Assessing the Effects of Climate Change on Terrestrial and Marine Flora and Fauna: A Review

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ASSESSING THE EFFECTS OF CLIMATE CHANGE ON TERRESTRIAL AND MARINE FLORA AND FAUNA: A REVIEW

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Abstract:

Climate change is possibly the most pressing environmental threat of our time, with its impacts cascading across the globe and affecting all aspects of life, including flora and fauna. This review aims to provide a comprehensive overview of climate change's negative impacts on terrestrial and marine ecosystems, highlighting key areas of concern and potential consequences. Rising temperatures, altered precipitation patterns, and extreme weather events have several negative impacts on terrestrial ecosystems and shifts in species distribution and range. in addition to changes in plant phenology and productivity and increased vulnerability to disease and invasive species. In marine ecosystems, increased atmospheric CO2 and water temperature lead to ocean acidification, coral bleaching, and reef degradation. Moreover, deoxygenation, sea level rise, and changes in fish distribution and abundance. The negative impacts of climate change on plants and animals have significant consequences for human well-being. Habitat loss and species extinction threaten biodiversity, food security, and ecosystem services like water purification and carbon sequestration. Additionally, climate change-induced disruptions to marine ecosystems can impact coastal communities that rely on fisheries and tourism for their livelihoods. Understanding the negative impacts of climate change on flora and fauna is crucial for developing effective mitigation and adaptation strategies. This includes reducing greenhouse gas emissions, investing in renewable energy sources, protecting, and restoring natural habitats, and implementing sustainable land and water management practices. By acting now, we can protect our planet's biodiversity and ensure a healthy future for all living things. The impacts of climate change are complex and vary depending on the specific ecosystem and species. There are also potential positive impacts of climate change, such as the expansion of suitable habitats for some species in certain regions.

Keywords: Climate change, Food security, Flora, Fauna, Ecosystems, Marine ecosystems, Terrestrial ecosystems, Biodiversity, Environmental protection.

Introduction

Climate change is a pressing global issue that carries significant consequences, posing a threat to the future of our planet therefore, our planet faces a major threat: the impact of climate change. As the Earth warms, its delicate ecosystems are already feeling the strain, and things are only expected to get worse. Each ecosystem is unique, with its location, makeup, and natural controls (Seppälä et al., 2009). Climate change disrupts this balance through rising temperatures, unpredictable rain patterns, and extreme weather. This disruption destroys habitats, limits resources, and makes ecosystems more vulnerable to invasions and diseases. climate change and our need for food could wipe out up to 23% of natural habitats by

2080 (Beyer and Manica, 2020). Land use and climate changes have already robbed mammals, birds, and amphibians of 18% of their homes on average (Beyer and Manica, 2020). As animals are forced to adapt, migrate, or find new homes. This increases the chances of new and dangerous diseases emerging.

Marine ecosystems, like coral reefs, are on the front lines of climate change. Warming seas and increasingly acidic water threaten the delicate balance of life in these underwater worlds. As water temperatures rise, coral reefs expel the colorful algae they rely on, turning stark white in a process called bleaching.

Terrestrial ecosystems, including forests, grasslands, and tundras are battling climate change. As temperatures rise, the plants and animals that call these places home are forced to move or adapt. This disrupts the delicate balance of the ecosystem, making it harder for wildlife to find food and shelter. Population declines and even extinction for some species. Climate change already threatens nearly 11,000 species listed as vulnerable or endangered (IUCN, 2021). However, the impact isn't limited to wildlife. In addition to the direct impacts on fauna and flora, climate change also has far-reaching consequences for human societies. Changes in ecosystem services, such as water availability, crop productivity, and disease transmission patterns, can have significant socio-economic implications.

Climate change is a massive, global problem. It affects everything from our environment to our societies and economies. Scientists from many different fields are working together to find solutions (Adger et al., 2005; Leal et al., 2021; Feliciano et al., 2022). The Earth's temperature is rising fast – almost double the rate it was a century ago. Since 1880, the Earth's temperature has steadily been rising at a rate of 0.14 degrees Fahrenheit (0.08° Celsius) per decade. However, this rate has nearly doubled to 0.32 degrees Fahrenheit per decade. 2021 was one of the hottest years on record, and July 2023 holds the record for the hottest month ever. In 2021, the average surface temperature across oceans and land was 1.51 °F (0.84 °C) warmer compared to the 20th-century average of 57.0 °F (13.9 °C), and 1.87 ˚F (1.04 ˚C) warmer than the pre-industrial period of 1900. As a result, 2021 was recognized as the sixth warmest year (Lindsey and Dahlman, 2022), as depicted in Figure 1. It has been determined that July 2023 has been the highest worldwide average temperature of any month. These rising temperatures bring more extreme weather events and other risks that are becoming harder to manage. This escalation in climate-related and non-climatic risks will lead to more frequent interactions, giving rise to compound and cascading risks that pose greater challenges in terms of control and management (Moustafa et al., 2023a).

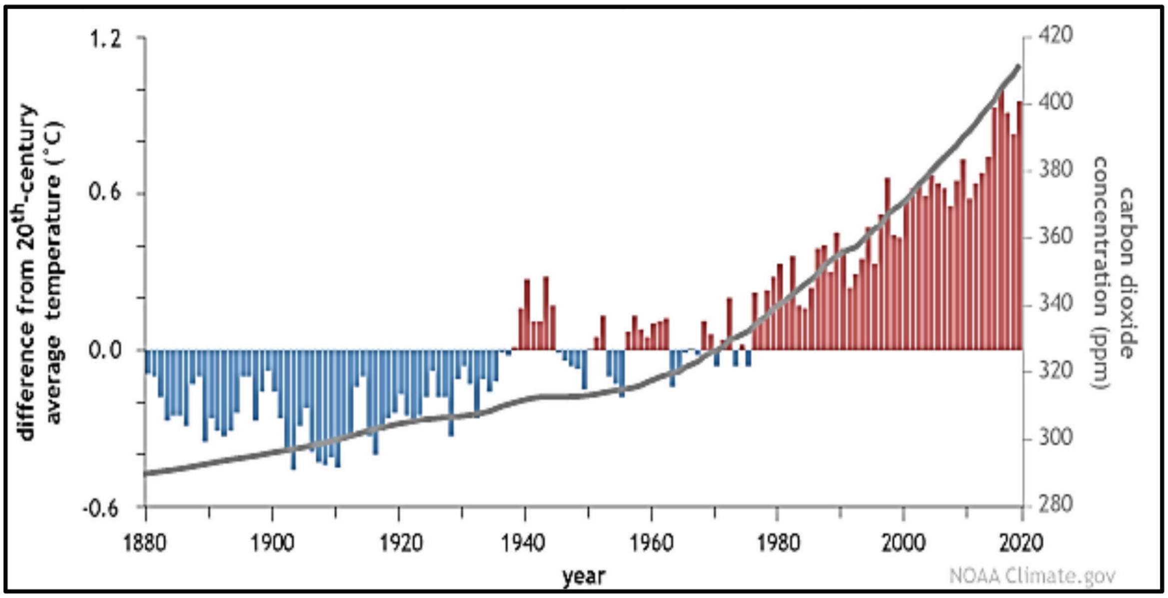

Figure 1: Yearly temperature compared to the twentieth-century average (red and blue bars) from 1880–2019, based on NOAA NCEI data, plus atmospheric CO2 concentrations (grey line): 1880-1958 from IAC, 1959-2019 from NOAA ESR (Image credit: Original graph by Dr. Howard Diamond (NOAA ARL), and adapted by NOAA Climate.gov.).

