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LOSING BIODIVERSITY: THE IMPACT OF CLIMATE CHANGE

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ABSTRACT

This abstract reveal that the world is facing a biodiversity extinction crisis, which is being intensified by the impacts of climate change. The challenges of climate change are significant, extending beyond the visible effects of melting ice caps and rising sea levels. For the past two decades, this issue has consistently held a critical place on the international agenda, recognized alongside desertification, soil degradation, and biodiversity loss as a primary global environmental threat. While climate change has gained considerable attention in the media and public discourse, the concurrent danger of biodiversity loss remains inadequately understood. The ongoing biodiversity extinction crisis is closely linked to climate change, and this detailed research article emphasizes the importance of addressing both crises collaboratively and comprehensively. The loss of biodiversity is not only a moral and environmental concern; it has significant economic and public health implications as well. It influences resource availability, affects disease transmission risks, and increases vulnerability to environmental disasters. The findings of this research highlight the need for enhanced public understanding and integrated strategies to safeguard the global environment and its diverse ecosystems effectively.

Key words: Climate change, biodiversity loss, coral reefs, ecosystem health, global warming, species extinction.

INTRODUCTION

Biodiversity refers to the variety of life on Earth, encompassing all its forms, from genes and bacteria to entire ecosystems like forests and coral reefs. The biodiversity we observe today has developed over 4.5 billion years of evolution, yet it increasingly faces challenges for survival due to climate change. The frequency and intensity of natural disasters, such as floods, droughts, cyclones, hurricanes, typhoons, and wildfires, have become increasingly evident. In 2021, the top five countries most affected by climate change included Japan, the Philippines, Germany, Madagascar, and India. These disasters not only lead to the loss of many human and animal lives but also result in significant economic losses for both urban and rural populations. For instance, deadly floods and landslides in 2020 forced approximately 12 million people to leave their homes in India, Nepal, and Bangladesh. According to the World Meteorological Organization's comprehensive report published in August 2021 (WMO-No.1267), climate change-related disasters have increased fivefold over the last 50 years. Recent years have undeniably highlighted the extreme and unpredictable nature of weather patterns, accompanied by a significant rise in both the frequency and intensity of natural disasters. In earlier decades, it was possible to predict annual weather patterns, such as the onset and conclusion of monsoon rains, allowing farmers to plan their sowing periods accordingly. However, weather patterns are now changing almost every year, leading to significant losses for farmers. The extent of annual rainfall and the areas associated with heavy or light rainfall have also become uncertain. Regions previously known for scant rainfall have begun to experience much heavier rains, while areas typically associated with heavy rainfall are receiving less. Additionally, the timing and extent of snowfall in temperate regions have become highly variable. Global temperatures have steadily risen over more than a century, with the rate of increase accelerating in recent years, reaching record levels. Human activities, such as farming, deforestation, and the burning of fossil fuels for energy, release carbon dioxide into the atmosphere, creating a greenhouse effect that traps heat and accelerates the warming of the Earth. The consequences of this warming trend are already apparent, with extreme weather events like heatwaves, floods, and storms causing widespread devastation. If prompt action is not taken, the consequences of climate change are expected to intensify, posing a risk of irreversible damage to both society and ecosystems. If current warming rates continue, average global temperatures are projected to rise by over 1.5°C compared to pre-Industrial Revolution levels by

2030.We can see that the climate change is profoundly shaping our world today, leading us toward a mass extinction event where many forms of life, particularly tropical marine life, could become extinct. Hundreds of wild animals have gone extinct since 1500, and an estimated 1 million species are at risk in the coming decades. The sixth mass extinction is imminent, and it will mostly be caused by human activity.

METHODOLOGY

The study draws on qualitative and quantitative data from a wide range of secondary sources, including research papers, articles, official websites, and journals, to arrive at a comprehensive conclusion.

