> "H Habitat fragmentation (forest clearance and conversion into pastures and intensive cultivations);
>
> I Invasive species (able by themselves to cause local mass extinctions in entire regions as well as on islands and archipelagos);
>
> P Population growth and urban macro-agglomerates;
>
> P Pollution (agricultural, industrial, chemical pollution of air, water and soils);
>
> O Overexploitation of biological resources by overfishing and overhunting"[41]

Although this list covers the majority of human imposed threats, it does not include the threat of climate change. Climate change is a unique threat to not just biodiversity and the environment, but also to humans, as well. The rate at which climate change is causing global temperatures to rise and environments to shift will likely take centuries to return to normal. We are seeing mass amounts of deglaciations, wildfires, coral bleaching, and loss of ecosystems. "On all inhabited continents in the past year, we have witnessed the economic and physical displacements of human populations due to flooding and drought, which in turn has overwhelmed natural systems."[42] Therefore, I am including climate change alongside the HIPPO model's threats to biodiversity.

Marine Ecosystems

I would like to preface by stating that there is not one singular marine ecosystem. Below I describe the overarching threats to three major ecosystems that exist within our oceans: coastal ecosystems, coral reefs, and arctic ecosystems.

One of the threats to our ocean ecosystems is a result of over exploitation of its resources. As human populations increase, cultures and societies that depend on seafood as their main source of protein cause a demand for more fishing.[43] As the world's economy becomes more global, the demand for seafood can reach a much larger market. These unrestrained fishing practices also have been known to shift food webs. A notable example is the exploitive whaling industry.[44] Industrial fishing practices also affect nontargeted species in marine ecosystems. Nontargeted marine species are considered fish, invertebrates, birds, or mammals that are accidentally caught while fishing for a specific species. Most of the time, nontargeted species are discarded, injured while being caught, or killed once caught. This is primarily caused from unsustainable fishing practices like bottom trawling and dynamite fishing.[45][46]

Another threat that can take many disruptive forms, is pollution. One such type of pollution that primarily affects coastal regions and coral reefs is eutrophication. Eutrophication is the introduction of excess nutrient (often nitrogen) enrichment, ultimately leading to a cycle of enhanced algae blooms.[47][48] Eventually, the enriched algae bloom dies and decomposes leading to a depletion of oxygen in the water, resulting in a "dead zone" that can suffocate marine species living within the area. Ocean water, or fresh water, can become polluted with excess nitrogen through fertilizer and fossil fuel combustion runoff. Annually, the Gulf of Mexico develops a dead zone from the mass amount of polluted runoff originating in America's farm belt and traveling down the Mississippi River.[49]

Other pollutants found in marine ecosystems include organic pollutants, such as brominated flame-retardant and pesticides entering our oceans through river disposal. There are large amounts of heavy metals from offshore dumping, pharmaceutical waste, and sewage runoff. These metals include mercury, cadmium, silver, nickel, selenium, lead, copper, chromium, arsenic, and zinc. Oil spills have caused long-term effects on ecosystems. It is estimated 10 million tons of oil has entered marine ecosystems by means of spills, ballast water, maintenance of refineries, and land-based dumping. Studies have shown these pollutants and toxins can be traced to all parts of the ocean, and cause abnormalities, reproductive failures, disease, and immune suppression in marine species.[50]

The final major pollutant threatening ocean ecosystems is plastics. Plastics that have entered marine ecosystems can cause mortality in wildlife by entanglement, ghost fishing, and ingestion.[51] Plastic debris can range in large clumps of knotted waste to bits of plastic eroded down to microscopic particles. This range in size means plastics threaten a vast majority of marine species. Another harmful characteristic of plastics is

their ability to float wherever the ocean currents take them. Whirlpools and circular motions within ocean currents have caused large collections of plastic debris to accumulate together, one such mass exists in the North Pacific central gyre.[52]

The next major threat to marine ecosystems is habitat fragmentation. On the surface, the ocean might look like vast amounts of water interconnected between continents. Space to live seems abundant from our view from the surface. However, not every marine species has the capability or instinct to simply swim to any part of the ocean. Destruction of ocean habitats comes at a high cost to biodiversity. Coastal ecosystems and coral reefs are particularly affected. Wetlands are drained and converted into hardened shorelines and oyster reefs have been overharvested past the point of replenishment. Developed countries have passed laws conserving and rebuilding reefs and coastal ecosystems. However, countries of the tropics are most at risk of losing their coastal marine ecosystems.[53]

Artic ecosystems have seen the loss of habitat not by direct humans' influence, but by human induced climate change and global warming. Increases in the temperature of the atmosphere and Arctic Ocean water have directly caused a decrease in ice caps at a rate of 10% per decade. Some predict the Arctic Ocean will be ice-free by 2050. Polar bears, seals, and ice dwelling amphipods are directly feeling the effects of the melting ice.[54]

Another effect of human imposed climate change and global warming is the increase of carbon in the atmosphere being absorbed into our oceans. This has led to an acidification of ocean water. The pH levels of the ocean have dropped 0.1 pH since the Industrial Revolution, and it is believed the ocean will continue to drop another 0.3 to 0.4 pH units by the end of the century.[55] Such small changes can be detrimental to reef-building coral which grows by adding mass through calcification. When carbon levels and ocean acidity increase, coral loses its ability to calcify. The more acidic the ocean becomes, the less reef-building coral will grow.[5657] Similar effects to acidification can be seen in other shelled organisms, leaving many ecosystems built around shelled invertebrates extremely vulnerable.[58]

Climate change and global warming cause another problem for coral reefs. Coral is a type of animal known as a polyp. Coral provide a home for a microscopic plant known as zooxanthellae. This plant is the sources of the coral's vibrant colors. Much like the way humans and plants rely on each other through photosynthesis, coral releases carbon dioxide into the water, which is consumed by the zooxanthellae. In return, zooxanthellae produce carbohydrates and oxygen, which are harvested by the coral and used as energy to grow. However, as the ocean water warms with rising global temperatures, zooxanthellae produce too much oxygen and coral polyps expel them, leaving the coral bare and colorless. This process is also known as "coral bleaching." The rate and intensity coral is bleaching has resulted in coral species being listed as threatened, exceeding all terrestrial animal groups endangered apart from amphibians.[59] In addition, corals serve as a keystone species to reef and coastal ecosystems. Coral is a species that other organisms create habitats out of. An entire ecosystem can emerge from where coral grows. As Ken Calderia, an atmospheric scientist, states, "corals build the architecture of the ecosystem…So it's pretty clear if they go, the whole ecosystem goes."[60]

Tropical Rainforests

Tropical rainforests are the world's most biologically diverse ecosystems. With that diversity, comes an equally diverse list of threats caused by humans. The main driver of biodiversity loss comes in the form of habitat fragmentation through deforestation. The 1980s and 1990s saw an increase in human population size, leading to hundreds of small-scale farms and rural communities living within tropical forests. This population

of people became the primary drivers of deforestation. However, their capabilities of habitat fragmentation were limited to hand machetes, axes, and chainsaws. In more recent years, the globalization of the economy has led more industries to become involved in rainforest deforestation. The small-scale ranches and farmers from the 1980s and 1990s have been replaced with large scale agriculture, plantations, ranching, logging industry, fossil fuel and mineral extraction, and expanding infrastructure. Therefore, the rate at which tropical rainforests are shrinking has increased. More corporations mean more funding. More funding means more bulldozers can be purchased.[61]

