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Climate change impacts on earth's biodiversity- A review

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ABSTRACT: Biodiversity, the vast array of life on Earth, faces significant threats from climate change, which disrupts ecosystems and accelerates species extinction. Climate change, characterized by long-term changes in temperature, precipitation and extreme weather events, disrupts ecosystems and accelerates biodiversity loss. Maintaining a habitable climate and functioning natural systems is essential for human well-being too. Global initiatives like the Convention on Biological Diversity, Paris Agreement and the UN Sustainable Development Goals aim to address the dual crises of biodiversity loss and climate change. Historical climate variability has shaped biodiversity, but current rapid changes are unprecedented, threatening the delicate balance of life on Earth. The impacts of climate change are already evident, with rising temperatures causing shifts in species distribution, altered phenology, increased extinction rates and altered ecosystem services. Biodiversity underpins crucial ecosystem functions, including food security, water purification and disease regulation. Climate change exacerbates existing threats such as habitat destruction and pollution, leading to further declines in biodiversity. Protecting biodiversity requires global cooperation, policy integration and sustainable practices. Efforts to curb greenhouse gas emissions, restore habitats and raise public awareness are essential. Addressing research gaps and fostering international collaboration are also crucial for understanding and mitigating the impacts of climate change on biodiversity. Ultimately, safeguarding biodiversity is vital for maintaining the ecosystem services that support human life and ensuring a resilient future for all species on earth.

Key Words: Biodiversity, climate change, greenhouse gas, ecosystem, the biodiversity plan

INTRODUCTION

Biodiversity, the incredible variety of life on Earth, is under threat. While habitat loss and other human activities are major culprits, climate change has emerged as a powerful threat, disrupting ecosystems and pushing species towards extinction. Climate change, characterized by long-term shifts in temperature, precipitation patterns and increased frequency of extreme weather events, poses one of the most significant threats to biodiversity globally. The intricate balance of ecosystems is disrupted as species struggle to adapt to rapidly changing conditions, leading to shifts in species distribution, altered ecosystem functions and increased rates of extinction. A well-functioning natural system and a habitable climate are the foundations of people's good quality of life. Protecting biodiversity, adapting or mitigating species/ecosystems to changing climate and promoting an acceptable and equitable quality of life for all is the mandate of several global initiatives, particularly the Strategic Plan for Biodiversity 2011-2020 of the Convention on Biological Diversity (CBD), the Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCCC) and the UN Sustainable Development Goals (SDGs). While each of these initiatives has specific goals, they also clearly state that the challenges of biodiversity decline, climate change and human well-being are closely connected, and a failure to jointly address the dual crises of climate change and biodiversity decline can compromise people's good quality of life (IPBES, 2019).

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The very existence of life on earth is dependent upon a climate that has varied within relatively narrow bounds over hundreds of millions of years.[1,2] Climatic variability in the distant past has played a role in shaping contemporary biodiversity, through climate-induced species redistributions, extinctions, and originations.[3,4,5] Global biodiversity has increased over geological time despite climate changes, albeit punctuated by mass extinctions frequently associated with large or rapid climate changes.[6,7,8] Ancient global catastrophes had the potential to trigger evolutionary and ecological novelty, for example the assembly of modern Neotropical rainforests after the end Cretaceous mass extinction.[9] In the last 12,000 years global mean temperatures (GMT) have ranged between +0.7 and -1°C relative to the late 19th century baseline.[11,12] However, GMT is currently approaching the upper limits of that experienced within the last 1.2 million years, and is beyond the range experienced by humankind since the invention of agriculture.[13,14] Reciprocally, living organisms are a crucial part of the Earth system that keeps the local, regional and global climate sufficiently stable and suitable for life.[15]

Changes in the atmosphere and oceans can profoundly change the biosphere, the thin living film of life on Earth that is intrinsically coupled to the atmosphere and hydrosphere and provides the nourishing fabric within which human societies exist. Scientific research continues to refine the understanding of Earth's climate system and its interdependence on the biosphere. For the most part, projections indicate an increased likelihood of negative consequences of climate change for ecosystems and people. Indeed, climate-related impacts are already being witnessed and seem to be increasing in severity and frequency. Climate change is a direct and substantial driver of changes in nature that also interacts with and magnifies the impacts of other drivers, such as land use change, overexploitation, habitat loss, pollution and invasive species. Evidences from the fossil record[16,17] demonstrate that changes in climate can have a profound influence on the myriad of species that comprise Earth's biodiversity. To date, climate change has had a relatively modest effect on ecosystems and biodiversity, compared to direct anthropogenic actions such as overharvesting and land use change resulting in habitat loss. This relative importance is already changing, and the negative ecological impacts of climate change are becoming more apparent and very likely to intensify over the coming decades. Predicted climate change over the coming century is therefore likely to have a significant influence on biodiversity.[18]

Now there are enough scientific studies to support the impact of climate change on biodiversity and the changes including poleward and upslope shifts in distribution, changes in disease risk, phenological responses, coral bleaching and regional and global impacts across taxa. A global warming estimate of 1.5°C to 2°C is projected to cause a decline in range size for the majority of terrestrial species, which in turn will heighten the risk of global extinctions. Nearly half of threatened land mammals (other than bats) and a quarter of threatened birds have potentially already been negatively impacted by climate change in some part of their range. The number of threatened species is predicted to increase due to climate change. The ability for species to respond to climate change will depend on their abilities to disperse, move to favorable conditions, or evolve. Changes in natural ecosystems threaten biodiversity worldwide, and have implications for global food production. The rapid decline of biodiversity and changes in climate are tightly intertwined: they share underlying direct and indirect drivers, they interact, and can have cascading and complex effects that impact people's good quality of life and compromise societal goals.[19]