Rising temperatures are already damaging ecosystems around the world and scientists predict things will only get worse. The exact effects depend on where an ecosystem is, what it's like naturally, and how well it can handle change regarding the presence of specific factors that regulate the extent of these changes (Seppälä et al., 2009). Climate change isn't just an environmental issue – it's a complex problem that touches everything from nature to society and the economy. Scientists from many fields are working on solutions (Adger et al., 2005; Leal et al., 2021; Feliciano et al., 2022). The Earth's warming is causing ice sheets in Greenland and Antarctica to melt at an alarming rate. Data from NASA (from NASA's Gravity Recovery and Climate Experiment) shows these ice giants are losing billions of tons of ice each year where, Greenland lost an average of 279 billion tons of ice per year between 1993 and 2019 and the Antarctic lost around 148 billion tons of ice per year (Velicogna et al., 2020). This melted ice raises sea levels, threatening coastal areas around the world. In addition, some of the most well-known domestic and international consequences of climate change include unpredictable weather patterns and the consequent heightened sea level rise as shown in (Figure 2) (Lipczynska-Kochany, 2018; Murshed and Dao, 2020; Michel et al., 2021).

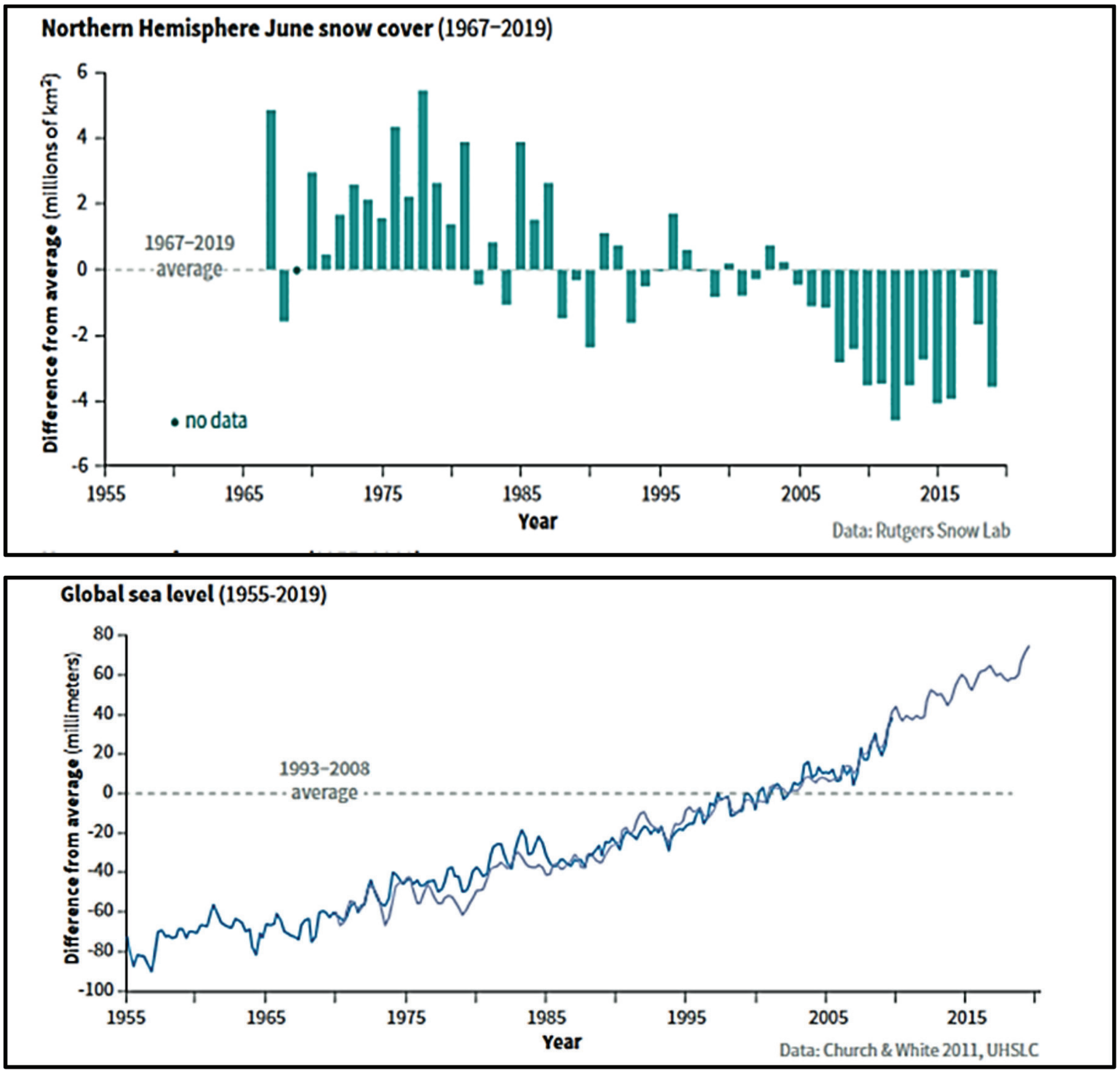

Figure 2: A large amount of observational evidence besides surface temperature records shows that Earth's climate is changing. For example, additional evidence of warming can be found in the decrease in June snow cover in the Northern Hemisphere, and the increase in global sea level. Source: NOAA Climate.gov

Human activities have become the primary driver of climate change over the past two centuries. This impact is intensified by the greenhouse effect (Bayer et al., 2015-2020). While natural events like volcanoes were once thought to be the main culprits of greenhouse gas emissions (CO2, methane, nitrous oxide, and water vapor), recent studies (Murshed et al., 2020-2022, Hussein et al., 2020, Sovacool et al., 2021, Usman and Balsalobre-Lorente, 2022) have shown that human actions are disrupting the Earth's climate balance. This human-induced climate change has emerged as the most pressing environmental crisis of the past decade, linked to industrialization, globalization, economic growth, population increase, and deforestation (Chen et al., 2015, Cloy, 2018).

