
The extent of the responsibility of anthropogenic activities on the emergence of the sixth mass extinction

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Abstract

The Earth is currently experiencing a mass extinction event, the sixth of its kind in the planet's history. This ongoing extinction period, which is often referred to as the Holocene extinction, is caused by a variety of factors, including climate change, habitat destruction, and pollution. The primary drivers of this catastrophic event are thought to be induced by human activity. The end of this era of mass extinction could have the potential to be marked with the endangerment, or extinction, of the human species.

This report aims to review and analyze the existing literature on the subject, including the impact of human activities such as deforestation, ocean acidification, urbanization and over-exploitation on global extinction rates. The report also assesses the causes of past mass extinctions and compares them with current conditions. Furthermore, key themes of the role of invasive species and habitat fragmentation are discussed. The findings of this report indicate a clear link between human activities and the current unprecedented extinction rate, highlighting the urgent need for action to address and mitigate the impact of anthropogenic activities on biodiversity loss.

Keywords: *Anthropocene, extinction, habitat destruction, ocean acidification, biodiversity*

Introduction

Climate change and habitat destruction have been major causes for concern throughout our recent history. Only now has it been discovered that we may be on the verge of the next mass extinction, which has been contributed to heavily by these factors, and is predicted to be the most devastating one yet. Though an extinction would no doubt be extremely disadvantageous to the human species

as a whole – by erasing potentially useful flora and fauna, discovered or otherwise – we may also inadvertently be the main cause of this disaster.

Identifying the sources responsible would allow us to do our best to mitigate them and raise awareness to prevent them from worsening the condition. The misconception that extinctions are a thing of the past, and that human beings will bear no extreme consequences to such a reality needs to be dismissed. The link between human activities and extinction has yet to be directly and thoroughly researched, as there is a gap in the information available, making this an extremely important topic to explore.

Paleontologists Anthony Hallam and Paul Wignall characterize mass extinctions as events that eliminate a “significant proportion of the world’s biota in a geologically insignificant amount of time.” ([Kolbert, 2014](#)). There have been five major mass extinctions on Earth in the past 600 million years ([Ripple, 2017](#)). These are the End-Ordovician, Late Devonian, End-Permian, Late Triassic, and End-Cretaceous extinctions – the latest of which happened 66 million years ago, well before the prevalence of human beings ([Racki, 2021](#)).

All existing life experiences extinction as an underlying part of evolution. Of all the species that have ever existed during the 600 million years of fossil history, just 2–4% are still alive now. Invertebrate and mammal species have had average lifespans of 5-10 and 1-2 million years, respectively. One out of every 14 species goes extinct every year, according to more recent extinction records for birds and mammals lost over the past 50 years. This means that each species has an average lifespan of 10,000 years, which is 100–1000 times shorter than the lifespan of species found in the fossil record. According to these calculations, extinction rates now are generally 1000–10,000 times higher than they were in the past, making the current rate of species decline at least equal to historical major extinctions. ([Mace, 1998](#))

Since extinction is a common part of the evolutionary process, some scientists wrongly believe that there is no reason for concern about the sixth one. This is not true because, as previously observed, the rate of species extinction is now as much as 100 times the normal rate. Additionally, this current extinction is not a product of evolution, but rather a result of a rare occurrence that is changing the environment so rapidly that many organisms cannot evolve in response to it. ([Ceballos & Ehrlich, 2018](#))

Whether this rapid shift in natural ecosystems and the atmosphere is a result of primarily human actions, or if it is a by-product of events that would have happened without human interference is what this report aims to investigate.

The role of ocean acidification in extinctions

Around one-fourth of all carbon dioxide in the atmosphere is absorbed by oceans over an extended period of time, causing its pH to decrease and becoming acidic. This process is known as ocean acidification ([Gattuso & Hansson, 2011](#)).

One of the main drivers of the Cretaceous-Paleogene extinction, famously known to be the elimination of dinosaurs, has been found to be the decrease in pH of the world's oceans following a meteor hit. The meteor collided with sulfur-filled rocks that released the gas into the atmosphere, producing extensive acid rain ([Shelton, 2019](#)). The increased acidity of the ocean caused the calcified chalk-like shells of various species, as well as carbonate and sulfate rocks, to be dissolved ([Henehan et al., 2019](#)). This annihilated three-fourths of all plant and animal species that were inhabiting the Earth at the time. The die-off of a large quantity of various plant species further exacerbated the effects of excess carbon dioxide in the atmosphere. "The ocean acidification we observe could easily have been the trigger for mass extinction in the marine realm." Pincelli Hull, assistant professor of geology and geophysics, said to Yale News (2019).