As the global economy grows, human interest in the tropical rainforests has grown. Road expansion has made once remote regions of rainforests more accessible. This has opened the door for more illegal land colonization, logging, hunting, and mining. Powerful countries are putting more pressure on poorer tropical governments and communities to exploit their biological resources. For example, China has become the world's largest importer of tropical timber. More than half of all timber being shipped around the world is heading to China.[62] Another economy-driven threat to tropical rainforests comes from the desire to find alternative biofuel sources. Currently 85 million barrels of petroleum are consumed each year. Some believe Earth has reached its "peak oil," meaning supply will begin to decline causing humans to turn to biofuel as an alternative. Tropical locations serve as the best climate and cheapest land for the growth of biofuel producing plants. Both the demand for timber from powerful outside nations and the potential necessity of biofuel will only increase the rate at which tropical rainforests habitats are altered or destroyed. Either scenario will leave the land inhabitable for many species of wildlife.[63]

Another major threat to tropical rainforests comes in the form of invasive species. As humans become more internationally mobile, pathogens are more easily transferred from continent to continent. Pathogens can include bacteria, viruses, or other microorganisms that cause diseases. While tropical ecosystems are on average already more diverse than other biomes, pathogen invaders have been particularly impactful to tropical rainforests. New pathogens introduced to tropical rainforests can create drastic mortality rates in plants and animals. As stated previously, the chytrid fungus alone has caused the extinction of 200 frog species.[64] Other notable examples are the avian malaria parasites, which infected Hawaiian birds, and Ebola virus, which is transferring and causing mass die offs of human communities in Africa, but also large populations of gorillas and chimpanzees. The invasive and deadly nature of pathogens, specifically in tropical locations, shows that wildlife is not the only group threatened by our globalized world. Humans are putting other human health at risk as well.[65]

Finally, the last threat to tropical rainforests is climate change. Unlike other ecosystems of the world where temperatures can fluctuate with seasons, tropics tend to have a narrower range in average temperatures. This means the species that reside in tropical climates are less likely to adapt to shifting temperature changes. Although tropical rainforests are typically warmer, species living there will struggle to withstand the ever-warming temperatures, thus, increasing the likelihood for extinction. A study suggests that native mountain residing vertebrates from the tropics of Queensland, Australia will have to adjust to a 2°C increase in mean temperature. The study also suggests that this increase in average temperature could result in one eighth of species extinction. Although studies like this one exist, it is difficult to predict exactly how ecosystems will react to global climate change. Preventative measure for tropical regions' communities and wildlife can be challenging to develop when the future of its ecosystems is difficult to predict.[66]

Grasslands

Earth's grasslands and savannas cover 40% of Earth's terrestrial surface. Historically, grasslands have been a

birthplace for civilization. Nearly every cereal crop - barely, rice, rye, sorghum, and wheat - grew from grasslands. This ecosystem served as the pre-domesticated home of cattle, donkey, goats, and sheep. Today, grasslands still play a vital cultural role in agricultural and pastoral communities, but are facing a devastating threat of habitat fragmentation through land conversion.[67] Open grassland ecosystems are being disproportionally disrupted by land conversion into agricultural plots to serve the increasing human population size across the globe. North American prairies have declined by 97% since 1830, Sub-Saharan African grasslands have lost 35 million km^2 , South American has lost 1.4 million km^2 , and Asia has lost 1.2 million km^2 .[68]

With the conversion of natural grasslands into agricultural plots comes the disruption of wildlife migratory and grazing patterns. Many governments, organizations, and communities are aware of these implications towards wildlife. However, bird flight patterns and large mammal migration does not conform to local, state, or international borders, making conservation policies lack continuity.[69] Additionally, the sizes of established conservancies are usually too small and resemble islands, surrounded by human influences and infrastructure. When this occurs, a species' population size decreases, leading to less selective breeding. Negative effects can be seen in species genetic diversity through inbreeding and abnormalities. For example, a population of wolves colonized Isle Royale off the coast of Lake Superior in the 1940s. Throughout the decades, a winter ice bridge formed less and less frequently, limiting the trips these wolves could take to breed with other wolf populations, reducing their genetic diversity and causing inbreeding-related problems. Since the decline in these opportunities, the Isle Royale wolf population has greatly declined. In 2015, only three wolves remained, one of which could be observed with a visibly shorter tail and twisted spine.[70] Although these wolves do not reside in a grassland community, the competition over land use creates challenges connecting ecosystems throughout the world's grasslands.

A large motivator to convert grassland into farmland comes from the demand for biofuel. The vast openness of grasslands provides enough space for an increase in agricultural productivity needed to meet the demand for biofuel. Unfortunately, modern agricultural practices negatively affect water and air quality by utilizing fertilizer and pesticides and depleting the soil of its nutrients. Such practices create soil more susceptible to erosion, resulting in the fertilizer and pesticide pollutant runoff, subsequently creating algae blooms and "dead zones" in freshwater and ocean habitats. In addition, the plants being grown for biofuel cannot store as much carbon as the natural flora grown in grasslands.[71] Grasslands can store more carbon in the soil than above ground vegetation.[72] In other words, grasslands are ecosystem that suffer disproportionately shrinking. Yet, on a planet with more and more carbon in our atmosphere, grasslands could help store the gas causing large global climate change.

Deserts

Deserts have long been the forgotten ecosystem in the public discussions of conservation. The notion that deserts are barren biomes that lack biodiversity is simply not true. In fact, this perception of desert ecosystems has led to the decrease in desert biodiversity that is disproportionately unchecked compared to other ecosystems.[73][74] However, like the ecosystems described above, deserts have not remained untouched by the age of the Anthropocene.

The Sahara Desert is "the largest warm desert in the world with land coverage, including the Sahel, of about 1,123,000 km^2 ."[75] One of the biggest threats to its ecosystems includes habitat fragmentation. For deserts, fragmentation can be shaped by multiple human sources. One source comes in the form of competition over

limited resources. Humans have lived in deserts for thousands of years. However, climate change is affecting deserts by limiting the little supply of resources that already was. Humans are now in competition with wildlife over these resources. Agricultural expansion and over grazing vegetated regions of deserts have displaced wildlife from their natural habitats. Water sources are being completely extracted or diverted towards dense human populations or industry. What water and land are left to wildlife are being polluted.[7677] In the United States, the Mojave Desert has seen habitat fragmentation due to military training sites, highway construction and vehicle use, and livestock grazing.[78]

Another source of habitat fragmentation comes from the investment in drilling and mining. The physical border of the oil industry is cutting off wildlife corridors and connectivity between protected areas.[79] Niger, which has historically housed local desert species, has recently increased their oil extraction. "Such increased oil prospection activities have, for example, now led to the endangerment of the last known population of addax."[80] In the United States southwest, the Trump administration is proposing to eliminate 85% of Bear Ears National Monument and half the size of Grand Staircase-Escalante National Monument. This proposal has been made in order to access major coal deposits that currently sit within Grand Staircase-Escalante and uranium with Bear Ears. These protected areas have previously helped scientists study how rangeland practices can affect ecologically diverse ecosystems, and are currently home to populations of mule deer, black bears, and mountain lions.[81]

With the increased human encroachment of desert ecosystems, comes the threat of invasive species. In desert ecosystems, invasive species can present two problems. First, some invasive species have the ability to overtake and outnumber native species. This can alter the food availability for some wildlife.[82] In desert ecosystems, resources are scarce, and wildlife has adapted to survive off a limited menu. In the Mojave Desert, desert tortoises are struggling to consume enough nutrient efficient vegetation due to the abundance of nonnative plants. The second concern that can arise with invasive species in deserts is their ability to withstand environmental conditions. Deserts are hot and the vegetation there is designed to endure the hot and dry climate. Nonnative vegetation does not have the same capabilities and can be more susceptible to wildfires. Again, in the Mojave Desert, wildfires have been spurred on by the invasive grass *Bromus rubens*.[83]

Mountains

Mountains are a geographic feature revered for their natural beauty, cultural symbolism, and spiritual significance. Often mountains are placed under protection for these reasons. In 2009, about 17% of the world's mountain areas, outside of Antarctica, were under protection of some kind, while only about 13% of Earth's terrestrial land, outside of Antarctica, is protected.[84] However, mountain ecosystems remoteness and low population density does not make them immune to the threats of the Anthropocene. Mountain ranges exist in our deserts, tropical rainforests, and temperate climates. The location of the mountain range and climate it resides in can determine the type of threats a mountain ecosystem may face.