DISCUSSION

The connection between climate change and biodiversity is well-established. While the Earth's climate has naturally changed over time, the current rapid pace of climate change is hindering ecosystems and species from adapting, resulting in increased biodiversity loss. Extreme weather events are occurring more frequently, and the timing of biological events is shifting. Our wildlife is in decline. Climate change disproportionately affects the polar regions, tropical rainforests, and coastal areas compared to other parts of the world. This situation could have significant consequences for the health of the planet and our future. The consequences of climate change are already apparent.

Global temperature pattern

Global temperatures have been rising for over a century, with an acceleration in recent years, reaching record highs. We contribute to this rise in temperature through activities such as agriculture, deforestation, and burning fossil fuels for energy, which release carbon dioxide into the atmosphere. These carbon emissions led to the greenhouse effect, trapping heat and causing the Earth to warm at a much faster rate than would occur naturally. "We recently had the hottest year on record, with severe storms, devastating floods, and extreme heatwaves destroying lives and livelihoods. The challenges we face will only get worse unless we act quickly, bringing us closer to causing irreparable harm to ecosystems and society, according to Kirsten Schuijt, Director General of WWF International WEF (Global Risk Report 2024). If the current rate of warming continues, average global temperatures are likely to increase by more than 1.5°C (2.7°F) by 2030 compared to pre- Industrial Revolution levels.

The information from NOAA Climate.gov about global temperature

The graph displays global surface temperatures from 1880 to 2023, comparing them to the 20th-century average (1901-2000) (Fig. 1). Blue bars signify years with cooler temperatures than the average, while red bars denote warmer-than-average years.

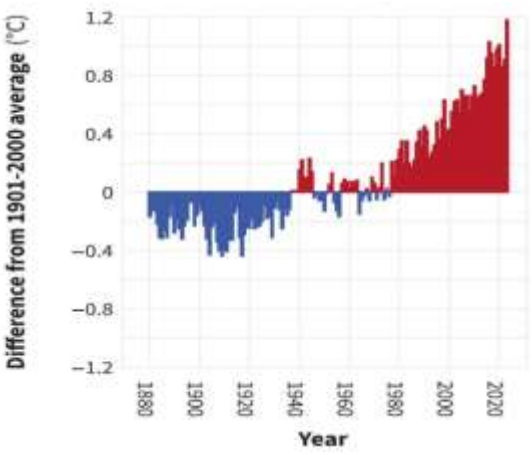

Fig 1: Yearly surface temperature from 1880–2023 compared to the 20th-century average (1901-2000). Source: https://www.climate.gov/news-features/understanding- climate/climate-change-global-temperature

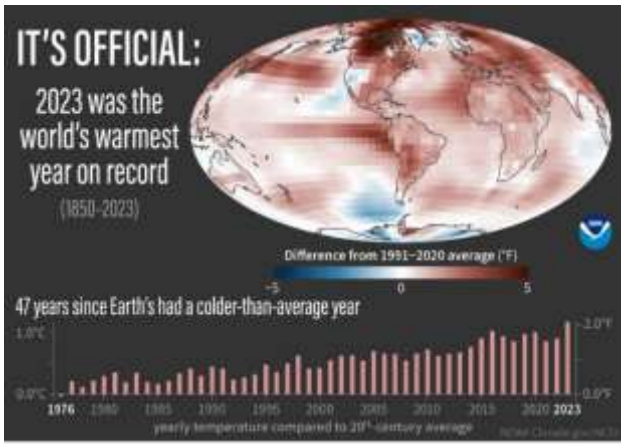

Fig 2: The bar graph shows global temperatures each year from 1976 (left) to 2023 (right) compared to the 1901-2000 average. (NOAA Climate.gov image, based on data provided by NOAA National Centers for Environmental Information).

Source:https://www.climate.gov/news-features/understanding-climate/climate- change-global-temperature

The graph indicates that 2023 was the warmest year on record since global measurements began in 1850, surpassing previous years by a significant margin. Notably, all ten of the warmest years in the historical record have occurred within the last decade (2014-2023). The blue bar on the far left illustrates that 1976 was the last year to be cooler than the 20th-century average, while the bar on the far right shows that 2023 set a new record for being the warmest year ever

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recorded.