Human activities such as economic growth, increased energy consumption, and waste management practices have led to a surge in greenhouse gas emissions. These gases come from various sources including landfills, agriculture, and industrial processes. The combination of industrialization, fossil fuel burning, and other human-induced factors has caused global temperatures to rise, threatening our planet. Climate change is altering precipitation patterns worldwide, affecting the amount and timing of rainfall. Regions like Asia are expected to experience longer monsoon seasons, while parts of Africa will become increasingly arid, leading to significant changes in overall precipitation. (Shongwe et al., 2009; Gebrechorkos et al., 2019).

Climate change is a serious threat to the health and balance of both land and water ecosystems. As the climate continues to shift, it will drastically alter the makeup and productivity of these environments, leading to unpredictable and potentially harmful consequences. Protecting biodiversity is essential as it acts as a safety net against these disruptions (Figure3). Consequently, biodiversity protection is necessary because biodiversity serves as nature's insurance policy against disasters.

Climate change is not just an environmental issue; it has severe social and economic consequences. Disruptions to ecosystems caused by climate change can lead to food shortages, water scarcity and crises, displacement of communities, and economic instability. This review will explore the negative effects of climate change on various ecosystems and how these impacts threaten food security and human health. By understanding the causes of climate change and taking action to reduce its effects, we can protect the delicate balance of ecosystems of our planet and ensure a healthy future for generations to come.

Effect of climate change on biodiversity

Worldwide biodiversity is rapidly declining as a result of human activity (Jetz et al., 2007; Bellard et al., 2012; Fardila et al., 2017; Barlow et al. 2018). Scientists have published their analysis on threats to over 150,388 species, showing that over 42,000 might become extinct, frequently as a result of human activity. This is how the risk of extinction for plants

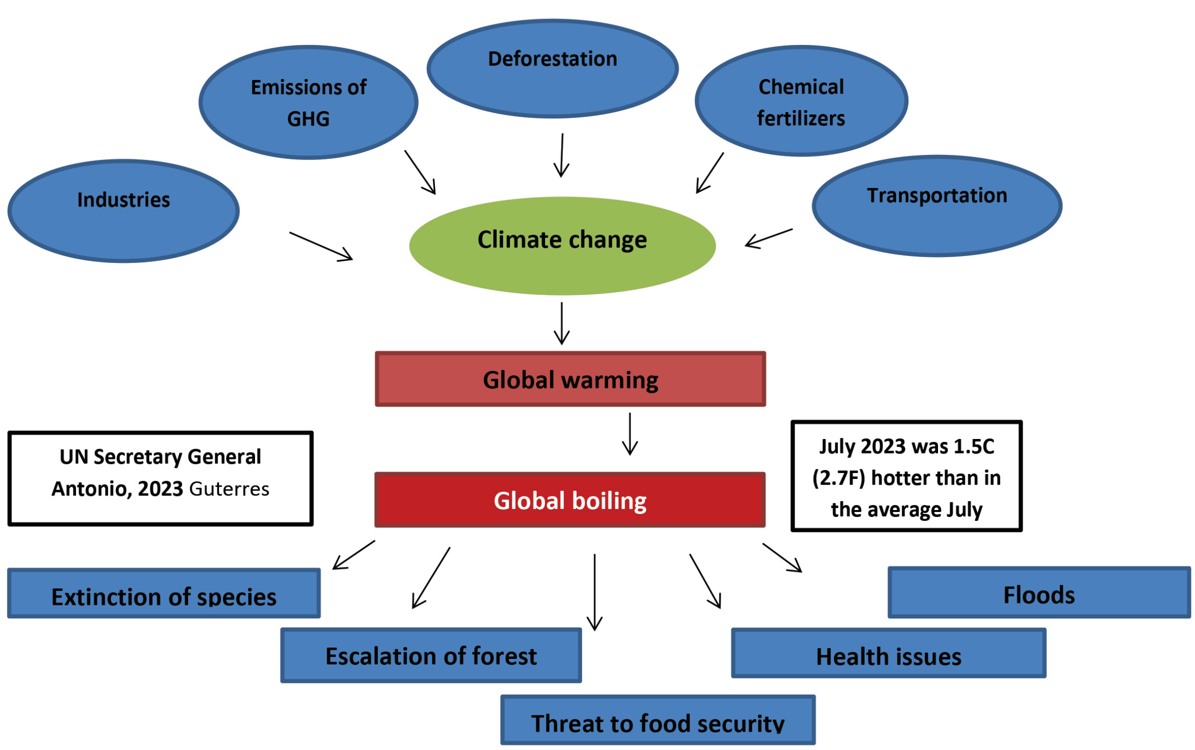

Figure 3: Impact of continuous anthropogenic activities in turning from the global warming era to the era of global boiling.

and animals is routinely assessed (IUCN red list, 2022). These five threats to biodiversity—invasive alien species, habitat modification, overexploitation, climate change, and extinction chains—are the main causes of the current loss of biodiversity (Brook et al., 2008; Guo et al., 2017; Sonwa et al., 2017). According to the IPCC assessment (IPCC, 2013), the global temperature and precipitation are expected to rise, and during the next 50–100 years, climate change is predicted to be one of the main causes of biodiversity loss.

Extreme weather events have clear and occasionally grave humanitarian consequences, but climate change is also having a variety of other effects on our planet's ecosystems and biodiversity. The expansion of species ranges through migration, changes in species compositions and interactions through adaptation, changes in resource availability, the spread of disease to new areas, modifications to protected area features, and shifts in ecosystem resilience are some of the effects of climate change on biodiversity (UNEP, 2007; Trew and Maclean, 2021). In addition, because of changes in temperature, precipitation, and flooding, climate change is placing additional strain on ecosystems and species. In addition to population size and age structure, decomposition, nutrient cycling, water flows, species composition, and interactions, it directly affects the growth and behavior of organisms (Trew and Maclean, 2021). Monzón et al. (2011) observe that climate change has caused the extinction of 19 species, and according to the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species, climate change threatens 4161 species, include 33% at risk from climate change-induced habitat alteration, 29% due to temperature extremes, and 28% due to drought (IUCN 2016). According to a study published in Nature by (Thomas et al. 2004), climate change could lead to the extinction of over a million terrestrial species in the next 50 years.

Africa is renowned for its rich biodiversity, hosting countless unique and endangered species. However, this biological wealth is under increasing threat, with species populations declining rapidly. Climate change poses a significant risk to Africa's ecosystems and the diverse life they support (Fouad et al. 2023). Research has shown that rising temperatures and changing precipitation patterns are already impacting biodiversity and ecosystem services of plant (Lepetz et al. 2009; Guo et al., 2017; Sonwa et al. 2017; Matata and Adan 2018). For instance, studies in Cape Floristic Region of South Africa have revealed that numerous plant species are at risk of extinction due to climate change (Midgley et al., 2002) found that 11% of the species studied are at risk of extinction, and 42% of the species' modelled range sizes have shrunk under the projected climate-change scenarios. Additionally, the endemic Ethiopian wolf (Canis simensis) is struggling to adapt to the extended dry periods and shrinking availability of water and other resources by changing climate conditions (Sintayehu, 2018).