Many mountain ecosystems are threatened by habitat fragmentation. Their ecosystems are shrinking and losing connectivity through human imposed methods previously stated, such as deforestation and growth of agricultural industry. However, some mountain ecosystems face unique forms of habitat fragmentation. European mountains, while relatively well protected, are experiencing the loss of habitat due to the increase in human recreational infrastructure, such as ski resort construction.[85]

Another method of habitat fragmentation is in the form of mining and mountaintop-removal. A concentration

of areas along the Appalachian Mountains have faced the environmental impact of mountaintop-removal mining for coal since the 1960s when the practice began. The removal of a mountaintop does not just significantly decrease the size of the mountain ecosystem, it creates a landslide-like effect of environmental concerns that spread down into lower elevated regions of the mountain community. Soil composition changes, and freshwater streams become susceptible to more sediment and mining site pollutant runoff. This in turn affects the biodiversity of freshwater streams and the drinking supply for the surrounding ecosystems and humans. Studies have shown that there is a link between the practice of mountaintop-removal mining and the loss of benthic macroinvertebrates, as well as the decline of salamander populations in below valley streams.[86]

This region of North America is not the only mountain ecosystem affected by mining caused habitat fragmentation. Africa is currently facing a mining boom, where three regions with unique biodiversity are at risk. One of these regions is the Albertine Rift Mountains. Outside countries, such as China, Brazil, Russia, India, Canada, and Australia are increasing investments in African mines. With this growth in human interest comes direct human impact. For example, interest in the iron-ore within the Mount Nimba Biosphere Reserve, a World Heritage Site, has led to a decrease in the site's size by 1,550 hectares, or about 3,830 acres. Further fragmentation is being caused by the construction of railroads to link mining sites to coastlines.[87]

Invasive species are another threat to most mountain ecosystems. Both direct and indirect human introduction of nonnative species in mountain regions has occurred. Humans are increasingly using mountain regions for both recreational and conservation-minded ecotourism purposes. In Europe, an increase of nonnative species has been intentionally introduced to communities around ski slopes and mountain resorts.[88] The North American little brown bat population is rapidly decreasing from the caves of the eastern United States, leaving the species endangered. An introduction of a white power-like fungus has been killing off little brown bats since 2006. Initially, scientists were puzzled as to why the white fungus was suddenly affecting the bat population, suspecting it to be an introduced, nonnative species. These suspicions were slightly confirmed, when photos of the first documented case of bats showing the effects of the fungi, named white-nose syndrome, were observed in the Howe Caverns of upstate New York.[89] Wildlife biologist Al Hicks remarks, "It's kind of interesting that the first record we have of this is a photograph from a commercial cave in New York that gets about two hundred thousand visits a year."[90]

The second means of nonnative species being introduced to mountain regions is through human caused climate change. Warming climates are causing lower level plant species to populate higher elevated mountain regions. It is important to note that many of these plant species are native to the region, but do not historically grow at higher elevations. Some mountain ecosystem climates seem to be more affected by this form of invasion than others. For example, a change in flora can be seen at Haleakala National Park on the Hawaiian island of Maui. Pines have been invading high elevations, completely transforming the communities that were typically shrublands into tall forests. Similar transformation of vegetation composition can be seen in Chile and South Africa.[91]

Climate change is also directly affecting the ice caps, snow, and glaciers on top of many mountains around the world. Currently, mountain cryosphere (snow, ice, or permafrost) serves as an extremely vital source of water. 50% of the world's population depends on fresh water from mountain regions. However, over recent decades, rising air temperatures have caused a reduction in the area and volume of glaciers, snow, and ice.[92] While it is typically a less diverse area of wildlife, the snow-covered ecosystems of mountain tops play an important role in the health of ecosystems below it. Rain that falls on top of snow causes a variety of threats and impact on

wildlife communities and human society. Increased erosion and movement of sediment can cause flooding, landslides, and glacier lake outbursts. The deposition of sediment will affect water quality for humans and lower level aquatic habitats.[93] Mountain ecosystems are increasingly becoming a great indicator of how the impact of one ecosystem can trickle down and affect many others.

Community of Caretakers

At this point, I have described in detail how humans are negatively impacting and exploiting Earth's resources and ecosystems. With all this information, one may ask, why does the preservation of biodiversity matter? The majority of humans on Earth have gone on living their lives since the disappearance of the passenger pigeon and golden toad. So why should one care about the fate of the little brown bat, desert addax, or coral reefs? In the words of Dr. Martin Luther King Jr.,

> "It really boils down to this: that all life is interrelated. We are all caught in an inescapable network of mutuality, tied into a single garment of destiny. Whatever affects one destiny, affects all indirectly."[94]

Beyond humanity's capacity to empathize with others, there is scientific evidence that a community of caretakers can benefit the world as a whole. In 2019, the United Nations (UN) released a report on the accelerating rate of species extinction, describing its implications on human well-being. Around 4 billion people rely on natural medicine or medicines derived by nature.[95] $577 billion US dollars of global crops are at risk from the loss of pollinators.[96][97] Protecting pollinating species will benefit natural ecosystems and the world's agricultural economy. Over exploitation of resources and rapid habitat destruction have led to poor soil quality and desertification of ecosystems, shrinking the land available for humans to produce food. On the other hand, well preserved natural vegetation and wetlands have proved to help regulate water flow, soil erosion, and reduce flash flooding. The preservation of these ecosystems can protect communities from natural disasters, while protecting water supply.[98] Already, 40% of the global population lacks access to clean and safe drinking water.[99] The melting snow and ice caps on mountains will cause more frequent sediment erosion, adding another threat to Earth's water supply, but also may cause infilling of hydropower reservoirs, turbine abrasion, and destruction to human developed infrastructure.[100]

Thankfully, not every human or community's goal is to exploit Earth's natural resources at the expense of wildlife and biodiversity. There are many communities that have preserved indigenous cultures' traditions, and they practice these methods of coexisting alongside nature. Studies have shown that extinction rates are slower on land managed by indigenous groups.[101] For example, indigenous communities of the Pacific Northwest have been involved in restoring shellfish populations and native plant species to the region. Other agricultural practices that integrate cultivated and native plants into a garden have yielded cases of 300-500 species within a garden.[102]

It is becoming clear that there needs to be more recognition and partnerships between industry, the scientific community, and indigenous communities. In Hungary, traditional grazing practices have long been allowed throughout the country's grasslands. Yet, upon the establishment of national parks, government authorities restricted and outright banned these practices on the grasslands.[103] However, other outside communities are embracing the lessons that can be learned from indigenous communities, such as the successful partnership between American pastoralists, ranchers, scientists, and the Maasai people of Kenya. The American ranchers

gave insight to the Maasai about their experiences of land subdivisions, degradation, and loss of livelihood. They educated the Maasai on adapting practices to a changing economy. The Maasai educated the ranchers about communal herding and avoidance of localized drought. The exchange of experiences, knowledge, and practices between the two communities was summarized by a Maasai elder "Your past is our future and our past is your future."[104]