Analysis of NASA about global temperature

This graph illustrates the change in global surface temperature compared to the long- term average from 1951 to 1980. According to data from NASA/GISS, Earth's average surface temperature in 2023 was the highest recorded since consistent recordkeeping began in 1880. NASA's findings are consistent with independent analyses conducted by the National Oceanic and Atmospheric Administration (NOAA) and other research groups (Figs. 2 & 3). Overall, in 2023, the Earth was approximately 2.45 degrees Fahrenheit (about 1.36 degrees Celsius) warmer than the late 19th-century preindustrial average (1850- 1900). The past decade has been the warmest, according to NASA.

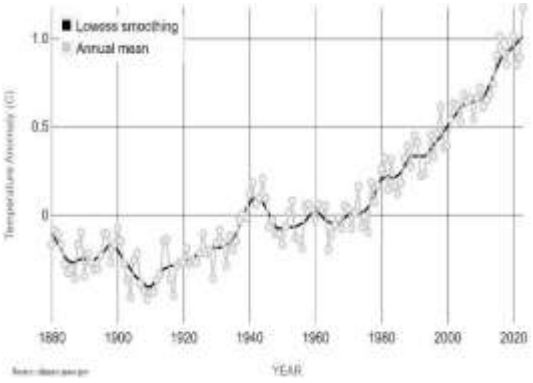

Fig 3: Graph shows the Global mean temperature over time since 1880 (NASA, 2017)

Impact on Biodiversity

Biodiversity—defined as the 'diversity of life' on Earth—is crucial for the planet's health and survival. Climate change is a major factor driving biodiversity loss, while biodiversity itself plays a vital role in mitigating climate change. The two are undeniably interconnected and cannot be viewed separately.

Many species are struggling to adapt to rapidly changing weather conditions, which could eventually lead to their extinction. Long-term studies spanning over 100 years have revealed that several bumblebee species in North America and Europe are unable to keep up with the changing climate, resulting in their disappearance from southern areas of their range (Kerr et al., 2015). Most flowering plants rely on animals for seed dispersal (Beckman et al., 2020). Climate change and other environmental disturbances, such as defaunation, have diminished long-distance seed dispersal, reducing the ability of fleshy-fruited species to track climate change by 60%, thereby severely impacting their ability to shift ranges (Fricke et al., 2022).

On land, rising temperatures have compelled many animals and plants to migrate to higher elevations or latitudes, often towards the Earth's poles, which has significant consequences for ecosystems. The risk of species extinction increases with each additional degree of warming.

In marine environments, rising temperatures heighten the risk of irreversible loss of marine and coastal ecosystems. For example, live coral reefs have diminished by nearly half over the past 150 years, and further warming endangers nearly all remaining reefs. Overall, climate change jeopardizes ecosystem health, influencing the distribution of plants, animals, viruses, and even human settlements. This can lead to increased opportunities for animals to spread diseases and for viruses to transfer to humans.

Human health is also at risk due to the reduced ecosystem services provided by nature, such as food production, medicinal resources, and livelihoods.

Increasing global temperatures, ocean acidification, and extreme weather events—ranging from heat waves and droughts to floods and wildfires—are rapidly transforming global ecosystems. Larger organisms, in particular, often require thousands to millions of years to evolve and adapt to new climates, yet Earth's climate is changing faster than many species can cope with. According to an IPCC special report on the impacts of global warming of 1.5 ℃ above pre-industrial levels, which discusses related greenhouse gas emission pathways in the context of global responses to climate change, sustainable development, and poverty eradication, under a scenario of 1.5 °C warming, 6% of insects, 8% of plants, and 4% of vertebrates are projected to lose over half of their climatic range. For a global warming scenario of 2 °C, these figures increase to 18% of insects, 16% of plants, and 8% of vertebrates. If warming reaches 3.2 ℃ above pre-industrial levels, it is projected that 49% of insects, 44% of plants, and 26% of vertebrates will lose more than half of their historical geographic range. **Impact on terrestrial Biodiversity**

The health of ecosystems is impacted by climate change, which causes changes in the distribution of viruses, plants, animals, and even human populations. Consequently, there are more chances for viruses to infect humans and for animals to transmit illnesses. The loss of food, medicine, and livelihoods that nature supplies as a result of ecosystem services being reduced is having a detrimental impact on human health.