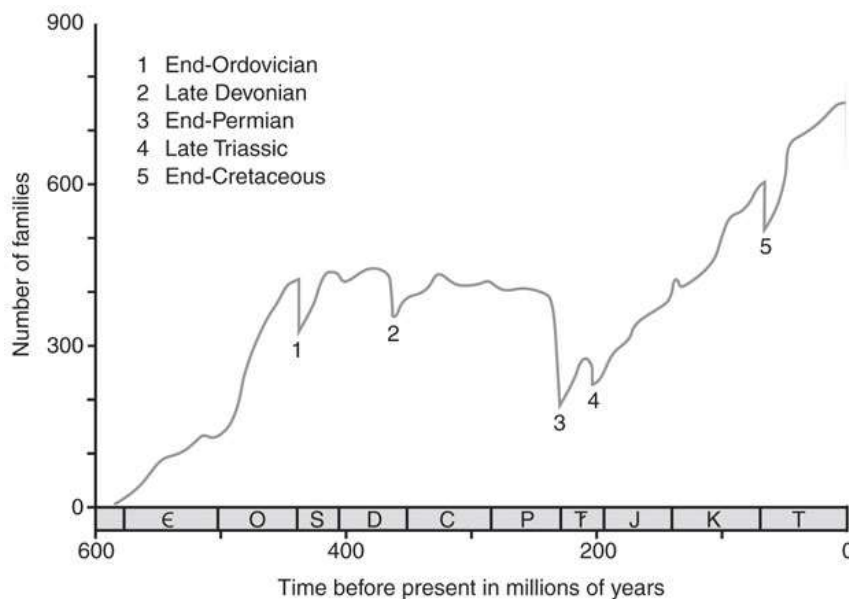
Ocean acidification has also been speculated to have played a key part in the largest mass extinction event in history - the Permian-Triassic extinction. Ninety percent of marine and seventy percent of terrestrial species have been estimated to have been wiped out by this event, which is thought to be caused by volcanic eruptions and asteroid impact, though evidence on the matter is difficult to collect. The CO₂ released by volcanoes significantly contributed to ocean acidification. This has been found out by using boron-isotopes to identify an abrupt increase in acidity in the second extinction pulse, which was not led up to by a gradual decrease in pH. ([Connors, 2015](#))

Matthew Clarkson, lead author of a new study on the topic, commented on the findings in a press release:

Scientists have long suspected that an ocean acidification event occurred during the greatest mass extinction of all time, but direct evidence has been lacking until now. This is a worrying finding, considering that we can already see an increase in ocean acidity today that is the result of human carbon emissions. ([Connors, 2015](#))

Figure 1

The 'Big Five' Extinctions



([Kolbert, 2014](#))

The most devastating mass extinction, the third (Permian-Triassic), caused a decrease of species families nearly double that of all the other extinctions, as seen in Figure 1. It was also here that the next mass extinction followed closely after – most likely because of the vulnerable state of biota at the time, and their interdependent needs.

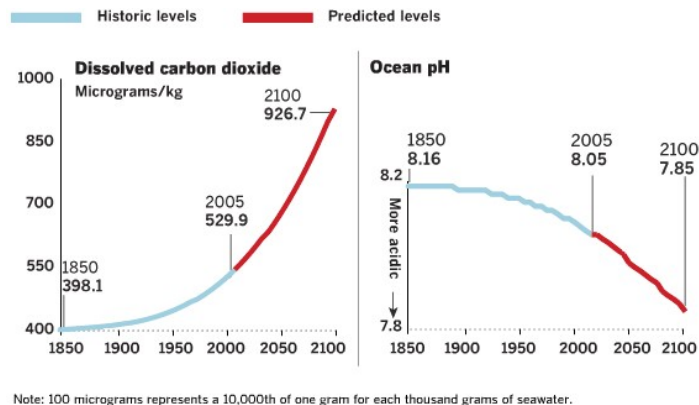
Ocean acidification had a part to play in both the third and fifth mass extinctions of the past. With the meteor impact, there was a sudden and rapid change in the composition of CO₂ in the ocean and in the air. While marine wildlife was mostly affected, plant species diminished as well as a result of acid rain and inadequate soil conditions. This further aggravated the imbalance of gases

in the air. It took hundreds of thousands of years for the carbon cycling process to return as it was pre-impact. ([Henehan et al., 2019](#))