Many species are under threat from rapidly changing climate conditions, which have already resulted in widespread local extinctions (e.g. Albano et al., 2021). Under the highest greenhouse gas emissions scenario, up to 50% of species could lose their suitable climatic circumstances by 2100 (Warren et al., 2018), while it is anticipated that the current global biodiversity redistribution (Pecl et al., 2017) will worsen. For instance, it is predicted that 29% of birds and 35% of mammals will have more than half of their climatic niche in nations where they are not already found (Titley et al., 2021).

Impacts of climate change on terrestrial ecosystems

Terrestrial plant communities comprise forests, woodlands, shrublands, and grasslands. They sustain important ecological functions like carbon sequestration and water supply, in addition to commercial operations like grazing and forestry (Daily, 1997). Prioritizing biodiversity conservation initiatives is essential to reducing these detrimental effects. The resilience of fauna and flora ecosystems in the face of climate change can be preserved by implementing sustainable land and water management techniques, lowering greenhouse gas emissions, and protecting and restoring habitats. The worldwide biogeochemical cycles of carbon, oxygen, water, and nitrogen are significantly influenced by plant communities and have a knock-on effect on the oceans, atmosphere, and climate. Because the distribution of animals on land is frequently determined by the spread of plants, plant community dynamics have an impact on biodiversity. Climate change-induced changes in the Earth's flora, as well as associated faunal changes, may have played a role in the evolution of the human lineage (Vrba et al., 1995; Scholz et al., 2007). As a result, human populations have a vested interest in understanding the implications of rapid global change on terrestrial plant groups.

Climate change and environmental degradation are driving a dramatic decline in land mammal and bird populations (Badr and Elshazly, 2024). In the past half millennium, roughly 150 bird species have vanished, and today, one in eight species faces extinction (Mooney et al., 2009). The crisis is intensifying, with climate change exacerbating the plight of over 10,967 species already listed as threatened by the IUCN. The Bramble Cay melomys, a mammal native to the Great Barrier Reef, stands as a tragic emblem of this crisis. Its extinction, directly attributed to rising sea levels, marks a stark warning of the consequences of unchecked climate change (IUCN, 2021).

As a result of climate and environmental changes, the population of land mammals and bird species is decreasing. Approximately 150 bird species have been lost in the previous 500 years, and one in every eight species is now threatened with extinction (Mooney et al., 2009). Climate change currently affects about 10,967 species on the IUCN Red List of Threatened Species, increasing the probability of their extinction. The mammal (Bramble Cay melomys) (Melomys rubicola) is the first mammal that reported to have been extinct as a direct result of climate change. Earlier found only on the island of Bramble Cay in the Great Barrier Reef, its habitat was damaged by rising sea levels (IUCN, 2021). Songbird migration patterns are undergoing significant changes. A long-term study (Buskirk et al., 2009) revealed that 78 bird species initiated their spring migration earlier over a 46-year period, while autumn migration remained relatively consistent. The ability of plants, birds, and animals to adapt to these shifts varies widely, influenced by their unique evolutionary history and ecological roles (Dawson et al., 2011).

Terrestrial species with a wide tolerance for temperature variations can adjust their geographic range (Mohamed et al., 2023). However, emblematic and less adaptable species are at risk due to habitat loss and extreme weather conditions (Mooney et al., 2009). Reduced rainfall and overgrazing by both wild and domestic animals are accelerating soil degradation. Freshwater ecosystems are facing a crisis as rising temperatures and the disappearance of wetlands and coastal lagoons threaten numerous aquatic species

(Willets et al., 2010). Clear evidence of human-induced climate change is apparent in various ecological systems. For instance, butterflies are emerging earlier in the spring (Kearney et al., 2010), fly genetics are evolving (Umina et al., 2005), and plant leaf shapes are changing (Guerin and Lowe, 2013). Forests in Australia are experiencing significant disruptions, and the extinction of a mammal in the Torres Strait highlights the severity of the issue (Waller et al., 2017; Harris et al., 2018). Agriculture is also impacted, with vineyards adjusting harvest times to accommodate shifting climate conditions by anthropogenic climate change (Jarvis et al., 2017; Aly et al., 2022).

Land-use change, and climate change pose severe threats to biodiversity. A study by Newbold (2018) employed two modeling approaches to forecasting the isolated and combined impacts of these factors on terrestrial vertebrate populations under four different scenarios. The research predicts that climate change will emerge as a primary driver of biodiversity loss in the coming decades, potentially surpassing the effects of land-use change by 2070. Considering both pressures, the study estimates an average cumulative species loss of 37.9% within vertebrate populations by the end of the century under a "business as usual" trajectory. Tropical grasslands and savannahs are projected to experience the most significant combined impacts of these environmental challenges.

Manes et al. (2021) found that endemic and native species are significantly more susceptible to the negative effects of climate change than introduced species across various ecosystems, geographic regions, and taxonomic groups. Endemic species, in particular, are highly vulnerable. Conversely, introduced species are projected to experience neutral or even beneficial impacts from changing climate conditions. The potential increase of introduced species, coupled with the vulnerability of endemic-rich areas, poses a significant threat to biodiversity. While there is general agreement that endemism amplifies species' risk to climate change, the specific magnitude of this vulnerability, as quantified by Manes et al. 2021, is notable the magnitude of this vulnerability was 6% higher for endemic compared to non-endemic species.

Impact of climate change on aquatic systems:

Climate change is impairing the resilience of aquatic ecosystems. Mitigating its severe impacts will require human intervention to reduce other environmental pressures and bolster these systems' ability to adapt (Prakash, 2021). Global warming is disrupting delicate ecological balances, potentially driving some species to extinction while benefiting others. As biological rhythms are thrown off by rising temperatures, the natural world is struggling to keep pace. Projections indicate a global temperature increase of 1.5 to 5.8 degrees Celsius by 2100 (Houghton et al., 2001), exacerbating these challenges.

Rising water temperatures will dramatically alter the productivity of aquatic ecosystems. While warmer conditions can boost biological activity, this often comes at a cost. Undesirable or even harmful species may thrive in these warmer waters. For instance, in smaller lakes, increased surface temperatures can lead to the decline of large predatory fish that prefer cooler environments. This imbalance can trigger excessive algal growth, deteriorating water quality, and endangering human health (Prakash, 2021). Climate change is a pervasive force affecting both marine and freshwater habitats.