Other communities are using conservation as a means of regaining power and control over their land, which has helped people rise out of poverty. Namibia has seen one of the most successful community-based conservation models that has expanded globally, known as community based natural resource management program (CBNRM) and Integrated Rural Development and Nature Conservation (IRDNC).[105][106][107] Colonization and Apartheid left the black population of Namibia without the education and resources to defend their livestock from wildlife predators. Drought and poverty led black citizens to turn to illegal poaching as a method of income since legal game hunting was limited to white citizens.[108][109] In the 1960s the IRDNC began developing a community-based conservation movement that helped black communities regain control over their own land and livestock, and offered opportunities for decision-making on conservation topics.[110][111][112] The IRDNC needed members of the community who were knowledgeable about the surrounding environment and wildlife to work within their program. Local Namibian community leaders realized the best people for this job were the poachers. The IRDNC took into account the history of these Namibian communities, put the needs of the community first, and provided job opportunities for poachers.[113]

The benefits of such a method of conservation can be seen through the access of property rights and power given back to the communities of Namibia. Individuals within the community now have medical access, scholarship opportunities, support for local teachers, human/wildlife insurance for pastoralists, support for traditional authorities, and community sport teams. [114] Namibia has seen an increase in populations of elephants, springbok, oryx, zebra, lions, leopards, and the largest population of free roaming black rhino in the world.[115][116] The entire country has seen a near disappearance of poaching and illegal hunting.[117]

Jane Goodall has seen a similar success using a community-based conservation model in the communities surrounding Gombe National Park and Lake Tanganyika called TACARE. Like the CBNRM and IRDNC in Namibia, TACARE focuses on improving the livelihood of people in the villages over strict conservation practices. Goodall explained that the program helps villagers obtain freshwater wells, construct suitable schools, provide microloans to women, provide scholarships for girls to finish secondary school, and improve family planning education and education about HIV/AIDS.[118] She states in her TED talk that "as a result of this program, something's happening for conservation."[119] By improving the quality of the people around the Great Gombe Ecosystem, villagers have a better understanding of their connection to the ecosystem, and practice better conservation practices.[120]

The 2019 UN report provides disheartening information such as the fact that since 1992 urban areas more than doubled, plastic pollution has increased tenfold since 1980, about 300-400 million tons of heavy metals, solvents, toxic sludge, and other wastes are entering coastal ecosystems annually, and there are more than 400 ocean "dead zones" that are collectively greater than the size of the United Kingdom. The report totals that "Three-quarters of the land-based environment and about 66% of the marine environment have been significantly altered by human actions."[121] However, it also states that "On average these trends have been less severe or avoided in areas held or managed by Indigenous Peoples and Local Communities."[122] The examples of indigenous practices and community-based conservation above provide the entire world with exemplary models of how humanity can break away from our exploitive practices.

Strategies

I utilized the 5 Es model of instruction in my science classroom. This method of instruction is designed around five phases of implementation: Engage, Explore, Explain, Extend, Evaluate. By following this model, information is not front-loaded. Instead, students are given the opportunity to build authentic experiences and connections around a scientific phenomenon. Students "discover" the concepts they are learning about before direct instruction is ever implemented. When specific scientific concepts are finally introduced, students can relate back to their discoveries, opening the door for a deeper understanding of the curriculum.

Phase 1, or Engage, is a great opportunity for hands-on experimentation or exploration. However, human caused extinction and caretaker roles can be difficult to express through these methods. Technology-based simulations can be effective in providing a visual of the effects of extinction within an ecosystem. While we are currently experiencing mass extinction rates, extinction does take time. Young students can benefit from a time lapsed visual of a disrupted ecosystem. My district uses Explore Learning's Gizmos as an online laboratory and simulation option. Within this program, the Forest Ecosystem or Prairie Ecosystem simulators allow users to change the number of plant and animal populations within the ecosystem. Through a series of scenarios, students will observe how plants and animals are affected by human interactions. Similar ecosystem simulations can be found on Legends of Learning, PBS, and Study Jams.

In phase 2, Explore, students should be provided an opportunity to explore the "discoveries" they made from the previous lesson. Linking real world examples or current events to the previous day's lesson offers an opportunity for students to see meaning in their learning and stay engaged for the remainder of the unit. Cross curricular connections through reading can provide students with examples of human-caused extinctions and threats to biodiversity. Such articles can be found through resources such as ReadWorks, NEWSELA, NatGeo Kids, and PBS. More specific articles to consider reading are "What's the Big Idea about Biodiversity?" from ReadWorks and "What we lose when animals become extinct" from NEWSELA. Teachers can extend this exploration activity by introducing students to an independent research activity about species that have recently gone extinct. This will allow students to see another consequence of the information they just read. By researching these topics, students are transitioning from being given the information, to activity searching for the information they need to understand a topic.

During phase 3, Explain, teachers implement explicit instruction of scientific concepts and vocabulary. This phase gives teachers an opportunity to utilized differentiation instruction strategies, such as word walls, graphic organizers, VARK frameworks, Frayer model vocabulary charts, and gradual release. Although this phase heavily relies on teacher led instruction and lectures, there should still be time allotted for independent student work. Utilizing the gradual release model, the teacher should first teach material with students following along. Then, the teacher should guide students through the application of their knowledge. Finally, teachers should assign a small activity, giving students the opportunity to apply their skills independently. These activities can be cut and paste sorts, Kahoots, Quizziz, Peardeck, or Nearpod activities. Student performance on these activities will determine which students need conferencing during the phase 4.

Phase 4, Extend, and phase 5, Evaluate, will occur in conjunction. To extend their understanding of human impact on ecosystems, students will be assigned an ecosystem, as well as one to two endangered species from that ecosystem. Assigned species do not necessarily have to reside in proximity to each other. For example, American Bison and Black Rhino are two species that reside in grassland ecosystems, but on separate continents. Students will complete research-based inquiry of their species, ecosystems, human

threats, and human caretakers. To evaluate their learning, students will create a PowerPoint (if virtual learning is occurring) or a trifold poster (in person instruction) about their topic. In addition to my evaluation of their PowerPoint or trifold poster, I will create a jigsaw methods gallery walk for students to evaluate each other's ecosystems. This will assist them in drawing connections between human interaction and impact around the globe.

Classroom Activities

The nature of the 5 Es model of instruction offers a lot of independent student discovery and learning. However, there is a level of accountability that needs to be maintained for the 5 Es model to be effective. Since no teacher lead instruction has occurred during the first phase, Engage, students will practice making observations and critical thinking about their observations from the online lab. Possible critical thinking questions include:

What happened to the other animals when one was removed?

What happened to the plants when an animal was removed?

What could cause an animal to disappear from an ecosystem?

How could humans affect the plants and animals in this ecosystem?

When reading the exploration article, new information will be provided through the lens of a current events article. Therefore, students will review their reflection questions before reading as a group. In a traditional classroom, teachers can post the questions and sentence stems on the board. Virtually, students will receive these questions and sentence stems through a virtual PowerPoint. Typically, students are required to annotate an article to ensure they are pulling important details from the text. If classrooms are virtual, students will be using JamBoards to post sticky notes on a virtual whiteboard with key details they come across.

Once the article is read, reflected on, and discussed with peers, students will work in groups to begin briefly researching four species that have recently gone extinct: passenger pigeons, the great auk, the Carolina parakeet, and Tasmanian tiger. The goal of this exploration activity is for students to find evidence of human impact through independent research. Information students are required to research includes:

What type of ecosystem did this animal live in?

When did this animal go extinct?

Why did this animal go extinct?

How do you think these ecosystems were affected by these animals going extinct?