Sudden carbon dioxide influx into the atmosphere is occurring again, millions of years later. This time, it is not by a naturally occurring event, but rather, it is one caused as a result of the development of industry and the burning of fossil fuels. This, though slower than the swift impact of an extraterrestrial strike, is still relatively abrupt. After the beginning of the Industrial Revolution, CO₂ levels have drastically risen, and might soon match those of the previous mass extinction. This is serious cause for concern, as the last time such conditions arose, it was the first time in 100 million years that such a great number of species were killed off (Fig. 1).

Figure 2

Global dissolved CO₂ concentrations and ocean pH from 1850 to 2100 (projected)



(dolphinaris, 2017)

According to Figure 2, CO₂ levels in the atmosphere before and during the start of the Industrial Revolution were significantly less than they are today and started increasing exponentially after 1850. They are expected to nearly double by the end of the century, from 529.9 mg/kg to 926.7 mg/Kg. Ocean pH has a direct relationship with CO₂, becoming more acidic as time passes.

Every year, there is an increase in the annual average CO₂ concentration. The burning of fossil fuels is among the main causes of this. As human-driven emissions have increased, the rise in CO₂

has accelerated. By 1986, there had been a 25% increase after more than two hundred years. Twenty-five years later, in 2011, the increase had risen to 40%. ([Betts, 2021](#))

Ocean acidification is a driving factor for extinction that has been caused both naturally and by humans. The extent to which ocean pH has decreased over the last few years might not have been so drastic were it not for the reliance of the industrial innovations of human beings on fossil fuels and non-renewable forms of energy.

Coral reef destruction and extinction is an indicator of the extent of the impact of ocean acidification. It was discovered in the 1980s that that carbon dioxide could dissolve reefs. Several scientific reports have found and claimed that the Great Barrier Reef, along with the majority of other coral reefs worldwide, will have eroded into debris and rubble in the next half century. ([Kolbert, 2014](#))

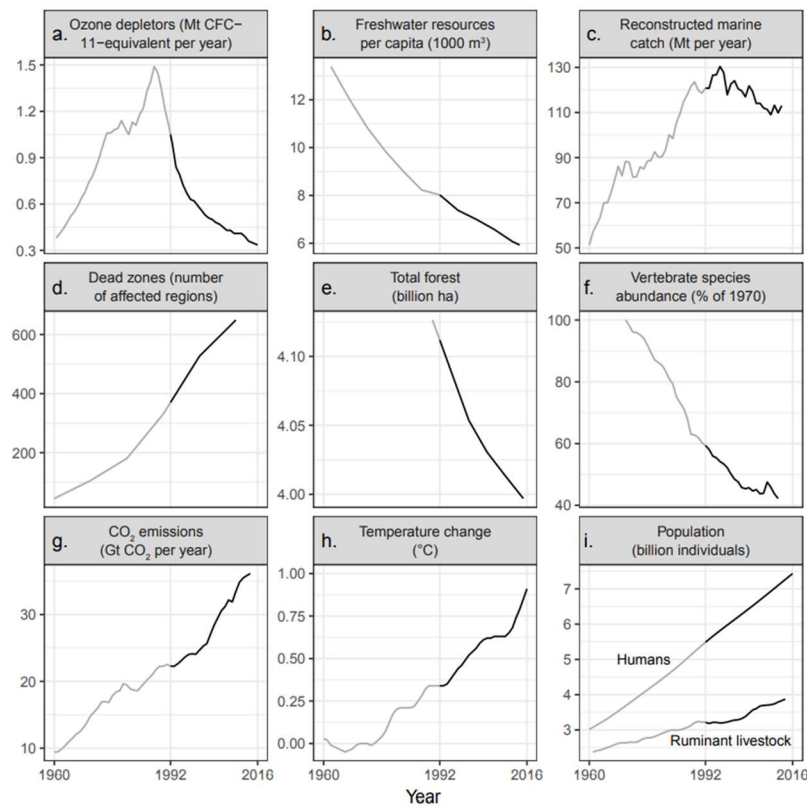
Habitat destruction through deforestation and urbanization

One of the major ways that human beings have changed the geographic landscape and infrastructure of the natural world is through the expansion of housing and industry. Roads, mines and excavation areas have been paved out to collect raw materials and make passages for convenient transport.