Marine ecosystem:

Marine ecosystems are vital to the health of our planet, influencing both marine and terrestrial environments (Townsend et al., 2003). However, climate change is severely impacting these crucial ecosystems (Brierley and Kingsford, 2009). Global warming has caused widespread damage, including habitat loss, invasion by alien species, rising temperatures, ocean acidification, pollution, and nutrient overload (Mooney et al., 2009).

Jackson (2008) reports a catastrophic decline in marine megafauna, with populations of sharks, blue whales, oysters, seagrass, and coastal wetlands plummeting by 80%, 90%, 65%, and 67% respectively due to changing climate patterns. Moreover, Polovina et al. (2008) observed a significant expansion of nutrient-poor ocean waters by 6.6 million square kilometers over two decades, linked to global warming.

Carozza et al. (2018) predict a substantial 30% reduction in global fish biomass by 2100. This decline is attributed to decreased energy availability for larger marine life due to nutrient limitations, shrinking phytoplankton, and temperature-related mortality, which collectively accelerate growth rates

Mangrove, seagrass, and salt marsh ecosystems are under increasing pressure from both local and global stressors. Human activities, including resource exploitation, pollution, tourism, coastal development, and aquaculture, have exacerbated threats to mangroves in particular (Moustafa et al., 2023b). While mangroves are disappearing globally at a rate of 1-2% annually, the risk posed by rising sea levels is growing. Up to 20% of mangrove forests could vanish by 2100 (Danovaro et al., 2008). Although mangroves can often adapt to sea-level rise by inland migration, this can harm other coastal habitats like salt marshes, which provide essential ecological services (Satyanarayana et al., 2013).

Coral reefs are facing unprecedented challenges due to warming ocean temperatures, leading to frequent coral bleaching and mortality events. These conditions, combined with local pressures like habitat destruction, overfishing, and ocean acidification, are causing widespread coral reef decline. By 2050, complex coral ecosystems may become rare (Baker et al., 2008). The loss of coral reefs in the Coral Triangle threatens food security for over 100 million people (Mooney et al., 2009). Marine heatwaves (MHWs) are occurring more frequently in all oceans, causing significant damage to marine ecosystems. Cheung and Frölicher (2020) highlight the importance of considering MHWs when assessing climate change impacts. These extreme events can exacerbate the effects of rising ocean temperatures, leading to dramatic changes in fish populations and distribution in regions like the northeast Pacific

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1- Freshwater ecosystem:

Freshwater ecosystems are critical for global biodiversity and ecosystem services. Freshwater ecosystems are sensitized to the impacts of environmental alteration, which may cause irreversible harm to these ecosystems. Within the next few decades climate change will have many considerable ecological impacts on most of the freshwater ecosystems as per the current climatic predictions. One of the most major impacts to be caused by climate change will be on freshwater flow regimes.

Freshwater habitats may be the most threatened ecosystems in the world. They are biologically diverse and serve important roles in providing ecosystem services on a large scale (Mooney et al., 2009). Many species within these fragmented habitats have limited ability to disperse as the environment changes, water temperature and availability are climate dependent, and many systems are already exposed to various anthropogenic stressors such as contaminants, pollutants, and noises (Woodward et al., 2010).

Climate change's impact on inland aquatic ecosystems will range from the direct effects of the increase in temperature and carbon dioxide concentration to indirect effects through changes in the hydrology resulting from the alteration in the regional or global precipitation regimes and the melting of ice cover (Anonymous, 2007). Climate change affects freshwater ecosystems not only by increased temperatures but also by changed river flow regimes. However, with one exception, transferable quantitative relations between flow alterations and ecological responses have not yet been derived (Döll and Zhang, 2010). Most endemic fish go extinct due to increased warming and the lack of northern migration (Matthews and Zimmerman, 1990). Thus, climate change affects freshwater ecosystems directly or indirectly and the communities that are present within these ecosystems.

The causes of threats to global freshwater biodiversity can be observed in terms of over-exploitation (primarily affecting vertebrates such as fish, reptiles and some amphibians), water pollution, flow modification, destruction or degradation of habitat, and invasion by exotic species and these causes in the declination of freshwater biodiversity from microbes to megafauna (Dudgeon et al., 2006). Environmental changes occurring on a global scale, such as nitrogen deposition, warming, shifts in precipitation and runoff patterns are all major threats to freshwater systems (Woodward et al., 2010).

2.1 Effects of Climate Change on Lakes

Climate change is significantly altering lake ecosystems globally. Rising air temperatures are driving increases in water temperature and evaporation rates, affecting lakes in both temperate and tropical regions (Zinyowera et al., 1998; Schindler, 2001). As a result, some lakes may transition from outflowing to inland water bodies with increased salinity (Schindler, 2001). Furthermore, climate-induced droughts and reduced groundwater recharge can contribute to lake acidification. Groundwater often neutralizes acidity, and its decline weakens a lake's ability to buffer against acidification (Schindler, 2001).

The overall increase in lake temperatures imposes higher metabolic demands on biotic communities. Cold-water fish, in particular, may encounter challenges in accessing prey populations as a result. While higher temperatures may offer slightly more favourable conditions during winters, these benefits are insufficient to compensate for losses experienced in other seasons (Shuter and Meisner, 1992).

In lakes that are not limited by nutrient availability, the relative abundance and density of fish may exhibit variations. Additionally, overall fish productivity is anticipated to increase, leading to potential increases in fish harvest (Tyedmers and Ward, 2001). Although much of the research has focused on a limited number of fish species, adverse impacts on a single species can have cascading effects on the entire population.

To illustrate this, a case study conducted in a lake in Wisconsin, USA, demonstrated the consequences of a summer kill event involving planktivorous herring. This event resulted in a 50% reduction in zooplankton predation, leading to an increase in larger zooplankton and intensified zooplankton grazing. Consequently, a substantial decline in phytoplankton abundance was observed (Kitchell, 1992).

2.2 Effects of Climate Change on Rivers

Depending on latitude, the consequences of climate change on rivers are predicted to differ widely. Temperature changes will mostly influence temperate rivers and lakes, although changes in precipitation timing and quantity may have a significant impact on tropical rivers. An increase in atmospheric temperature will intensely affect water temperature in many rivers because of the high surface-to-volume ratio (Tyedmers and Ward 2001). Extreme flooding events and landslides have the potential to disrupt river courses and remove significant woody debris (Carpenter et al. 1992). Where precipitation decreases, stream flow volume may also decrease, and reductions in runoff will reduce the concentrations of organic matter and DOC in rivers. At headwaters, warmer water and decreased oxygen show negative effects on the eggs and larvae placed there (Carpenter et al. 1992). Changes in water level have a stronger effect on river fishes than by changes in temperature (Hassan et al., 2020). As the floodplains dry up due to closer of the rainy season, members of the "whitefish" guild (sensitive to reduced oxygen levels), move back to the main river channel. "Blackfishes", that is more tolerant of, or adapted to, low oxygen levels, remain in marginal floodplain habitats that become disconnected from the river and may even dry up completely (Welcomme, 1979).

