HIGH SCHOOL EDITION
Journal of Student Research
Volume 13 Issue 2 (2024)

Climate Change: A Comprehensive Overview of Its Consequences

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ABSTRACT

Climate change is increasingly discussed in national and international politics, science, technology and many other news subjects and has become a growing threat in most recent years. Climate change is often misconceived as warmer weather at inappropriate times of year but in reality is a deeply complex issue that has many consequences on many different aspects of life. The way that it affects one species is likely to trickle up or down and affect any other species with which it interacts. Side effects of climate change may impact the plants and animals that we eat, how things grow and are made, disease prevalence and so much more. Thus, it is important to examine and understand the extent to which it can cause harm. This understanding will promote advocacy for climate change awareness and mitigation strategies that may be able to slow its progress and prevent as much damage as is currently predicted.

Introduction

Climate change is a mass issue known across the world, affecting countless individuals as well as many animal, plant and microbial species. The United Nations defines climate change as "long-term shifts in temperature and weather patterns," (United Nations, n.d.) and acknowledges that while these shifts can occur naturally, human activity is to blame for most of climate change that has occurred since the 1800s due to the burning of fossil fuels and their generation of greenhouse gases. NASA's Global Climate Change website emphasizes that climate change is primarily driven by increased human emissions of greenhouse gases that trap heat and have detrimental consequences (NASA, 2023). These consequences include the shrinking of glaciers and ice sheets, earlier breaking and melting of ice in bodies of water such as lakes and rivers, and changes to plant and animal life cycles and geographic ranges (bb). These consequences have many downstream effects as well that negatively affect various species all over the globe, including those on land, in water and in the Arctic.

Climate change has more than 50 indicators documented by the United States Environmental Protection Agency (EPA). Indicators are well researched and documented effects of increased greenhouse gas emissions on the environment and people. These indicators are divided into different categories: greenhouse gases, weather and climate, oceans, snow and ice, health and society, and ecosystems (EPA, n.d.) though many of these indicators overlap and affect each other. Emissions and atmospheric concentrations of greenhouse gases are measured and recorded (EPA, n.d.). Weather and climate effects such as U.S. and Global temperatures and extreme weather events such as flooding, heat waves, heavy precipitation, and droughts are documented (EPA, n.d.). Characteristics of the ocean such as ocean heat, sea surface temperature, sea level, coastal flooding, ocean acidity and land loss on the coast are examined (EPA, n.d.). Properties and patterns of snow and ice are also recorded, such as Arctic Sea ice melting and thinning, loss of ice sheets and glaciers, decreases in duration of and sizes of lake ice, snowfall amounts and frequencies, permafrost and freeze-thaw conditions (EPA, n.d.). Effects of climate change on ecosystems include wildfires, changes in streamflow and stream temperature, lake temperatures, bird migration patterns, leaf and bloom dates, and marine species distribution (EPA, n.d.). Health

and society are also impacted by climate change; extreme weather causes more heat-related illnesses and deaths, cold-related deaths, changes in residential energy use, temperature shifts cause changes in pollen season, growing and harvesting seasons for crops, as well as prevalence and spread of zoological diseases (EPA, n.d.).

As summarized by the EPA's Climate Change Indicators, the consequences of climate change spread far and wide. Many of the consequences are severe and will only get worse without appropriate solutions. The temperatures in the oceans have risen to a record temperature of 21.1ºC, the highest the world has ever seen in 100,000 years (Jones, 2023). In the last 150 years, the mean global temperature has risen about 1ºC which has affected at least 10,967 species on the IUCN's Red List of Threatened Species, leaving them increasingly susceptible to extinction (IUCN, 2022). The United States Centers for Disease Control and Prevention predicts that climate change will continue to threaten human health as a result of changes in physical, biological and ecological systems, likely leading to "increased respiratory and cardiovascular diseases, injuries and premature deaths related to extreme weather events, changes in the prevalence and geographical distribution of food, water-borne illnesses and infectious diseases, and threats to mental health (Centers for Disease Control and Prevention, 2022).