The increase in the total population of humans on the planet coincides with various disastrous natural phenomena that have been escalating along with the growth of our species, as can be seen in Figure 3.

Figure 3

Trends over time for environmental issues identified in the 1992 scientists' warning to humanity.



([Ripple, 2017](#))

Tropical forests and their biodiversity may be facing bleak futures due to unchecked deforestation and forest alteration brought on by human activities including logging, hunting, expanding agriculture, and human settlement. Thus, deforestation could have a part to play in the acceleration of the sixth mass extinction as it causes the loss of critical habitats for many species and disrupts the fragile balance of ecosystems. Additionally, forests play a crucial role in regulating the Earth's climate and retaining biodiversity, and their destruction leads to increased greenhouse gas emissions, soil erosion, and decreased carbon sequestration. ([Giam, 2017](#))

Carbon sequestration – the process by which carbon dioxide is removed from the atmosphere and stored in carbon sinks such as oceans, forests, and soils.

The loss of forest habitats also results in wildlife populations becoming fragmented, making it more challenging for species to interact and reproduce. This exacerbates the extinction of many species, particularly those that are already rare or have relatively narrow geographic ranges. The destruction of forests also has cascading effects on other ecosystems and the species they support, further accelerating the process of extinction.

Figure 3 reveals that total forest land has decreased by over 100 million hectares in the last 30 years, coinciding with vertebrate species loss as their habitat is gradually destroyed. This eradication of natural ecosystems can be attributed to climate change, global temperature increase, and over-exploitation of natural resources.

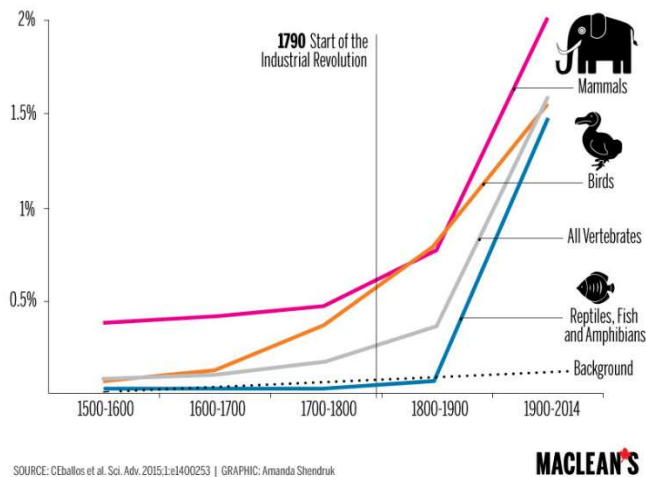
Though mass extinctions have been taking place well before the advent of *Homo sapiens*, this is the first one that we are in the midst of. To find out who the accountability of this incidence lies with, it is essential to look at the factors that are driving this mass extinction event, and to evaluate whether these would have been as severe without the involvement of the human species.

Figure 4

Extinction rates of vertebrates from 1500 to 2014, before and after the Industrial Revolution.

VERTEBRATE SPECIES EXTINCTION RATES

Cumulative, recorded as "extinct" or "extinct in the wild"



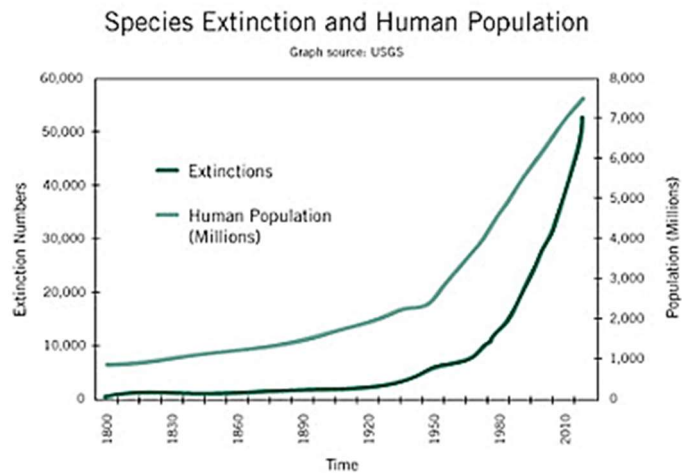
([Shendruk, 2015](#))