2.3 Effects of Climate Change on Wetlands

Wetlands are in particular vulnerable to the effects of climate change. As temperatures rise, rainfall patterns alter, evapotranspiration rises and water regimes are changed. A rise in atmospheric temperature will lead to the drying of many wetlands unless the rate of precipitation balances the rate of evaporation. Ephemeral wetlands with no channelized flow in or out could disappear completely, particularly if precipitation declines and groundwater is withdrawn for domestic consumption (Hassan et al., 2020). Coastal freshwater wetlands are particularly receptive to intense high tides resulting from a rise in storm frequency; these high tides can carry salts inland to salt-resistant vegetation and soils and could lead to the dislocation of freshwater animals by salt-resistant species (Michener et al. 1997). Destruction of coastal freshwater wetland communities will occur due to an increase in global warming as saline water invades, particularly if these communities cannot move inland due to development or dikes (Tyedmers and Ward 2001). Rare species may get lost if the ephemeral wetlands (especially in arid regions) dry up. For example, numerous endemic species of fairy shrimp in California that are critically threatened by habitat loss (Belk and Fugate 2000) could vanish if reduced rainfall and increased evaporation eliminates their shallow, vernal pool habitats.

Impact of climate change on food security and economy:

The impact of climate change translates from the environment, ecosystems and species to the productive sphere, to economic and social dimensions, bringing a range of additional risks to the availability of food, access to food and utilization of food, as well as on the stability of these characteristics, for both farm and non-farm households.

Both direct and indirect effects of climate change are seen in agricultural production systems as in Figure 4. Direct examples include the effects on certain agricultural production systems brought on by a change in physical attributes like temperature levels and rainfall distribution. Productivity is impacted by indirect effects when pests, pathogens, invasive species, pollinators, and other species are altered (Moustafa et al., 2023a).

One of the greatest threats of the twenty-first century is the negative impact of climate change on the natural components of the World's food security. Mitigating these effects is essential to meeting the future food needs of the global population. Crop yield has already been negatively impacted by climate change, especially for major food crops like wheat, maize, and rice, which are staple foods in many nations (Lobell et al., 2011; Syed et al., 2022). Climate change can increase the danger of wildfires. Wildfires are major risks to farmlands, grasslands, and rangelands (Gowda et al., 2018). Temperature and precipitation changes will increase the occurrence and range of insects, weeds, and diseases. This may lead to a greater need for weed and pest control (Ziska et al., 2016).

Warmer temperatures may improve crop yields in some areas, but climate change is expected to have a negative overall effect, resulting in decreased food supplies and increased food prices (Nelson et al., 2009). Sub-Saharan Africa and South Asia already have significant levels of food insecurity and is expected to experience the greatest reduction in food production (Schmidhuber and Tubiello, 2007, Nelson et al., 2009, Gornall et al., 2010).

Elevated carbon dioxide levels in the atmosphere are expected to decrease the levels of zinc, iron, and other key nutrients in crops (Myers et al., 2014). Changes in rainfall patterns cause flooding and drought in agricultural areas. Increased temperatures increase the need for agricultural water and increase their susceptibility to dry spells (Nelson et al., 2009). Higher temperatures and carbon dioxide levels encourage the growth of weeds, insects, and other pests, which can ruin crops and put farmers out of business. The average output of the three main food crops: rice, maize, and wheat will decrease by 3–10% for every 1°C increase in temperature, according to recent IPCC climate assessments that included large

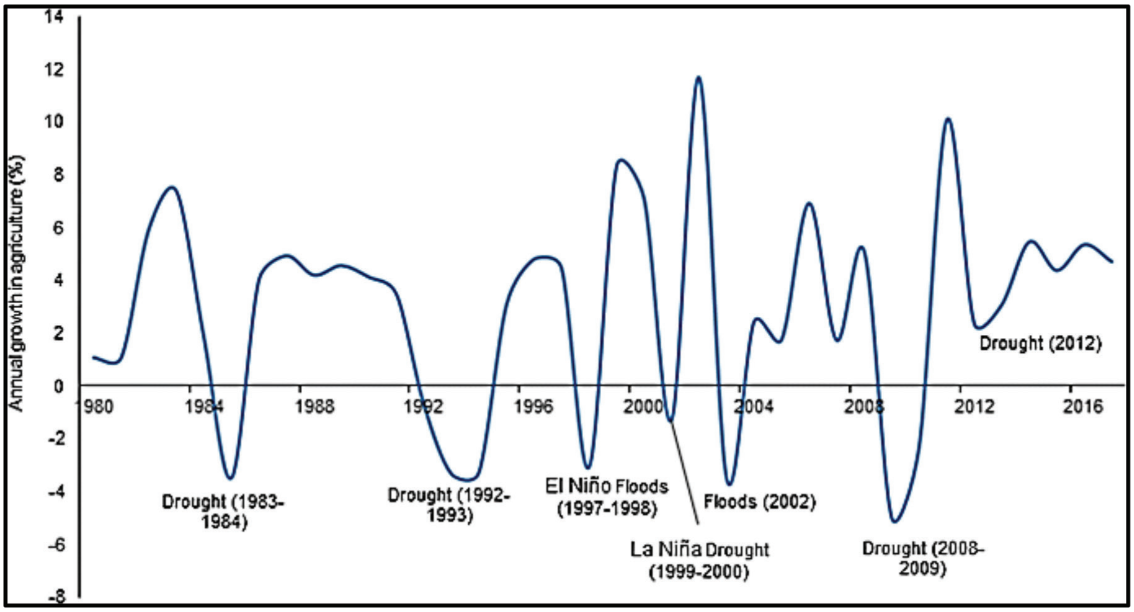

Figure 4: Climate extreme events and agricultural growth trends. Source of data: Annual growth in agriculture: WB, WDI Accessed November (2018)

uncertainties (Challinor et al., 2014, 2018). Forest productivity may be shifted if especially vulnerable, yet ecologically essential species are lost due to the physiological effects of climatic stresses (Kramer et al., 2020).

Fish production is projected to decline by 5-10% by 2050, particularly in tropical marine regions (Barange et al., 2014; Lam et al., 2016). Rising temperatures, nutrient fluctuations, and ocean acidification will alter fish distribution (Brander, 2010; Hollowed et al., 2013). These changes will have severe consequences for human health, with an estimated 845 million people facing mineral and zinc deficiencies, and 1.4 billion experiencing vitamin B12 and fatty acid shortages (FAO, 2016; Golden et al., 2016). A global assessment of fish farms revealed a significant decline in productivity, with a potential 88% biomass loss by 2050 (Costello et al., 2016; Gaines et al., 2018; Bradley et al., 2019).