By the middle of the unit, students are finally participating in the direct instruction or Explain phase of the unit. Each of my students have an interactive notebook, which they log notes, graphs, observations, and diagrams for class. Within the notebooks, students are required to record information, vocabulary words, and concepts. Students also create diagrams, draw pictures, and graph data. These notebooks should be referred back to, taking on a role of reference material. At this point in the lesson, students will be assigned activities at the end of daily lessons to complete independently. These activities will monitor how well students understand the essential information of the standard.

At the end of the unit, students will engage in a week-long independent research-based project. It is vital that students develop the proper skills in accessing, assessing, and interpreting information through books and media, as well as through online resources such as NatGeo Kids, Kiddle, and Epic Books. Once students are assigned their ecosystem and endangered species, students will be required to research the following information: the endangered species habitat and niche, human threats to the ecosystem, human threats to the endangered species, caretakers of the ecosystem. In addition, students will have to create a diagram of their endangered species food web and organism, population, community, and ecosystem pyramid (Figure 2).[123]

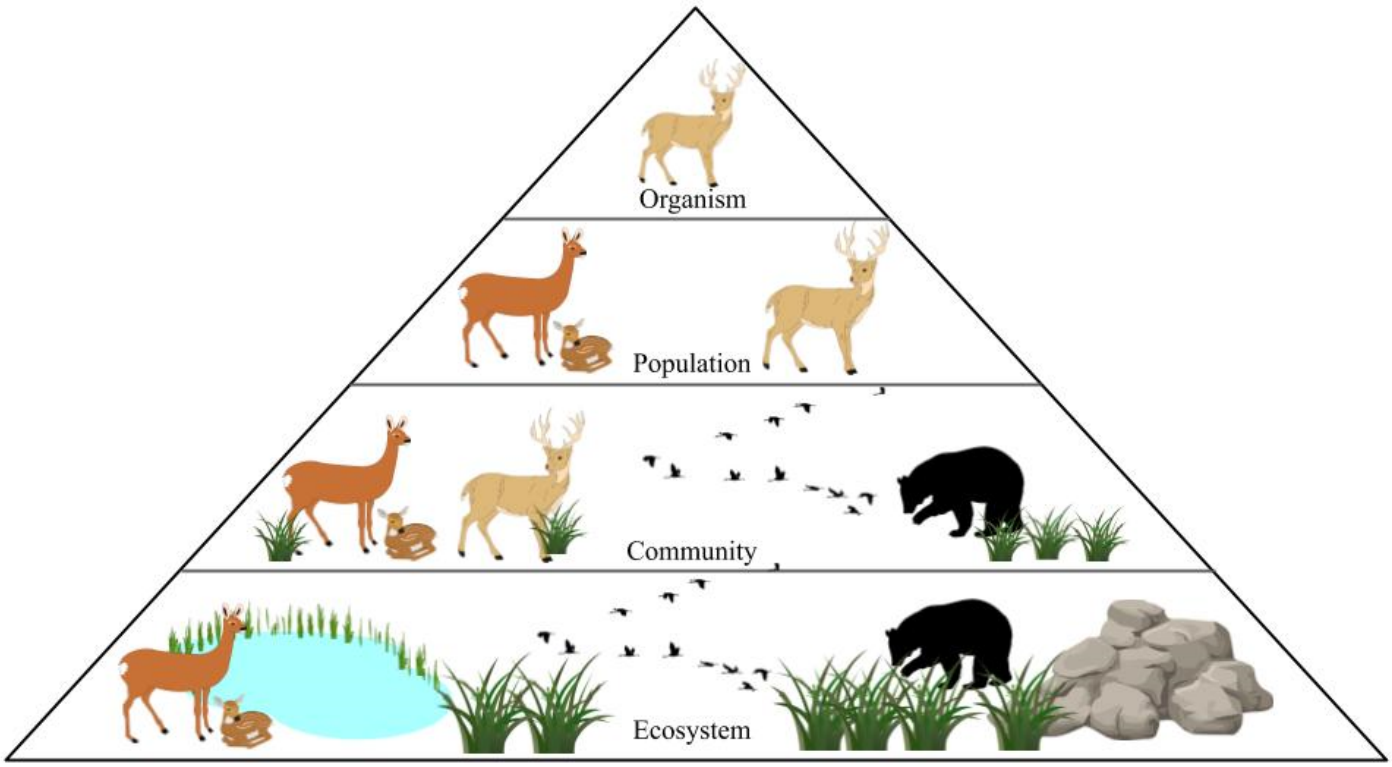

Figure 2. Ecosystem Pyramid.

Once students complete their projects, they will participate in a jigsaw gallery walk, if the unit was completed in the classroom. During a virtual classroom setting, students will be required present their ecosystem virtually, as well as complete a jigsaw activity based on each other's presentations. The goal of this activity is to allow students to compare and contrast their topic with other ecosystems and endangered species.

Appendix on Implementation of District Standards

Virginia Department of Education Standards of Learning

SOL 4.3 The student will investigate and understand that organisms, including humans, interact with one another and with the nonliving components in the ecosystem. Key ideas include

a. interrelationships exist in populations, communities, and ecosystems;
b. food webs show the flow of energy within an ecosystem;
c. changes in an organism's niche and habitat may occur at various stages in its life cycle;
d. classification can be used to identify organisms

Next Generation Science Standards

While my district does not utilize the Next Generation Science Standards, my unit can be adapted to the following standards:

3-LS4-3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

3-LS4-4. Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

In addition, my unit. Implementing my unit will provide opportunity for vertically aligns with the following middle school standards:

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Classroom Resources

Explore Learning Gizmos

NEWSELA

Readworks.org

Kiddle.co

Epic Digital Library

World Wildlife Fund

IUCN Red List

Bibliography

Averill-Murray, Roy C., Catherine R. Darst, Kimberleigh J. Field, and Linda J. Allison. "A New Approach to Conservation of the Mojave Desert Tortoise." BioScience 62, no. 10 (2012): 893-99. Accessed July 8, 2020. doi:10.1525/bio.2012.62.10.9.

Bartlett, Lewis J., David R. Williams, Graham W. Prescott, Andrew Balmford, Rhys E. Green, Anders Eriksson, Paul J. Valdes, Joy S. Singarayer, and Andrea Manica. "Robustness despite Uncertainty: Regional Climate Data Reveal the Dominant Role of Humans in Explaining Global Extinctions of Late Quaternary Megafauna." *Ecography* 39, no. 2 (2015): 152-61. Accessed June 19, 2020. doi:10.1111/ecog.01566.

Berkes, Fikret. "Rethinking Community-Based Conservation." *Conservation Biology* 18, no. 3 (June 2004): 621-30. Accessed June 8, 2020. doi:10.1111/j.1523-1739.2004.00077.x.

Boudreaux, Karol, and Fred Nelson. "Community Conservation In Namibia: Empowering The Poor With Property Rights." *Economic Affairs* 31, no. 2 (2011): 17-24. Accessed May 20, 2020. doi:10.1111/j.1468-0270.2011.02096.x.

Brito, José C., Raquel Godinho, Fernando Martínez-Freiría, Juan M. Pleguezuelos, Hugo Rebelo, Xavier Santos, Cândida G. Vale, Guillermo Velo-Antón, Zbyszek Boratyński, Sílvia B. Carvalho, Sónia Ferreira, Duarte V. Gonçalves, Teresa L. Silva, Pedro Tarroso, João C. Campos, João V. Leite, Joana Nogueira, Francisco Álvares, Neftalí Sillero, Andack S. Sow, Soumia Fahd, Pierre-André Crochet, and Salvador Carranza. "Unravelling Biodiversity, Evolution and Threats to Conservation in the Sahara-Sahel." Biological Reviews 89, no. 1 (2013): 215-31. Accessed July 8, 2020. doi:10.1111/brv.12049.