Figure 4 shows that there has been gradual decline in the number of vertebrate species since the 1700s, which became much steeper after the 1900s. Amphibians are believed to be the primary victims of recent extinctions, with almost $1/5^{\text{th}}$ of the species currently extinct or endangered. ([Ceballos, Ehrlich & Raven, 2020](#)). They have been known as one of the oldest and most resilient organisms on earth, and their sudden decline brings out great concern.

Their decline could be due to the fact that amphibians reside in and are dependent on both land and water, unlike most other categories of organisms. With both these ecosystems facing extreme changes in recent years, they are more susceptible to the negative impacts of human activities and any damage inflicted upon their environment. This trend is likely to accelerate because most amphibians occur in the tropics and have small geographic ranges that make them vulnerable to extinction. Mammals are also disappearing at an astonishing rate - particularly larger mammals - as is discussed in a later section.

Figure 5

Correlation between human population and species extinction, from 1800 to 2010.



[\(Biodiversity Crisis, 2012\)](#)

What can clearly be seen in this graph is that as the human population spiked after the 1950s, so did average extinction numbers. Previously, extinction rates were almost constant with the exception of background extinction. Human population numbers were also slow in growing during this time.

The sudden surge of population numbers meant that more resources suddenly had to be allocated to the increasing populace. More land was needed for agriculture and housing, and fossil fuels burned for generating electricity and powering automobiles. Natural resources such as palm oil were extracted from trees, leaving them vulnerable. Overfishing and coastal renovation lead to marine ecosystems such as coral reefs being damaged and putting at risk the lives of the species that depend on them.

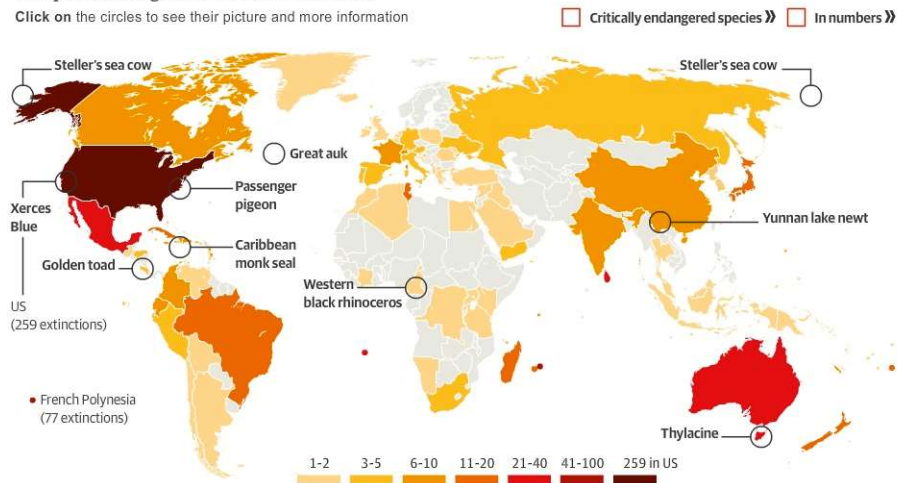
Figure 6

Number of species that recently went extinct, by country – IUCN Red list.