Extreme weather events pose significant risks to economic growth by damaging infrastructure and reducing labor productivity. As the world adapts to rising temperatures, economic output will decline. Inflation will increase due to higher food, energy, and insurance costs.

At the household level, climate change can reduce income and financial stability through lower yields, increased production costs, and fluctuating prices. This can force the sale of assets, hindering long-term economic prospects. Risk aversion discourages investment, further impacting productivity and sustainability.

At a national level, exposure to climate risks can activate shocks on agricultural production and food availability, with risks of market disruptions, effects on supply and storage systems, as well as growing in agricultural commodity prices (food and feed), impacting accessibility and stability of food supplies for the entire population, particularly in countries with significant shares of the population spending a large part of their income on food. This activates macro-economic effects for countries for which agriculture an important part is of constitutes an important source of employment. At a global level, climatic shocks impact areas of global importance for food supplies and have remote impacts through effects on (i) supply flows and food price spikes, with increased market volatility; and (ii) influences on bilateral contracts and/or import/export behaviour, with disruption of trade patterns. Trade is expected to play a major role in adjusting to climate-change-driven shifts in agricultural and food production patterns. Recent experience shows that climate change effects on food price volatility are greatly affected by domestic policies, with export bans contributing to price fluctuations.

Climate change and diseases

Habitat disruption is the main driver of the loss of biodiversity, and climate change may play a role by pushing species to shift habitat and altering the geographical range of species (Bale, 2020; Xiao et al., 2020). As species alter habitats, this brings animals in closer range to people and livestock which then serve as a vehicle for introducing a global pandemic. At least 10,000 virus species have the ability to infect humans but, at present, many are circulating silently in wild mammals, changes in climate and land use will provide opportunities for viral sharing among previously geographically isolated species of wildlife (Morales-Castilla et al., 2021). An example is the extreme conditions that occurred in Wuhan, China, the epicenter of the COVID-19 pandemic, where bats and pangolins recently emerged as the main vectors responsible for the transmission of coronaviruses because of the housing in crowded, open markets in filthy conditions and proximity to humans (Bale, 2020; Xiao et al., 2020).

There is a need for urgent efforts to limit climate change to address the emergence of new pandemics in the future. According to emerging evidence it is suggested that in our world of climate change, there is growing encroachment on animal habitats that may impact health and risk for infectious diseases. According to Schwartz (2020), the confluence of COVID-19 and climate change has become the most difficult and dangerous public health problem ever, surpassing the influenza pandemic that first appeared in 1918, when environmental degradation had not yet escalated. Additionally, Wu et al. (2020) from the Harvard School of Public Health hypothesized that COVID-19 severity may be influenced by air quality. Despite the fact that the study did not specifically relate air quality to climate change, further research is needed on this important linkage.

Global boiling

According to U.N. Secretary-General António Guterres, July was the hottest month ever recorded on our planet. It clearly marks a turning point from the previous era of global warming to an era of global boiling as in Figure 5. This is evident all over the globe; from heat waves in North America and southern Europe, to floods in China and India, to wildfires in Greece. Global boiling has already unleashed a wave of extreme weather events across the globe including Record-breaking air temperatures in Southern Europe, wildfires in Greece, Spain, Portugal, Croatia, and parts of North Africa (Moustafa et al., 2023a). The current climate change has already affected 27 million km2 (18.3 % of land), which occurred in all biomes (Elsen et al., 2022). Climate change has negatively impacted the distribution of 47 % of 873 terrestrial non-volant threatened mammal species and 23.4 % of 1.272.

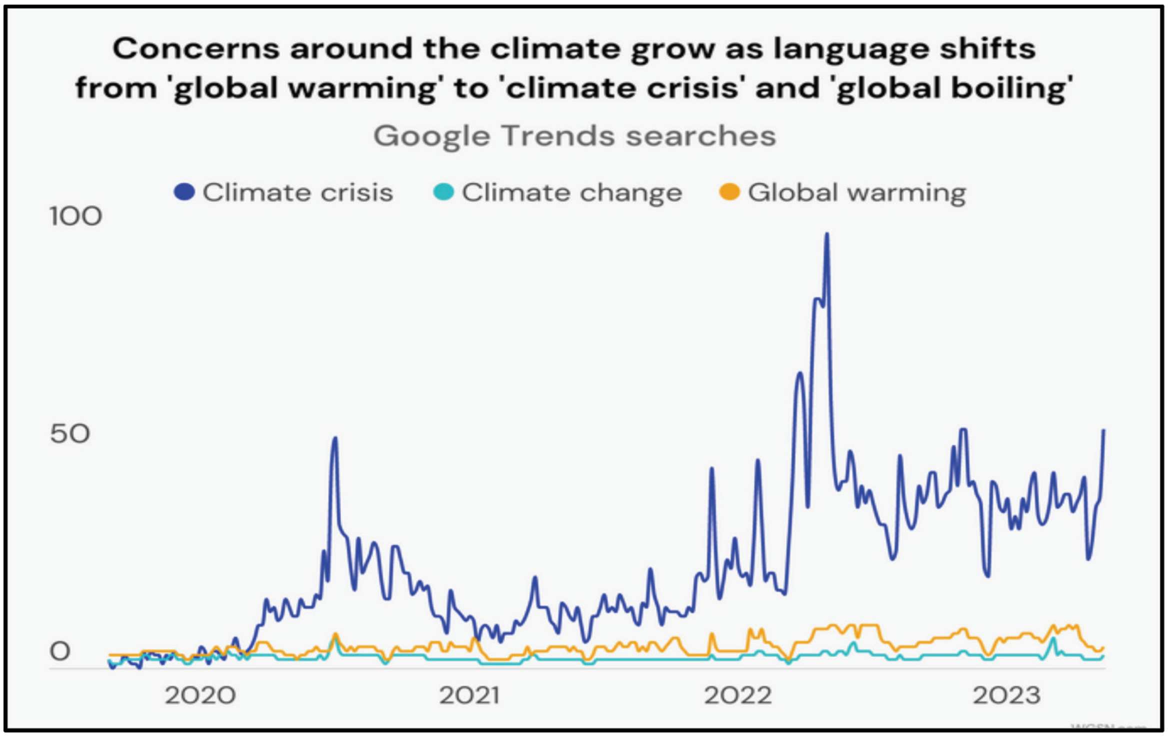

Figure (5): climate change shift from global warming to global warming and climate crisis (NASA, 2023).

Alleviating the effects of climate change

Despite some progress on an international front, there is no doubt that our changing climate is already affecting species, ecosystems and people. We therefore need to take urgent action to cope with the changes we are observing (such as unreliable weather patterns and extreme events) in order to extend human and scheme resilience in the future.