Crain, Caitlin M., Benjamin S. Halpern, Mike W. Beck, and Carrie V. Kappel. "Understanding and Managing Human Threats to the Coastal Marine Environment." Annals of the New York Academy of Sciences 1162, no. 1 (2009): 39-62. Accessed July 12, 2020. doi:10.1111/j.1749-6632.2009.04496.x.

Curtin, Charles, and David Western. "Grasslands, People, and Conservation: Over-the-Horizon Learning Exchanges between African and American Pastoralists." Conservation Biology 22, no. 4 (2008): 870-77. Accessed July 12, 2020. doi:10.1111/j.1523-1739.2008.00945.x.

Duncan, Clare, Daniela Kretz, Martin Wegmann, Thomas Rabeil, and Nathalie Pettorelli. "Oil in the Sahara: Mapping Anthropogenic Threats to Saharan Biodiversity from Space." Philosophical Transactions of the Royal Society B: Biological Sciences 369, no. 1643 (2014): 20130191. Accessed July 8, 2020. doi:10.1098/rstb.2013.0191.

Education, Virginia Department of. "Science Standards of Learning – Adopted 2018." VDOE :: Science Standards of Learning - Science Previous Version, Adopted 2003. Accessed July 15, 2020. http://www.doe.virginia.gov/testing/sol/standards_docs/science/2018/index.shtml.

Edwards, David P., Sean Sloan, Lingfei Weng, Paul Dirks, Jeffrey Sayer, and William F. Laurance. "Mining and

the African Environment." *Conservation Letters* 7, no. 3 (2013): 302-11. Accessed July 8, 2020. doi:10.1111/conl.12076.

Elewa, Ashraf M. T. *Mass Extinction*. Berlin: Springer, 2008. Accessed June 19, 2020. https://link.springer.com/book/10.1007/978-3-540-75916-4.

Ellis, Erle C. Anthropocene: A Very Short Introduction. Oxford: Oxford University Press, 2018. Accessed July 8, 2020. http://dx.doi.org/10.1093/actrade/9780198792987.001.0001.

Fargione, Joseph E., Thomas R. Cooper, David J. Flaspohler, Jason Hill, Clarence Lehman, David Tilman, Tim Mccoy, Scott Mcleod, Erik J. Nelson, and Karen S. Oberhauser. "Bioenergy and Wildlife: Threats and Opportunities for Grassland Conservation." BioScience 59, no. 9 (2009): 767-77. Accessed July 7, 2020. doi:10.1525/bio.2009.59.9.8.

Goodall, Jane. TED, 2007. Accessed June 2, 2020. https://www.ted.com/talks/jane_goodall_how_humans_and_animals_can_live_together.

Greshko, Michael. "What Are Mass Extinctions, and What Causes Them?" Mass Extinction Facts and Information from National Geographic. September 26, 2019. Accessed June 15, 2020. https://www.nationalgeographic.com/science/prehistoric-world/mass-extinction/.

Hoole, Arthur, and Fikret Berkes. "Breaking down Fences: Recoupling Social–ecological Systems for Biodiversity Conservation in Namibia." *Geoforum* 41, no. 2 (September 5, 2009): 304-17. Accessed May 20, 2020. doi:10.1016/j.geoforum.2009.10.009.

Huss, M., B. Bookhagen, C. Huggel, D. Jacobsen, R.s. Bradley, J.j. Clague, M. Vuille, W. Buytaert, D.r. Cayan, G. Greenwood, B.g. Mark, A.m. Milner, R. Weingartner, and M. Winder. "Toward Mountains without Permanent Snow and Ice." Earths Future 5, no. 5 (2017): 418-35. Accessed July 8, 2020. doi:10.1002/2016ef000514.

IBiology. October 24, 2019. Accessed June 20, 2020. https://www.ibiology.org/ecology/loss-biodiversity-human-dominated-world/.

Jackson, Jerome A., and Bette J. S. Jackson. "Extinction: The Passenger Pigeon, Last Hopes, Letting Go." The Wilson Journal of Ornithology 119, no. 4 (2007): 767-72. Accessed July 8, 2020. doi:10.1676/1559-4491(2007)119[767:etpplh]2.0.co;2.

Kasaona, John. TED. Accessed May 15, 2020. https://www.ted.com/talks/john_kasaona_how_poachers_became_caretakers?language=en.

Kolbert, Elizabeth. *The Sixth Extinction an Unnatural History*. New York: Picador, Henry Holt and Company, 2015.

Laurance, William F. "Emerging Threats to Tropical Forests." Treetops at Risk, 2013, 71-79. Accessed July 12, 2020. doi:10.1007/978-1-4614-7161-5_5.

Masood, Ehsan. "The Battle for the Soul of Biodiversity." Nature News. August 22, 2018. Accessed July 8, 2020. https://www.nature.com/articles/d41586-018-05984-3.

National Geographic Society. "Mass Extinctions." National Geographic Society. July 30, 2019. Accessed June

18, 2020. https://www.nationalgeographic.org/media/mass-extinctions/.

"Natural Solutions: Protected Areas Helping People Deal with Desertification and Drought." IUCN. March 09, 2020. Accessed July 9, 2020. https://www.iucn.org/content/natural-solutions-protected-areas-helping-people-deal-desertification-and-drought.

Ochoa-Ochoa, Leticiam, Robertj Whittaker, and Richardj Ladle. "The Demise of the Golden Toad and the Creation of a Climate Change Icon Species." Conservation and Society 11, no. 3 (September 2013): 291. Accessed July 8, 2020. doi:10.4103/0972-4923.121034.

Oxford English Dictionary, s.v. "Anthoropocene", accessed July 10, 2020, https://premium.oxforddictionaries.com/us/definition/american_english/anthropocene

Oxford English Dictionary, s.v. "Catastrophism", accessed July 11, 2020, https://premium.oxforddictionaries.com/definition/english/catastrophism

Oxford English Dictionary, s.v. "Eutrophication", accessed July 13, 2020,

https://premium.oxforddictionaries.com/definition/english/eutrophication?q=Eutrophication

Parson, Will. "Remembering That 'All Life Is Interrelated'." *Chesapeake Bay Program*, 16 Jan. 2020, www.chesapeakebay.net/news/blog/remembering_that_all_life_is_interrelated.

Patterson, Brittany. "Trump Poised to Shrink Two National Monuments." Scientific American. December 04, 2017. Accessed July 13, 2020. https://www.scientificamerican.com/article/trump-poised-to-shrink-two-national-monuments/.

Pauchard, Aníbal, Christoph Kueffer, Hansjörg Dietz, Curtis C. Daehler, Jake Alexander, Peter J. Edwards, José Ramón Arévalo, Lohengrin A. Cavieres, Antoine Guisan, Sylvia Haider, Gabi Jakobs, Keith Mcdougall, Constance I. Millar, Bridgett J. Naylor, Catherine G. Parks, Lisa J. Rew, and Tim Seipel. "Aint No Mountain High Enough: Plant Invasions Reaching New Elevations." Frontiers in Ecology and the Environment 7, no. 9 (2009): 479-86. Accessed July 8, 2020. doi:10.1890/080072.

Pievani, Telmo. "The Sixth Mass Extinction: Anthropocene and the Human Impact on Biodiversity." *Rendiconti Lincei* 25, no. 1 (2013): 85-93. Accessed May 1, 2020. doi:10.1007/s12210-013-0258-9.

Raup, D. M. "The Role of Extinction in Evolution." *Proceedings of the National Academy of Sciences* 91, no. 15 (1994): 6758-763. Accessed July 12, 2020. doi:10.1073/pnas.91.15.6758.