Where species went extinct

761 species have gone extinct in recent times*

Click on the circles to see their picture and more information



SOURCE: IUCN RED LIST

*Red list count began in 1996 but includes extinctions going back to 1500

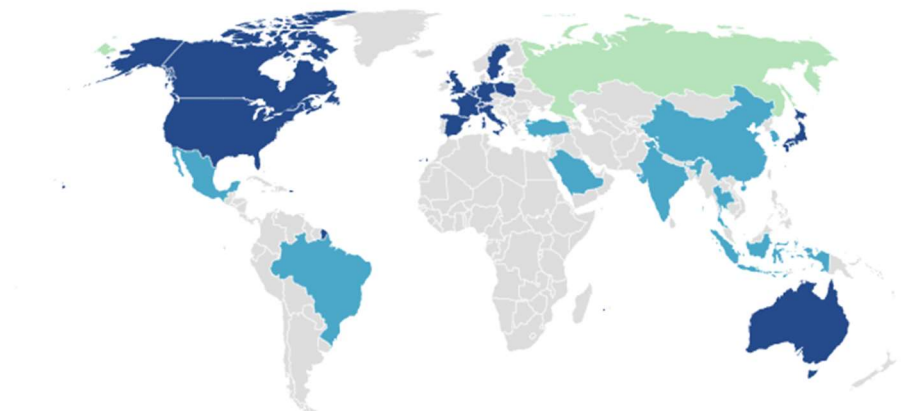
(The Guardian)

Figure 7

Map of the upper quartile of the most developed, or developing, countries in the world by GDP.

Top 25 Developed and Developing Countries by GDP

Developed Developing In Transition



[\(Top 25 Developed and Developing Countries, 2022\)](#)

The above two graphs show that there is a direct correlation between extinction rates and human development, or urbanization. Highly developed high-income countries (HICs) like Canada, U.S.A, Australia, Brazil, India and China appear to have the highest numbers of extinct species. In countries where secondary industries like manufacturing and refining are prevalent, resource extraction and pollution are the main contributors in creating a harmful environment that inhibits biodiversity. On the other hand, predominantly tertiary economies where commercial buildings, schools and hotels play a key role, as well as airports to support tourism, need to construct on undeveloped natural areas that might have been home to various species.

More than 25 million of the roughly 50 million square miles of land on Earth that are free of substantial amounts of ice has been developed by humans ([Kolbert, 2014](#)). Urban development is only one among the numerous human activities that destroys habitats, causing some of the highest local extinction rates and frequently eradicating the vast majority of native species ([McKinney, 2002](#)).

Literature Review

Though a considerable amount of research on the consequences of a possible sixth mass extinction has been done, the same cannot be said for the causes of such an event. The direct link between the factors intensifying the ongoing mass extinction has not been widely studied, although some reliable sources have tried to examine the connection. The aim of this literature review is to provide an overview of the historical causes of species loss and find links between current drivers. This review will draw on existing literature to identify the key concepts, approaches, and case studies related to anthropogenic activities facilitating the sixth mass extinction.

The beginning and current state of species decline

It is believed that the sudden and unnatural disappearance of various species began 11000 years ago, when humans first developed agriculture, according to Ceballos, Ehrlich and Raven (2020). The population of humans was much lower than what it is now, and requirements have since increased drastically since, as discussed earlier.

What sources commonly agree upon is that the vanishing of the golden toad, or *Incilius periglenes*, since 1989 is a symbol for the beginning of the extinction of amphibians, according to Kolbert (2014). A chytrid fungus, which is occasionally transmitted from place to place as a result of human activities and which targets populations that have been weakened by climatic instability particularly quickly, seems to be the main cause of the sudden extinction of so many amphibians.

Thus, humans have been responsible for the introduction of invasive species that have caused a rapid reduction in population sized of several amphibians in South America.

In her book, Kolbert (2014) examines the great auk, a species that went extinct in 1844 as a result of overexploitation by human settlers in Iceland who abused the bird for meat, fish bait, and many other purposes.

A large majority of the species that are extinct today are exceptionally large mammals. Scientists such as Lyell and Darwin believed that a drastic change in climate is what killed off these creatures. Others, however, argued that it was because human being hunted them, or were indirectly responsible for creating conditions that were unsuitable for them. There are three main reasons for this theory: the pulses of the extinction of large mammals coincide with human colonization; mammals survived natural catastrophes before the emergence of humans; no signs of malnutrition found from fossilized remains.

Overall, it seems quite likely that humans, rather than environmental factors, were to blame for the mass extinction of giant mammals due to the inadequacy of purely environmental explanations.

The effect of human intervention

Williams et al. (2015) state that there are certain markers that differentiate the current mass extinction from former ones, as outlined below.

There has been a massive translocation of species on a global level. Flora and fauna have spread throughout the world through import and export by human beings, and foreign species are inflicting havoc on prevailing ecological populations.

Humans quickly became a top predator on land and sea, taking over a large proportion of the world's primary production – the first time any such species has accomplished such a feat in the Earth's history. Mining and burning fossil fuels further dug up primary production from the past.