FFI is tackling this in two ways: climate change adaptation recognizes the real threat that temperature change poses for species and ecosystems. A number of years ago FFI began to look at project sites to spot how diversity in these areas may be affected and to develop ways for coping with these vulnerabilities. As well as observing the direct impacts of temperature change on diversity, they have been pioneering an approach to identify how people living in or near these sites are being affected by temperature change and helping them to adapt to these impacts (such as falling crop yields) whilst also not destroying their native ecosystems. Protecting vulnerable species and habitats: temperature change has the potential to push a good number of species over the brink into extinction. All of FFI's work is focused in some way on protecting threatened ecosystems and safeguarding endangered species.

Therefore, in summary, two basic measures are necessary to reduce the impacts of climate change: 1) practicing mitigation (reducing causes of climate change) by reducing the emission of greenhouse gases (GHGs) from the source, by substitution and conservation of energy, improving carbon sequestration, etc. and 2) practicing potential adaptation measures, (e.g. reducing the impacts of climate change). Important examples of adaptations are; a) reducing vulnerability (degree of susceptibility of a system to certain damage) to climate change impacts, focusing on coping strategies and practices to become beneficial by using opportunities associated with climate change by reducing susceptibility and external forces to develop the ability of resilience (increasing tackling capacity of the community and sectors to reduce risk and damages); b) have effective conservation strategies to maintain natural distribution of biodiversity and ecosystem services, and conserve species and genetic diversity; c) Improving productivity in terms of quality and quantity is vital to satisfy human needs, through adjusting different growth factors and solving effects of extreme events and associated problems, e.g. preventing the spread of pathogens, weeds, dispersion of insect and pests, etc.; d) minimize impacts of climate change (its cause and effects) progress in researching to identify the responses of plant species to different variable climate conditions, and identifying uncertainty in climate and try to avoid challenges in practicing adaptation;e) finally, increased environmental benefits from forest ecosystems by afforestation and reforestation to reduce degradation and loss of habitats.

Interpretation

Global warming, characterized by rising temperatures, altered precipitation patterns, and sea-level rise, is profoundly impacting ecosystems worldwide. Pedrono et al. (2016) advocate for the ecosystem services concept as a strategic response to biodiversity loss. This utilitarian approach complements traditional conservation efforts by emphasizing the benefits ecosystems provide to humans. While ecosystem services offer potential for climate change mitigation and adaptation, their future under rapid climate change is uncertain. However, the question remains as to how ecosystems will continue to provide those services in a time of rapid climate change. Most biological communities are disappearing due to climate change combined with other anthropogenic pressures, affecting the functionality of ecosystems that are close to collapse. Rather than maintaining existing ecosystems intact, the focus should be on recognizing their dynamic nature and protecting the functions and services they provide. The potential losses of species as the direct consequence of climate change must therefore be considered against the present background of other sources of anthropogenic change in environments. Increasing human populations resulting in increased demand for agricultural production combined with economic development of assets such as forest and mineral deposits are already threatening many native plant and animal communities.

Ecosystem patterns and processes, such as rates of primary productivity or input–output balance of chemical elements, respond in complex ways to climate change because of multiple controlling factors. For example, whether a forest is a carbon (C) source or sink depends on the balance of primary production and ecosystem respiration, processes that respond to different drivers; physical changes in ecosystems for instance, changes in thermal stratification patterns in lakes and oceans, flood and drying regimes in streams and rivers, or intensification of the hydrologic cycle across large basins lead to changes in ecosystem structure and function that have economic and human consequences. Often the extremes or changes in timing have greater impact than changes in average conditions and incur greater societal impacts and costs. Recognizing these issues, climate-change action plans and management strategies have begun to account for forecasted changes in extremes or seasonality (Grimm et al., 2013).

Recommendations

Several recommendations and solutions are required to mitigate these effects and to protect biodiversity. Focus on preserving existing habitats and restoring degraded ecosystems are crucial. This can involve reforestation, wetland protection, and the creation of protected areas to safeguard vulnerable species. The primary cause of climate change is the release of greenhouse gases. Implementing policies and practices that reduce emissions is crucial. This includes: transitioning to renewable energy sources; improving energy efficiency, and promoting sustainable transportation; embracing sustainable agriculture and forestry practices that protect biodiversity; promoting agroforestry, organic farming, and the use of sustainable land-use techniques to minimize the negative impact on plants and animals is recommended; promoting public awareness about climate change and its impact on flora and fauna; encouraging sustainable lifestyle choices, such as reducing consumption, adopting plant-based diets, and supporting environmentally-friendly initiatives; developing and implementing adaptation strategies that help ecosystems and species adapt to changing conditions. This can involve creating corridors to facilitate species migration, promoting habitat connectivity, and assisting species impacted by rapid changes.

Scientific research must be supported to understand the impacts of climate change on plants and animals better. Monitoring species populations, studying migration patterns, and identifying areas at high risk can help to formulate effective conservation strategies. Climate change is a global challenge that requires collaboration between nation, and encouraging international agreements, such as the Paris Agreement, are needed to ensure coordinated efforts in reducing greenhouse gas emissions and protecting biodiversity. Finally, the scientific community, policymakers, and the general public must work together to address the challenges posed by climate change. By investing in research, implementing evidence-based conservation strategies, and fostering international collaboration, we can protect the delicate balance of ecosystems and safeguard the well-being of future generations.

Conclusion

Climate change has already had a significant impact on plants and animals around the world, disrupting ecosystems and endangering numerous species. The extinction of species and the impact of climate change are closely interconnected. Climate change, primarily caused by human activities such as burning fossil fuels and deforestation, is altering ecosystems and habitats worldwide. This alteration poses significant threats to many species, leading to increased rates of extinction. Climate change affects species in various ways. Rising temperatures can disrupt the delicate balance of ecosystems, affecting the availability of food, water, and suitable habitats. It can also lead to changes in migration patterns and reproductive cycles, impacting the survival and reproductive success of species. The loss of species due to extinction has far-reaching consequences. Biodiversity loss disrupts ecosystem functioning and can have cascading effects on other species within the ecosystem. It can lead to imbalances in predator-prey relationships, reduced pollination, and decreased resilience to environmental changes. Furthermore, the loss of species can have significant economic and social impacts. Many species provide essential ecosystem services, such as water purification, carbon sequestration, and pest control, which are crucial for human well-being and sustainable development. Addressing climate change and mitigating its impacts is crucial for preventing further species extinctions. This requires global efforts to reduce greenhouse gas emissions, protect and restore habitats, promote sustainable land and ocean management practices, and enhance conservation efforts. By taking action to combat climate change, we can help safeguard species and preserve the invaluable biodiversity of our planet.

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