As shown by numerous climate change research studies, these problems will only worsen as global temperatures continuously rise, accompanied by related radical environmental shifts, and cause downstream negative distinct changes in many species that will only cause problems for the entire world.

Climate Change and Marine Ecosystems

The rise of sea levels is one of the many consequences of climate change. Sea levels increase at around 3 millimeters per year, the total increase being estimated to be 65 centimeters by 2100 (Nerem et al., 2018). This rise in sea levels is caused by two main factors: the melting of ice glaciers and the volume of water expanding to the warmth of water (Lindsey, n.d.). These two factors stem from climate change, or more specifically, global warming. This constant rise of ocean levels will cause catastrophic issues for many species of animals currently and will only continue to grow in the future.

While this devastating consequence affects all marine creatures, it is particularly detrimental to many coast-reliant creatures, such as sea turtles and sea birds. Rising sea levels have significantly affected the life cycle of sea turtles as they change their nesting beaches, often by flooding or shrinking them. Changes in both the spatial and temporal makeup of their nesting sites make sea turtles, including green turtles and leatherback sea turtles, particularly vulnerable (Van Holle et al., 2019). Using digital elevation models and projections of field data and sea level rise, it has been predicted that, under mild climate change scenarios, 100% of sea turtle nesting habitats will be flooded and some sea turtle nesting rookeries may completely vanish (Rivas et al., 2023). Sea turtles' ability to reproduce and the ability of their hatchlings to survive is likely to be reduced because of this increased vulnerability of their habitats.

Shorebirds and seabirds are greatly affected by the rising sea levels. This is because of their reliance on coastal marine habitats (Van Holle et al., 2019). Firstly, because many have foraging sites around coasts, their hunting has become limited by rising sea levels. Additionally, because many of these species of birds lay their eggs on beaches, many of their nests are flooded and destroyed by rising sea levels (Van Holle et al., 2019). This subsequently leads to a great decline of these seabirds and shorebirds and failure to will clearly lead to a loss of population and possibly endangerment.

Ocean acidification, another effect of climate change, has great ramifications on marine ecosystems as well. Ocean acidification is caused by the increasing levels of carbon dioxide (CO_2) admissions. Due to the greater amount of CO_2 in the air, the ocean absorbs the CO_2, which is the causes decreased levels of pH in the water (Godbold & Calosi, 2013). This decrease in pH is troubling for many marine species, especially calcified animals such as mollusks and coral as the high acidity rate weakens their calcified bodies (i), making them more

vulnerable to predators. Ocean acidification may affect the overall ecology as well, as many species less susceptible to its effects may dominate over those that are (Kroeker et al., 2013). This could cause major imbalances in the food chain and many other issues.

Climate change has also led to a significant and quick rise in the average global temperature to 69.98ºF (21.1ºC) as of April 2023, over a degree higher than the average global temperature from 1982-2011, which was 68.72ºF (20.4ºC) (Pappas, 2023). This can cause marine heat waves that affect around 48% of the global oceans, as it is believed that the ocean absorbs about 90% of excess heat caused by the planet warming. This poses many threats to countless marine species, by causing harsher storms, changes in habitat and the overall ecosystem. Marine heatwaves cause coral bleaching as well: when the important algae *Zooxanthellae*, the organism that provides food and color to the coral, experiences an increase in temperature, it will leave the coral, resulting in the bleaching effect (Climate Central, n.d.). Prolonged coral bleaching leads to physiological damage and high levels of mortality in the corals (Hughes et al., 2017). Overall marine biodiversity has been shown to level off or decline as the global temperature has warmed as well (Chaudhary et al., 2021).