Rodríguez-Rodríguez, David, and Bastian Bomhard. "Mapping Direct Human Influence on the Worlds Mountain Areas." Mountain Research and Development 32, no. 2 (2012): 197-202. Accessed July 8, 2020. doi:10.1659/mrd-journal-d-10-00111.1.

Sandom, Christopher, Søren Faurby, Brody Sandel, and Jens-Christian Svenning. "Global Late Quaternary Megafauna Extinctions Linked to Humans, Not Climate Change." *Proceedings of the Royal Society B: Biological Sciences* 281, no. 1787 (2014): 20133254. Accessed June 18, 2020. doi:10.1098/rspb.2013.3254.

Selig, Elizabeth R., Will R. Turner, Sebastian Troëng, Bryan P. Wallace, Benjamin S. Halpern, Kristin Kaschner,

Ben G. Lascelles, Kent E. Carpenter, and Russell A. Mittermeier. "Global Priorities for Marine Biodiversity Conservation." PLoS ONE 9, no. 1 (2014). Accessed July 13, 2020. doi:10.1371/journal.pone.0082898.

Sneed, Annie. "What Conservation Efforts Can Learn from Indigenous Communities." Scientific American. May 29, 2019. Accessed July 7, 2020. https://www.scientificamerican.com/article/what-conservation-efforts-can-learn-from-indigenous-communities/.

“Species Extinction.” *IUCN*, 9 Mar. 2020, www.iucn.org/content/species-extinction.

Tilman, David, Michael Clark, David R. Williams, Kaitlin Kimmel, Stephen Polasky, and Craig Packer. "Future Threats to Biodiversity and Pathways to Their Prevention." *Nature* 546, no. 7656 (2017): 73-81. Accessed May 1, 2020. doi:10.1038/nature22900.

"UN Report: Nature's Dangerous Decline 'Unprecedented'; Species Extinction Rates 'Accelerating' – United Nations Sustainable Development." United Nations. Accessed July 7, 2020. https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/.

Wan, Xinru, and Zhibin Zhang. "Climate Warming and Humans Played Different Roles in Triggering Late Quaternary Extinctions in East and West Eurasia." *Proceedings of the Royal Society B: Biological Sciences* 284, no. 1851 (2017): 20162438. Accessed June 21, 2020. doi:10.1098/rspb.2016.2438.

Wassmann, Paul, Carlos M. Duarte, Susana Agustí, and Mikael K. Sejr. "Footprints of Climate Change in the Arctic Marine Ecosystem." Global Change Biology 17, no. 2 (2010): 1235-249. Accessed July 13, 2020. doi:10.1111/j.1365-2486.2010.02311.x.

Watson, James E.m. "Human Responses to Climate Change Will Seriously Impact Biodiversity Conservation: Its Time We Start Planning for Them." Conservation Letters 7, no. 1 (2013): 1-2. Accessed May 1, 2020. doi:10.1111/conl.12083.

Weldon, Ché, Louis H. Du Preez, Alex D. Hyatt, Reinhold Muller, and Rick Speare. "Origin of the Amphibian Chytrid Fungus." *Emerging Infectious Diseases* 10, no. 12 (December 2004): 2100-105. Accessed July 3`1, 2020. doi:10.3201/eid1012.030804.

Wickham, James, Petra Bohall Wood, Matthew C. Nicholson, William Jenkins, Daniel Druckenbrod, Glenn W. Suter, Michael P. Strager, Christine Mazzarella, Walter Galloway, and John Amos. "The Overlooked Terrestrial Impacts of Mountaintop Mining." *BioScience* 63, no. 5 (2013): 335-48. Accessed July 8, 2020. doi:10.1525/bio.2013.63.5.7.

Wilson, Edward O. "Threats to Biodiversity." Scientific American 261, no. 3 (1989): 108-16. Accessed July 6, 2020. doi:10.1038/scientificamerican0989-108.

Notes

[1] Raup, “The Role of Extinction in Evolution” 6758-6762

[2] “Species Extinction”, https://www.iucn.org/content/species-extinction

[3] Education, http://www.doe.virginia.gov/testing/sol/standards_docs/science/2018/index.shtml

[4] Raup, “The Role of Extinction in Evolution” 6758-6762

[5] “Species Extinction”, https://www.iucn.org/content/species-extinction

[6] Raup, “The Role of Extinction in Evolution” 6760

[7] De Vos “Estimating the Normal Background Rate of Species Extinction,” 452

[8] National Geographic Society, https://www.nationalgeographic.org/media/mass-extinctions/

[9] Greshko, “What Are Mass Extinctions, and What Causes Them?” https://www.nationalgeographic.com/science/prehistoric-world/mass-extinction/

[10] Wilson, “Threats to Biodiversity” 111

[11] Elewa, *Mass Extinction* 1-3

[12] National Geographic Society, https://www.nationalgeographic.org/media/mass-extinctions/

[13] Greshko, “What Are Mass Extinctions, and What Causes Them?” https://www.nationalgeographic.com/science/prehistoric-world/mass-extinction/

[14] Wilson, “Threats to Biodiversity” 111

[15] Elewa, *Mass Extinction* 1-3

[16] iBiology, https://www.ibiology.org/ecology/loss-biodiversity-human-dominated-world/

[17] Sandon, “Global Late Quaternary Megafauna Extinctions Linked to Humans, Not Climate Change,” 1

[18] Kolbert, *The Sixth Extinction: An Unnatural History,* 230

[19] Wan, “Climate Warming and Humans Played Different Roles in Triggering Late Quarternary Extinctions in East and Wes Eurasia,” 7

[20] Kolbert, *The Sixth Extinction: An Unnatural History,* 230

[21] Kolbert, *The Sixth Extinction: An Unnatural History,* 230

[22] Kolbert, *The Sixth Extinction: An Unnatural History*, 230

[23] Elewa, *Mass Extinction* 160-161

[24] Peivani, “The Sixth Mass Extinction: Anthropocene and the Human Impact on Biodiversity,” 90

[25] Ellis, *Anthropocene: A Very Short Introduction*, 53

[26] Peivani, “The Sixth Mass Extinction: Anthropocene and the Human Impact on Biodiversity,” 90

[27] Oxford English Dictionary

[28] Peivani, “The Sixth Mass Extinction: Anthropocene and the Human Impact on Biodiversity,” 91

[29] Image marked as available for reuse.

[30] Jackson, “Extinction: The Passenger Pigeon, Last Hopes, Letting Go,” 767 & 769

[31] Jackson, “Extinction: The Passenger Pigeon, Last Hopes, Letting Go,” 770

[32] Kolbert, *The Sixth Extinction: An Unnatural History*, 17

[33] Ochoa-Ochoa, “The Demise of the Golden Toad and the Creation of a Climate Change Icon Species,” 1

[34] Kolbert, *The Sixth Extinction: An Unnatural History,* 18

[35] Weldon, "Origin of the Amphibian Chytrid Fungus,” 2100

[36] Laurance, “Emerging Threats to Tropical Forests,” 163

[37] Weldon, "Origin of the Amphibian Chytrid Fungus,” 2100

[38] Weldon, "Origin of the Amphibian Chytrid Fungus,” 2104

[39] Kolbert, *The Sixth Extinction: An Unnatural History* 18

[40] Weldon, "Origin of the Amphibian Chytrid Fungus,” 2104

[41] Peivani, “The Sixth Mass Extinction: Anthropocene and the Human Impact on Biodiversity,” 91

[42] Watson, “Human Response to Climate Change Will Seriously Impact Biodiversity Conservation: Its Time We Start Planning for Them,” 2

[43] Crain, “Understanding and Managing Human Threats to Coastal Marine Environment,” 41