The environment is suffering greatly with each degree of temperature increase, and the likelihood of a species going extinct rises with each degree. Land animals and plants have been compelled by warming to relocate to higher altitudes, with many of them heading toward the poles.

Impact of Glaciers melting on coastal biodiversity

Researchers cautioned at the American Geophysical Union's annual meeting on December 13, 2021, that the rapid melting and degradation of Thwaites Glacier, one of the largest glaciers in western

Antarctica, might lead to the ice shelf's total collapse in a few of years. Sea levels could rise by more than 65 centimeters due to the amount of water stored in this glacier.

Source: https://www.un.org/en/climatechange/science/climate-issues/biodiversity

Because it sustains the entire West Antarctic Ice Sheet, which is being threatened by warm water linked to climate change, Thwaites Glacier is vital. The melting of Thwaites could ultimately result in the loss of the entire West Antarctic Ice Sheet, which has the potential to raise global sea levels by 3.3 meters. The timeline for this disaster may be sooner than anticipated (Voosen, 2021). If such an event occurs, the consequences for human populations and biodiversity loss could be unimaginable.

The melting of glaciers also contributes to the drying up of perennial rivers during the summer months, leading to water scarcity for billions of people and animals, as well as impacting food and energy production downstream. Rising sea levels and the melting of glaciers that feed these rivers could result in the migration of large populations, creating additional socio-economic challenges. Even if global temperature increases are limited to 1.5 °C (as discussed later), this could still lead to a global sea-level rise of between 1.7 and 3.2 feet by 2100. If temperatures increase to 2 °C, the effects could be catastrophic, resulting in the submergence of numerous islands, flooding significant coastal areas, and causing saltwater intrusion into surface and groundwater, along with increased soil erosion. For example, around 80% of the Maldives is less than one meter above sea level, making it particularly vulnerable to submersion.

e-issues/biodiversity Biodiversity in these islands and coastal regions would face extinction. Countries such as China, Vietnam, Fiji, Japan, Indonesia, India, and Bangladesh are identified as being at the highest risk. The Sundarbans National Park, a UNESCO World Heritage Site and the world's largest mangrove forest, spans over 140,000 hectares across India and Bangladesh and serves as a habitat for the Royal Bengal Tiger and various other species. The area has lost 12% of its shoreline in the last four decades due to rising sea levels and is likely to be completely submerged in the future.

Impact on Marine Biodiversity

Corals are among the marine species most affected by rising ocean temperatures and increased acidity. Coral reefs serve as habitats for thousands of other species, including sharks, turtles, and whales. Corals exist in a symbiotic relationship with algae, which provide colour and photosynthetic products to the corals. Coastal and marine ecosystems are at greater risk of irreparable loss due to rising ocean temperatures. Live coral reefs, for example, have nearly halved in the past 150 years, and further warming threatens to destroy nearly all remaining reefs.

Additionally, coral reefs worldwide are rapidly deteriorating due to climate change, and their survival in their current form beyond mid-century looks bleak.

Source:
https://www.un.org/en/climatechange/science/climat

The ecosystem as a whole will be disrupted if corals die.

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Corals are extremely sensitive to heat and acidity; even a temperature increase of 2–3°F above normal ocean water can lead to the expulsion of the symbiotic algae from their tissues, resulting in bleaching (Hoegh-Guldberg et al. 2017). Nearly one-third of the Great Barrier Reef—the world's largest coral reef system, which supports a significant tourism industry in Australia—has died as a result of global warming (Hughes et al. 2018).