Furthermore, the increase in heat causes problems that affect the life cycles, migration behaviors, and even entire food webs of marine species (Albouy et al., 2020). Many marine mammals, such as Bryde's whales and white-beaked dolphins, have exhibited radically different spatial ranges in response to global temperature increases and ocean warming. This change in spatial range alters the distribution of these mammals and alters the life cycles of prey of marine organisms and migratory species which can affect reproductive success and overall survival rates of marine mammals (Albouy et al, 2020). In the case of certain species of wild salmon, climate change has caused a drop in spawners, which may cause their extinction (Crozier et al., 2021), alter their ecosystems and impact food supplies.

Ramifications of Climate Change in The Arctic

Perhaps the most affected ocean region is the Arctic. The Arctic has suffered from heating around two times more than other parts of the ocean (Miller, 2023). Furthermore, it is commonly known that ice caps and glaciers are melting due to the increase in temperature, which is one of the leading causes of rising sea levels. Large amounts of melting ice have also caused the release of many harmful substances, such as contaminants and microplastics, that have resided in the permafrost (Miller, 2023). Similarly, glaciers melting earlier and faster than previously recorded also causes many imbalances in the nutrients and particles of the oceans, as the melting leads to changes in carbon and nutrient turnover. This shift in nutrients within the ocean leads to glacier algal blooms that further impact carbon and nutrient cycling (Williamson et al., 2019). This bodes ill for countless organisms living in the Arctic Ocean.

The heating ocean and its resulting nutrient imbalances has caused many fish species to decrease in body size. Furthermore, these changes in the organisms have caused many domino effects, such as a difference in prey distribution, changes in behavior, and difficulty breeding for many species, which further causes much damage to the ecosystems in the arctic oceans (Florko et al., 2021). For example, the melting of the ice-caps has destroyed many of the habitats for many species that rely on it for breeding, and many species have shifted in their hunting habits and patterns due to this effect.

The ringed seal is one of the most affected by climate change in the Arctic biome. Due to the melting of ice, many of their breeding sites and lairs have decreased. This causes them to be under great pressure and stress from the effects of climate change, as they heavily rely on the ice for these purposes. Ringed seals, along with other species, need the ice for nesting sites for their pups, along with it being their breeding site (Florko et al., 2021). Furthermore, one of its primary prey sources, the arctic cod, has suffered from the effects of climate change as well for similar reasons.

The arctic cod, among many others, rely on the sea ice for breeding and foraging. The arctic cods' main source of food is plankton, which resides in the sea ice. However, because of the reduction of ice, the

arctic cod suffers from consuming less phytoplankton, less breeding, and losing much of its habitat (Florko et al., 2021). This issue affects arctic cod and many others, similarly to the ringed seal. This issue is detrimental to additional species that heavily rely on the ice, and as the ice continues to melt, many of these species will be on the precipice of extinction or severe endangerment. Issues with one category of species will only threaten all the other species of an ecosystem, as all of ocean life is connected.

Climate Change and Terrestrial Species

As climate change deals detrimental consequences to the oceans, there are also deleterious effects on life on land. These harmful effects range from overheating, severe changes in weather, disruptions in life cycles, changes in species interaction, and the potential spread of diseases. If these effects continue to worsen over time, as predicted by many models, many species will face extinction or new health threats, there will be collapse in ecosystems, and countless more consequences.

The overheating world already has countless detrimental issues of its own. The world has gotten around 2ºF hotter on average compared to the 1800s and is projected to increase by 4.8ºF by the end of the century (IFAW, n.d.). Terrestrial species facing this issue have many problems, such as the loss of habitat. The heat has affected food sources and vegetation and many animals are unable to effectively forage vital resources, and many are forced to relocate entirely (State of the Planet, n.d.). These factors could cause many animals to go into endangerment or, worse, extinction.

Climate change, specifically global warming, has also detrimental effects on many species' life cycles. Many hibernation cycles have been disrupted as many animals are woken earlier than usual due to the increase in temperatures. In many cases, this causes many animals to wake up earlier than their prey, which causes them to suffer and even starve. The pygmy possum hibernation cycle is one example of being disrupted to wake up too early (State of the Planet, n.d.). This causes them to wake up earlier than their prey, the bogong moth, causing many to starve (State of the Planet, n.d.). Similarly, the roe deer have fertility rates by day, which are now occurring after the first flowers, which are now blooming earlier than usual. This disorientation has caused a lack of food for the roe deer, which leads to declines in the roe deer's populations (State of the Planet, n.d.).