Evolution, a process typically dictated by natural selection and survival of the fittest, is now seemingly being impacted by human actions. Through the domestication of animals and livestock,

and the cultivation and selective logging of trees, the natural course of evolution has been altered. Human management efforts, including conservation, inadvertently impact the way organisms adapt to their surroundings.

Invasive Species

Invasive species refer to non-native species that have been introduced into a new ecosystem, typically as a result of human activities such as international trade, transportation, and travel.

Earlier, the example of the chytrid fungus, which is not native to South America, was seen to have eradicated the Panamanian golden frog population as well as several other amphibian species in the area. Kolbert (2014) further discusses the *Geomyces destructans* fungus causing the die-off of bats in New York, and then spreading to West Virginia. The pathogen seemed to have crossed natural barriers like rivers, mountains and oceans, made possible through humans.

Sometimes, when a species is brought to a new location, it eliminates the diversity of life there. Global species travel is thought to be moving backwards, to the age of the single interconnected supercontinent Pangea, where there are no natural barriers.

Habitat Fragmentation

A vast, continuous region of natural habitat can be fragmented into smaller, isolated pieces as a result of human activities like urbanization, agriculture, logging, and mining. The ultimate result is a landscape made up of isolated patches surrounded by terrain that is inadequate for the species that rely on that habitat. These are more vulnerable to the effects of environmental disturbances such as drought, floods, and fires, which can reduce the resilience of ecosystems and increase the risk of local extinctions.

Furthermore, because the borders of habitat fragments are exposed to different climatic and environmental conditions than the inside, edge effects such greater exposure to wind, sunshine, and predators may arise. These have the potential to change the makeup of animal and plant groups and degrade habitat quality. Populations may become genetically isolated as a result of habitat

fragmentation, which also reduces genetic diversity and raises the risk of inbreeding and genetic drift.

Kolbert (2014) studies the direct relationship between land area and biodiversity. A 25-acre patch of rainforest in Brazil known as ‘Reserve 1202’, which is surrounded by barren land and remains of cut-down trees, was compared to the main rainforest area miles away. It had been noticed over the years that there had been a gradual decline in overall biodiversity, even though it was a protected area. This is because transitory obstacles to diversity are more inclined to be catastrophic when there are fewer species and less habitat space available. It can therefore be concluded that the fragmentation of the rainforest ecosystem leads to rapidly diminishing biodiversity.

There are a number of weaknesses relating to Kolbert’s book. Firstly, there is a limited geographic focus, exploring only North America, Europe and Asia. Second, the book does not give voice to many marginalized groups, such as Indigenous peoples and their traditional ecological knowledge, who have important views on biodiversity loss and conservation. Lastly, an over-reliance on personal anecdotes may give a skewed perspective on the sixth mass extinction.

The works of Gerardo Ceballos have been widely cited throughout this report, and their influence make up a large proportion of the research conducted. Over-dependence on one source could mean that biased information was unconsciously included and credited, as the author may have a value judgement or vested interests in the matter.

Methodology

The methods that have been implemented to obtain reliable information to answer the research question and provide background information have been outlined below. The objective of this research was to determine the role of human activities on the ongoing mass extinction and evaluate if it was the main contributing factor in the issue.

A literature review is included in the report as a means to attain information through reliable journals and articles, as well as descriptive and relevant books. These sources are checked thoroughly for validity, recency and their significance towards the research goal. The T.R.A.A.P. technique (Timeliness, Relevance, Authority, Accuracy and Purpose) was used to test the authenticity of data gathered from news articles, international organizations, published papers in journals, websites and books. The scholarly expertise and qualifications of an author were examined before citing their work in the report.

There are several advantages connected to using a literature review method in a report. A comprehensive overview of the existing literature on the research topic helps gain a deeper understanding of the collected data and integrate existing knowledge. Additionally, gaps in research can be identified and areas that are understudied or require further investigation emphasized. Evidence for supporting arguments and conclusions is more easily attained, helping build a strong case for the research question.

However, there are some limitations to using this method. The quality of each source cannot be easily assessed - methods, sample sizes, and other factors can impact the validity of the results. Moreover, a large number of studies need to be looked through for relevant, unbiased information to be found, and this is a time-consuming process. Some sources may be outdated or contain references that are no longer considered accurate. Nevertheless, precautions have been taken to mitigate these disadvantages.