According to UNESCO, if greenhouse gas emissions continue at the present rate, coral reefs in all 29 reef-containing World Heritage sites will cease to exist as functioning

ecosystems by the end of this century. (iucn.org/resources/issues-brief/coral-reefs-and-climate-change). The loss of these reefs would lead to a significant decline in marine biodiversity, triggering a chain reaction as other ecosystems struggle to survive alongside the reefs. A recent assessment of the risk of ecosystem collapse for coral reefs in the Western Indian Ocean, which covers about 5% of the global total, indicates a range from critically endangered to vulnerable (Obura et al. 2022).

Impact on Arctic Biodiversity

The melting of ice in the Arctic region due to global warming is threatening the survival of native animals such as polar bears, Arctic foxes, and Arctic wolves. The rise in sea levels also poses a risk of extinction for many endangered and endemic plant and animal species in submerged coastal areas and islands. There are over 180,000 islands across the globe that harbour 20% of the world's biodiversity.

In a study by Bellard et al. (2013), the consequences of sea level rise of 1 to 6 meters were assessed for 10 biodiversity hotspots located on islands, particularly focusing on their endemic species at risk of potential extinction. The findings revealed that 6% to 19% of the 4,447 islands examined would be completely submerged, depending on the rise in sea levels. Among these, the Caribbean islands, the Philippines, and Sundaland were identified as significant hotspots, representing a potential threat to 300 endemic species.

The UN Report on climate change:

The UN Report on climate change, compiled by more than 90 authors from 40 countries and drawing upon an analysis of 6000 scientific publications, was released in October 2018 in South Korea. This report highlighted several critical findings:

- Surpassing a 1.5 °C rise in global temperature would result in catastrophic consequences for ecosystems, communities, and economies.
- Even with a 1.5 °C increase, coral reefs are predicted to deteriorate by 70–90%, and 99% of reefs are predicted to be destroyed at 2 °C.
- The intensity and frequency of storms, floods, droughts, and forest fires are expected to escalate.
- Presently, the world has experienced a warming of about 1 °C since preindustrial times and is heading towards a 3–4 °C warming by 2100, unless there are rapid and substantial reductions in CO_2 and other greenhouse gas emissions in the upcoming decades.

This report served as a wake-up call to all of us regarding the critical nature of climate change

Link between climate change and biodiversity:

The link between climate change and biodiversity has been well established. Throughout Earth's history, the climate has changed, leading to the rise and fall of various ecosystems and species. However, rapid climate change now poses a significant challenge to ecosystems and the ability of species to adapt, resulting in increased biodiversity loss.

The primary drivers of current biodiversity loss include habitat modification, overexploitation, climate change, invasive alien species, and chains of extinction. Changes in land and sea usage contribute the most, accounting for 34% of biodiversity losses over the past century, followed by direct species exploitation at 23%. Climate change and pollution each contribute 14%. It is projected that the impact of climate change will surpass other threats in the twenty-first century, both through direct effects and by exacerbating the interactions with other drivers.

Regions such as the Arctic, Antarctic, and high latitudes are experiencing alarming rates of warming. In the Arctic, the reduction in sea ice extent, thickness, and age profoundly impacts the ecosystem. Melting is accelerated by the decreasing reflecting surface caused by the thinning ice cover. From the algae that develop on the underside of multi-year ice to different marine species higher up the food chain, many of which are highly adapted to life on or beneath the ice, this impacts the entire ecosystem. Many species are in danger of going extinct as a result of these swift changes, not just

the famous polar bear.

The unprecedented rise in greenhouse gas concentrations is pushing oceans toward conditions not seen in millions of years, posing the risk of irreversible ecological transformations. Human- induced climate change is disrupting the ocean's biological processes, leading to reorganization of community structures and the potential for unexpected ecological changes.

Warren et al. (2018) conducted a global analysis that looked at how the distribution of plants, insects, and vertebrates is affected by climate change. According to the report, around 18% of insect, 16% of plant, and 8% of vertebrate species are expected to lose more than 50% of their global range for every 2 °C increase in temperature. These percentages, however, decrease to 6% for insects, 8% for plants, and 4% for vertebrates if the temperature increase is kept to 1.5 °C.