In another direction, dealing with disrupted life cycles, this heat has caused disorientations in the birthing stages. Many species are birthing earlier than the norm, which makes survival for their offspring a lot more difficult. In one case in a Dutch park, a species of caterpillar emerged earlier than usual. Their predators, the great tit, are not matching the emergence of these caterpillars in laying their eggs. Because their chicks now have much fewer options for prey, the species have been in a state of decline (State of the Planet, n.d.). These are just a few cases of disruptions in the life cycle. Many more animals suffer from these disorientations, and many could face extinction if they continue (IFAW, n.d.).

Natural Disasters

Changes in weather have been shown to have detrimental effects on terrestrial life. Due to climate change, weather patterns have taken dramatic extremes in that they have become mainly acutely hotter and, in some cases, even colder in some regions (Thomas, 2023). Furthermore, natural disasters such as storms, droughts, and wildfires have become much more severe and catastrophic due to the changes in climate (Earthjustice, 2023). While this greatly affects the human population, it also has ruinous effects on terrestrial life (Earthjustice, 2023).

For extreme storm events such as hurricanes, some animals have adapted to survive the storm by taking shelter, burying into the ground, or retreating into their nests or to safer locations (National Geographic Education Blog, 2018). However, despite their survival, a large part of their lives may be disrupted. One major negative effect that these species cannot escape from is the removal of many food sources. Specifically, storms

generally destroy fruits, berries, and nuts, which causes many animals to be left with minimal food sources (National Geographic Education Blog, 2018). Squirrels are one of the worst affected, as their main source of nuts is lost during these powerful storms (National Geographic Education Blog, 2018). Furthermore, many oysters are wiped out during these storms, causing many birds that rely on them as a food source to be killed off as a result (National Geographic Education Blog, 2018). While storms of these kinds are natural and have occurred forever, climate change causes them to become a lot more powerful and devastating, consistently leaving animals to suffer from the effects.

Climate change has caused droughts to become more frequent, extreme, and lasting. The rising temperatures cause higher frequencies of evaporation, which takes away the moisture and only worsens the drought (Wehner et al., 2017). Climate change also shifts the precipitation patterns and frequencies in certain areas (Wehner et al., 2017). Climate change has increased the frequency and intensity of heavy precipitation in much of the Northern Hemisphere (Min et al., 2011). For the most part, climate change causes warmer winters, which means snowfall has majorly decreased in some areas, causing droughts to become even drier, leading to devastating downstream effects on vegetation and animal populations (Wehner et al., 2017).

Animals in areas where droughts are prevalent are affected most by the lack of water. All animals rely on water, and a lack of it causes animal populations to decrease in numbers (Messmer, 2021). For example, animals that rely on water for nesting sites, such as young deer and elk, become much more susceptible to predators due to the lack of water (WWF.CA, 2020). Beavers, muskrats, and more animals that rely on water for their habitats have a much more difficult time finding and creating habitats due to the lack of water. Without enough water, they cannot build the homes they need to survive. Droughts also causes a lack of food for animals, as plants deprived of water shrivel up and may die of malnourishment. A lack of food causes animals also to become malnourished and causes severe casualties and reductions in population sizes.

Droughts force animals to relocate as they are left to search for more water-sufficient locations (Messmer, 2021). This could further lead to unusual human and animal interactions. As they search for more resources, this leads them to find resource-rich urban locations, causing animals to come into contact with houses and create situations that would harm both parties. This may also cause animals to move more frequently onto roadsides and cause more collisions and animal deaths (Messmer, 2021). Those animals suffering from droughts, unable to find new sources of water, and continually suffering from little to no water intake will be killed off in a variety of ways.