Secondary sources have been predominantly used to collect and analyze data because they were the most suitable for the topic and field of research that was chosen, as well as the most fitting for the time-frame available. Qualitative and quantitative types of data have both been utilized in a

mixed method approach to investigate the information examined in the research, though quantitative methods were mostly used. Observations and case studies have helped to understand the underlying meanings, trends and patterns of data. Statistical analyses were utilized to identify relationships between variables and to make predictions about future outcomes.

Though a sufficient amount of evidence has been gathered from various sources such as the internet and local libraries, other techniques could have been employed to collect information. Primary data collection through structured interviews with paleontologists and professionals in the field of biology and environmentalism could have been used to attain qualitative testimony on their underlying perceptions and attitudes regarding the sixth mass extinction with relation to human activities. Surveys could also be useful in getting opinions on how the problem that human emissions and practices cause could be mitigated on a local and global scale.

Conclusion

This study aimed to explore the main drivers and accelerants of the sixth mass extinction and effectively utilized a literature review method to evaluate secondary sources that lead to answer the research question.

It had been previously thought that the ongoing mass extinction was a natural part of the course of the earth's history – an unavoidable event – as the preceding five were. The triggers involved in bringing about the wiping out of a large percentage of all species on earth had been assumed to have been accelerated by humans, perhaps, but not caused entirely by them. The findings of this report discovered that it is most likely that human beings are the primary cause of this devastating catastrophe. Not only did they initiate the beginning of this mass extinction event, but they exacerbated it as well, making it so that mitigation attempts are less effective than they otherwise would have been.

One of the most pronounced impacts that humans have had on the environment in excess greenhouse gas production, including CO₂ through the burning of fossil fuels and excessive deforestation. This, in turn, resulted in the acidification of the world's oceans and an increase in average global temperatures. Tropical forests and marine ecosystems are put under great stress, and could be on the verge of collapsing, and no longer being able to support species that are dependent on them.

Several groups have been affected in recent years, amphibians especially. The chytridiomycosis fungus, whose spread has been sped up by global warming, was disseminated further by international travelers. On narrowly adapted and widely spread species, the rising pressure from habitat destruction and climate change is expected to have significant effects.

Artificial carbon sequestration is a possible technique that could be used to mitigate the effects of excess CO₂ in the atmosphere through means of human-made technologies such as carbon capture and storage (CCS). This could be used in conjunction with renewable energy sources to create a low-carbon energy system. Moreover, new economic opportunities such as the development of carbon markets and the creation of additional jobs would greatly benefit communities. However, the cost of implementing such technologies and potential environmental impacts associated with these large-scale projects mean that this method is not without compromise.

To lessen the adverse effects of habitat fragmentation, conservation efforts should concentrate on safeguarding and restoring habitat corridors that connect pieces to sustain gene flow and permit species to travel across habitat patches, which can help to lessen the adverse consequences of habitat fragmentation. For the protection of ecosystems and biodiversity, efforts must be made to stop the introduction of invasive species in foreign habitats and limit their spread. This can involve taking steps like being alert about emerging species, creating inspection and quarantine protocols, and managing or relocating invasive species when they are found. The 17 sustainable development goals (SDGs) set out by the United Nations could play a key role in reversing the damaging effects of human exploitation, industry and spread on the environment.

The primary focus of the report was to investigate whether or not humans were responsible for the emergence of the sixth mass extinction. This statistic was not easy to measure as there is no set criteria as to how different activities and their impacts are ranked relative to each other. Several sources had varying opinions on the importance of different factors in aiding the current extinction event, making it difficult to come to an accurate conclusion. However, this obstacle was overcome by finding commonalities between context that sources provided, and prioritizing expert opinion that was well-regarded by other researchers.

The report could have been improved by utilizing more recent sources and making extensive comparisons on their strengths and weaknesses. Looking into other themes such as plastic and

industrial pollution would have provided further evidence for the subject matter and could have been discussed in the report.

This research provided essential insight that helped develop individual perspective on the topic by creating awareness of the disastrous affects that humans may inadvertently have on the planet. The urgent issue of the negative impacts of the Anthropocene brought into light the importance of sustainable growth and responsible development, and the acknowledgement that ‘humans might be the problem, but they are also the solution’.

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