Drivers of climate change:

Deforestation- The exploitation of forests significantly contributes to climate change. Trees play a crucial role in regulating the climate by absorbing carbon dioxide (CO2) from the atmosphere. When trees are cut down, this beneficial effect is lost, and the carbon stored in the trees is released back into the atmosphere.

Mining- Modern life is highly dependent on the mining and metallurgical industry. The raw materials utilized in the production, transportation, and building of commodities are metals and minerals. This market is responsible for 5% of all greenhouse gas emissions from extraction to distribution.

Intensive farming- One significant cause of global warming is intensive farming. This includes not only the growing number of livestock but also the use of plant protection products and fertilizers. Cattle and sheep, for instance, produce large amounts of methane during digestion, while the application of fertilizers results in nitrous oxide emissions.

Wrong waste disposal methods- Waste management methods such as landfills and incineration release greenhouse gases and toxic substances, including methane, into the atmosphere, soil, and waterways. This contributes to the intensification of the greenhouse effect. Achieving effective waste management will be challenging without reducing fossil fuel emissions.

Massive use of fossil fuels- The extensive reliance on fossil fuels is the primary cause of global warming, as the combustion of coal, oil, and gas emits carbon dioxide— the most significant greenhouse gas— as well as nitrous oxide.

Overconsumption of natural resources- Overconsumption significantly contributes to climate change by leading to the overexploitation of natural resources and increasing emissions from international freight transport, both of which exacerbate global warming.

Measures for climate change mitigation:

A legally binding agreement was approved at the Conference of Parties (COP 21), which took place in Paris in 2015, with the goal of keeping global warming well below 2 °C, with a preference for keeping it at 1.5 °C by 2100 compared to pre-industrial levels. However, under the current emissions scenario, the world is projected to experience warming of 3–4 °C by the end of the century. At COP 26, which took place in Glasgow in November 2021, this topic was further explored. There, numerous nations committed to achieving net-zero carbon emissions by 2050 and halting deforestation, two crucial steps in achieving the 1.5 °C target. Despite these commitments, a temperature increases of about 2.4 °C is anticipated.

To meet the goals established in the 2015 Paris Agreement, the global share of electricity generated from coal must be reduced from the current 37% to no more than 2% by 2050. Additionally, a significant expansion of renewable energy sources is required, and net CO2 emissions must decline by 45% from 2010 levels by 2030 to achieve net-zero greenhouse gas emissions around 2050.

In addition to these measures, urgent actions are needed to limit the temperature rise to 1.5 °C and to support biodiversity and human welfare: -

Shift Towards Renewable Energies - One of the most effective ways to combat climate change is to transition away from fossil fuels. What are the alternatives? Renewable energy sources such as solar, wind, biomass, and geothermal energy can provide sustainable solutions.

Energy and Water Efficiency- While producing clean energy is vital, it is equally important to reduce energy and water consumption. This can be achieved by using more efficient devices, such as LED light bulbs and innovative shower systems, which save resources and costs.

Sustainable Transportation - Encouraging the

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use of public transportation and carpooling, along with promoting electric and hydrogen-powered vehicles, can significantly reduce CO_2 emissions and help fight global warming.

Sustainable Infrastructure - To lower the CO_2 emissions from buildings— stemming from heating, air conditioning, hot water usage, and lighting—it is essential to construct new low-energy buildings and renovate existing structures.

Sustainable Agriculture and Forest Management - It is crucial to promote better utilization of natural resources, halt extensive deforestation, and implement greener, more efficient agricultural practices.

Responsible Consumption and Recycling - Adopting responsible consumption habits is vital for various products, including food (especially meat), clothing, cosmetics, and cleaning supplies. Furthermore, recycling is imperative for effectively managing waste.

CONCLUSION

Climate change has had a profound impact on marine, terrestrial, and freshwater ecosystems globally. This has led to a decline in local species, an increase in disease prevalence, and mass mortality of plants and animals, resulting in the first climate-driven extinctions. The signs of rising temperatures affecting biodiversity are evident and are compounded by changing rainfall patterns, extreme weather events, and ocean acidification, which all exert mounting pressure on ecosystems. Additionally, wildlife is struggling with the heightened frequency and severity of fires, storms, and droughts. These factors pose long-term risks to ecosystems and could alter the composition of species that can thrive in these environments.