Wildfires have also become increasingly prevalent as climate change progresses. A wildfire is a natural disaster or phenomenon, which is when a forest catches fire and causes mass damage to it. The forest catches fire for a multitude of reasons, such as strong winds causing sparks and lightning, and around four out of 5 of these fires are caused by humans (National Oceanic and Atmospheric Administration, n.d.). While natural forest fires are a very natural phenomenon that benefits wildlife by providing a "required reset," they have become significantly more devastating, lasting, and severe due to climate change. The warming weather causes many forests to become drier and warmer, which gives the fires optimal conditions to burn (National Oceanic and Atmospheric Administration, n.d.).

In the events of these fires, many animals have adapted to escape and even thrive off of the new burnt environment (National Geographic Education, n.d.). However, many animals that are not mobile enough such as slow, young, or small animals, may suffer from the flames and suffer fatal burns as a result (National Geographic Education, n.d.). This scenario worsens megafires, which are occurring at higher frequencies as climate change advances. A megafire, a once rare, now common phenomenon, is a wildfire that has grown to an extremely large effect beyond acre sizes (National Geographic Education, n.d.). Megafires can cause entire habitats to change, entire species to see severe decreases in population numbers, and for the entire geography of an affected area and its biodiversity to change. Forest fires and megafires also emit high levels of greenhouse gases, which is one of the leading causes of global warming, further contributing to the cycle of climate change and harming all forms of life.

Climate Change and Human Life

Human activity over the past hundreds of years has been the most significant driver of climate change. While saying that humans are the most significant species being affected by climate change is not only subjective but also likely untrue, they are impacted significantly in several different ways. Human life is reliant on and benefits from many different species, ranging from microbes to animals. As a result, when other species are affected by climate change, humans are indirectly as well. They are also directly affected as climate change has been shown to impact human health and diseases.

Food safety and availability are both threatened by climate change. Aflatoxins are a highly toxic bacterial pathogen that can cause chronic and acute toxicity in humans. Using predictive models and climate change data, it was concluded that aflatoxin contamination of maize kernels will likely become more prevalent and have disastrous consequences on maize production, affecting the safety of food products that humans eat directly as well as feed used to feed animals that humans consume (Battilani et al., 2016). Similar models have predicted that great variability in yield size and quality of wheat would be seen as a result of higher temperatures, changes in precipitation and drought conditions which are all side effects of climate change (Shayanmehr et al., 2020).

The CDC highlights existing health threats and diseases that result from climate change, as well as predicts that new ones will emerge (Centers for Disease Control and Prevention, 2022). While the exact threats will vary by region, it is likely that allergies, stress-related disorders, vector-borne diseases, respiratory diseases, food and waterborne diseases and more may become more common. In Europe, climate change and rising temperatures alter the incubation period of pathogens that are carried by vector organisms such as ticks and mosquitos. Pathogens and their vectors may be able to survive in new geographical areas, affecting new host organisms, as temporal changes occur (Semenza & Suk, 2018). In Quebec, there has been a rise in seasonal allergic rhinitis due to warmer temperatures and higher carbon dioxide levels that stimulate pollen production of many allergenic plants (Demers & Gosselin, 2019). The growing season of these plants lasts longer due to increased temperatures as well, leading to increased human exposure and allergy development.

Conclusion

Climate change has devastating effects on all forms of life, big and small, regardless of what environment they live in. Various examples from a range of scientific studies emphasize the idea that a negative effect on one organism is a negative effect on all, as different organisms are all so deeply connected, regardless of if they live in the ocean or on land. Climate change only shows signs of worsening; heat levels are increasing, water levels are increasing, natural disasters are increasing, and many more consequences that threaten the survival of many animal, plant, and microbial species. Without appropriate mitigation measures, climate change will continue to progress and likely lead to mass extinction events, harsher living conditions and ultimately, the end of life as we know it.

Acknowledgments

I would like to thank my advisor for advising me on this topic and providing me with the resources to research it.

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