[44] Crain, “Understanding and Managing Human Threats to Coastal Marine Environment,” 41

[45] Crain, “Understanding and Managing Human Threats to Coastal Marine Environment,” 41

[46] Kolbert, *The Sixth Extinction: An Unnatural History*, 141

[47] Oxford English Dictionary

[48] Crain, "Understanding and Managing Human Threats to Coastal Marine Environment," 41-42

[49] Crain, "Understanding and Managing Human Threats to Coastal Marine Environment," 42

[50] Crain, "Understanding and Managing Human Threats to Coastal Marine Environment," 42-43

[51] Crain, "Understanding and Managing Human Threats to Coastal Marine Environment," 43

[52] Crain, "Understanding and Managing Human Threats to Coastal Marine Environment," 43

[53] Crain, "Understanding and Managing Human Threats to Coastal Marine Environment," 40

[54] Wassman, "Footprints of Climate Change in the Arctice Marine Ecosystem," 1236 & 1239

[55] Crain, "Understanding and Managing Human Threats to Coastal Marine Environment," 45

[56] Crain, "Understanding and Managing Human Threats to Coastal Marine Environment," 45

[57] Kolbert, *The Sixth Extinction: An Unnatural History,* 141

[58] Crain, "Understanding and Managing Human Threats to Coastal Marine Environment," 45

[59] Kolbert, *The Sixth Extinction: An Unnatural History,* 142

[60] Kolbert, *The Sixth Extinction: An Unnatural History,* 140

[61] Laurance, "Emerging Threats to Tropical Forests," 160

[62] Laurance, "Emerging Threats to Tropical Forests," 160-162

[63] Laurance, "Emerging Threats to Tropical Forests," 160-162

[64] Laurance, "Emerging Threats to Tropical Forests," 163

[65] Laurance, "Emerging Threats to Tropical Forests," 163-164

[66] Laurance, "Emerging Threats to Tropical Forests," 164

[67] Curtin, "Grasslands, People, and Conservation: Over-the-Horizon Learning Exchange between African and American Pastoralists," 871

[68] Curtin, "Grasslands, People, and Conservation: Over-the-Horizon Learning Exchange between African and American Pastoralists," 871

[69] Curtin, “Grasslands, People, and Conservation: Over-the-Horizon Learning Exchange between African and American Pastoralists,” 871

[70] iBiology, https://www.ibiology.org/ecology/loss-biodiversity-human-dominated-world/

[71] Farigone, “Bioenergy and Wildlife: Treats and Opportunities for Grassland Conservation,” 767-775

[72] Curtin, “Grasslands, People, and Conservation: Over-the-Horizon Learning Exchange between African and American Pastoralists,” 871

[73] Duncan, “Oil in the Sahara: Mapping Anthropogenic Threats to Saharan Biodiversity from Space,” 1

[74] Brito, “Unravelling Biodiversity, Evolution, and Treats to Conservation in the Sahara-Sahel,” 215

[75] Brito, “Unravelling Biodiversity, Evolution, and Treats to Conservation in the Sahara-Sahel,” 215

[76] Duncan, “Oil in the Sahara: Mapping Anthropogenic Threats to Saharan Biodiversity from Space,” 2

[77] Brito, “Unravelling Biodiversity, Evolution, and Treats to Conservation in the Sahara-Sahel,” 223-224

[78] Averill-Murray, “A New Approach to Conservation of the Mojave Desert Tortoise,” 894

[79] Duncan, “Oil in the Sahara: Mapping Anthropogenic Threats to Saharan Biodiversity from Space,” 2

[80] Duncan, “Oil in the Sahara: Mapping Anthropogenic Threats to Saharan Biodiversity from Space,” 2

[81] Patterson, https://www.scientificamerican.com/article/trump-poised-to-shrink-two-national-monuments/

[82] Averill-Murray, “A New Approach to Conservation of the Mojave Desert Tortoise,” 894

[83] Averill-Murray, “A New Approach to Conservation of the Mojave Desert Tortoise,” 894

[84] Rodríguez- Rodríguez, “Mapping Direct Human Influence on World Mountain Areas,” 199

[85] Rodríguez- Rodríguez, “Mapping Direct Human Influence on World Mountain Areas,” 199

[86] Wickham, "The Overlooked Terrestrial Impacts of Mountaintop Mining," 335-345

[87] Edwards, “Mining and the African Environment,” 302-303

[88] Pauchard, “Ain’t No Mountain High Enough: Plant Invasions Reaching New Elevations,” 482

[89] Kolbert, *The Sixth Extinction: An Unnatural History,* 193-195 & 205

[90] Kolbert, *The Sixth Extinction: An Unnatural History,* 205

[91] Pauchard, “Ain’t No Mountain High Enough: Plant Invasions Reaching New Elevations,” 480

[92] Huss, “Toward Mountains without Permanent Snow and Ice,” 418

[93] Huss, “Toward Mountains without Permanent Snow and Ice,” 425 & 427

[94] Parson https://www.chesapeakebay.net/news/blog/remembering_that_all_life_is_interrelated

[95] UN Report, https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/

[96] UN Report, https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/

[97] Masood, https://www.nature.com/articles/d41586-018-05984-3

[98] https://www.iucn.org/content/natural-solutions-protected-areas-helping-people-deal-desertification-and-drought

[99] UN Report, https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/

[100] Huss, “Toward Mountains without Permanent Snow and Ice”, 427

[101] Sneed, https://www.scientificamerican.com/article/what-conservation-efforts-can-learn-from-indigenous-communities/

[102] Sneed, https://www.scientificamerican.com/article/what-conservation-efforts-can-learn-from-indigenous-communities/

[103] Sneed, https://www.scientificamerican.com/article/what-conservation-efforts-can-learn-from-indigenous-communities/

[104] Curtin, “Grasslands, People, and Conservation: Over-the-Horizon Learning Exchange between African and American Pastoralists”, 873

[105] Kasaona, https://www.ted.com/talks/john_kasaona_how_poachers_became_caretakers?language=en

[106] Boudreaux, “Community Conservatoin In Namibia: Empowering The Poor With Property Rights”, 17

[107] Hoole, “Breaking down fences: Recoupling social-ecological systems for biodiversity conservation in Namibia,” 304

[108] Kasaona, https://www.ted.com/talks/john_kasaona_how_poachers_became_caretakers?language=en

[109] Boudreaux, “Community Conservatoin In Namibia: Empowering The Poor With Property Rights”, 18

[110] Berkes, “Rethinking Community-Based Conservation,” 622-624 & 627

[111] Kasaona, https://www.ted.com/talks/john_kasaona_how_poachers_became_caretakers?language=en

[112] Boudreaux, “Community Conservatoin In Namibia: Empowering The Poor With Property Rights”, 18

[113] Kasaona, https://www.ted.com/talks/john_kasaona_how_poachers_became_caretakers?language=en

[114] Boudreaux, “Community Conservatoin In Namibia: Empowering The Poor With Property Rights”, 20

[115] Boudreaux, “Community Conservatoin In Namibia: Empowering The Poor With Property Rights”, 20

[116] Kasaona, https://www.ted.com/talks/john_kasaona_how_poachers_became_caretakers?language=en

[117] Boudreaux, “Community Conservatoin In Namibia: Empowering The Poor With Property Rights”, 20

[118] Goodall, https://www.ted.com/talks/jane_goodall_how_humans_and_animals_can_live_together

[119] Goodall, https://www.ted.com/talks/jane_goodall_how_humans_and_animals_can_live_together

[120] Goodall, https://www.ted.com/talks/jane_goodall_how_humans_and_animals_can_live_together

[121] UN Report, https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/

[122] UN Report, https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/

[123] Image created by author