Many plants, amphibians, and reptiles, however, cannot adapt quickly enough to keep pace with these climatic shifts. Even species that can adapt face barriers due to the limited natural spaces available for migration and adaptation. Furthermore, global warming is contributing to rising sea levels through two primary mechanisms: the melting of glaciers, polar ice caps, and the Atlantic ice shelf, which adds water to the oceans, and the expansion of ocean water as it warms.

Additionally, the incomplete combustion of fossil fuels, biofuels, and biomass releases small carbon particles (less than 2.5 µm in size), known as black carbon. These particles absorb the sun's heat thousands of times more effectively than CO_2, contributing further to global warming. When deposited on snow, glaciers, or ice caps, black carbon accelerates their melting, which contributes to overall rising sea levels.

Rising ocean temperatures are particularly harmful to marine organisms, especially vulnerable corals that experience bleaching due to ocean acidification. If these issues remain unaddressed, we risk losing nearly half of the world's species in critical natural areas, such as the Amazon and the Galapagos, where many species could face local extinction by the end of this century.

Nature-based solutions, including managing working lands, restoring native vegetation, and protecting intact ecosystems, are essential to mitigating these impacts. Effective mitigation efforts must involve a significant reduction in greenhouse gas emissions and an expansion of forest cover. The findings underscore the importance of public awareness and highlight the need for integrated strategies to protect the global environment and its diverse ecosystems.

Immediate action must be taken to combat climate change, and existing efforts must be accelerated. Ultimately, we conclude that the climate and biodiversity crises are interconnected and must be addressed together.

REFERENCES

Beckman J, Ivanic M, Jelliffe JL, Baquedano FG, Scott SG (2020). Economic and food security impacts of agricultural input reduction under the European Union Green Deal's Farm to Fork and biodiversity strategies. EB-30 USDA, Economic Research Service, Res Agric Appl Eco 1-52.

Bellard C, Thuiller W, Leroy B, Genovesi P, Bakkenes M, Courchamp F (2013). Will climate change promote future invasions? Global change biology. (12), 3740-8.

Fricke EC, Hsieh C, Middleton O, Gorczynski D, Cappello CD, Sanisidro O, Rowan J, Svenning JC, Beaudrot L. (2022). Collapse of terrestrial mammal food webs since the Late Pleistocene. Science. 377(6609), 1008-11.

Hoegh-Guldberg O, Poloczanska ES, Skirving W, Dove S. (2017). Coral reef ecosystems under climate change and ocean acidification. Frontiers in Marine Science **4**, 252954.

Hughes TP, Kerry JT, Baird AH, Connolly SR, Dietzel A, Eakin CM, Heron SF, Hoey AS, Hoogenboom MO, Liu G, McWilliam MJ. (2018). Global warming transforms coral reef assemblages. Nature. 556(7702), 492-6.

Kerr JT, Pindar A, Galpern P, Packer L, Potts SG, Roberts SM, Rasmont P, Schweiger O, Colla SR, Richardson LL, Wagner DL. (2015). Climate change impacts on bumblebees converge across continents. Science. 34(6244), 177-80.

Lindsey R, & Dahlman, L (2024). Climate change, Global temperature. Climate. gov, 1-5.

Obura D, Gudka M, Samoilys M, Osuka K, Mbugua J, Keith DA, Porter S, Roche R, van Hooidonk R, Ahamada S, Araman A. (2022). Vulnerability to collapse of coral reef ecosystems in the Western Indian Ocean. Nature

Sustainability. (2), 104-13.
Voosen P. (2021). Global temperatures in 2020 tied record highs. Science mag.org, Science. 371(6527):334-335.
Warren R, Price J, Graham E, Forstenhaeusler N, VanDerWal J. ((2018). The projected effect on insects, vertebrates, and plants of limiting global warming to 1.5 C rather than 2 C. Science. 360(6390), 791-5.