IMPACT OF CLIMATE CHANGE ON BIODIVERSITY AND ECOSYSTEM SERVICES

The warming planet brings a cascade of changes and challenges. Rising temperatures disrupt the delicate balance of ecosystems, forcing life forms to shift their ranges northward or to higher elevations. One of the expected impacts of climate change on biodiversity is a shift in species' distributions toward the poles (i.e., northward shifts in the northern hemisphere, and southward shifts in the southern hemisphere). This is because climates generally get cooler moving away from the equator, so particular climate regimes will be expected to move toward higher latitudes under climate change. Hitch and Leberg (2007) provide a good example showing northward shifts in the breeding distributions of North American birds as a result of climate change.[20] As climate zones shift, many species are forced to migrate to more favorable conditions. However, not all species can move quickly or far enough to escape the changes. This can lead to local extinctions and changes in community composition. For example, montane species, which live on mountains, may be pushed higher up as temperatures rise, but they eventually run out of habitat. Similarly, marine species may move to cooler, deeper waters, affecting fisheries and the human communities that depend on them. Climate change exacerbates existing threats like habitat destruction, pollution and overexploitation. The rapid rate of environmental change outpaces the ability of many species to adapt, increasing their extinction risks. Studies predict that if current trends continue, at least one in six species could face extinction due to climate change. This loss of species diminishes the genetic diversity, which is crucial for ecosystem resilience and adaptability

The species which can't keep pace with the changing climate lead to local extinctions and a domino effect throughout the food chain. Climate change also intensifies extreme weather events like droughts, floods, and wildfires. These events devastate habitats and disrupt the lifecycles of countless species. Coral reefs, for example, bleach and die in warming waters, while intense fires scorch vast swathes of forests, wiping out entire communities. The oceans aren't spared either. Rising temperatures and increased carbon dioxide absorption are making them more acidic. This acidification disrupts the ability of shellfish and corals to build their shells and skeletons, jeopardizing the health of marine ecosystems.

Living organisms are the main actors in the global carbon cycle and play a central role in the dynamics of all the major greenhouse gases. However, it is not only the abundance of living organisms, but also their variety that matters. For example, diatom species richness in the ocean is intimately linked to the efficacy with which carbon from the atmosphere is sequestered in seafloor sediments.[21] On the land and in the ocean, the variety and specific types of soil and sediment biota influence biogeochemical cycling of nutrients and carbon[22,23], while the composition, variety and abundance of both plants and animals impact the carbon storage and cycle.[24-29] Increases in the greenhouse gas emissions, now exceeding 55 GtCO2 eyr"1, associated with fossil fuel combustion (84%) and land-use changes (16%) have altered atmospheric composition[30], and in turn the global climate system, influencing global temperatures, precipitation and the intensity and frequency of extreme weather events. Such climatic changes can act to exacerbate biodiversity decline, which can in turn, feedback to further impact climate.

Biodiversity underpins ecosystem services that are vital for human well-being, including food security, water purification, disease regulation and climate stabilization. As the biodiversity declines, definitely the related services of ecosystem will also suffer. Pollinators such as bees are essential for the production of many crops. Climate-induced changes in their populations can affect crop yields and food supply. Fish stocks are also affected by

changing ocean temperatures and acidification, impacting fisheries and communities that rely on them for sustenance and livelihoods. Forests and wetlands play a crucial role in water regulation by absorbing rainfall, reducing runoff and maintaining water quality. The degradation of these ecosystems due to climate change affects their ability to manage water resources, leading to more severe floods and droughts. Changes in climate can influence the distribution and prevalence of diseases. For instance, warmer temperatures can expand the range of vector-borne diseases like malaria and dengue fever, posing new health risks to human populations.

Increased temperatures and altered precipitation patterns can lead to more frequent and severe wildfires, pest infestations and diseases. These changes can reduce forest cover and degrade habitats, affecting countless species that rely on these environments. Rising sea temperatures and ocean acidification impact coral reefs, which are home to a quarter of all marine species. Coral bleaching, a stress response to elevated temperatures, results in the loss of coral cover and the biodiversity they support. Melting ice in the Arctic and Antarctic disrupts the habitat of polar bears, penguins and other species adapted to cold environments. Rising sea levels lead to loss of coastal habitats through coastal squeeze. Future losses of salt marsh and mudflats could have impacts on birds and invertebrates. Migratory birds may arrive at their breeding grounds at times when food resources are not yet available, leading to lower reproductive success and population declines.

Climate change will impact the diversity and structure of soil communities, leading to negative impacts on the movement of water and gases and also on the structure of the soil food web. Soil processes such as nitrogen mineralization, litter decomposition and soil respiration are sensitive to temperature and soil water content. This sensitivity results from changes in the composition and metabolism of soil communities and vegetation. Climate-driven changes in the diversity and structure of soil communities affect soil processes and physical properties (e.g. its porosity, which is increased by the action of earthworms). Increases in rainfall could lead to increased leaching of nutrients, changing plant community composition and causing nutrient enrichment of freshwaters

Phenology refers to the timing of biological events. Climate change can alter the timing of migration, breeding and flowering. Climate-driven mismatches in the phenology of plants and their pollinators have been observed. Changes in the seasonal timing and amount of precipitation could impact grassland species, affecting community composition. Rising temperatures have led to changes in composition of montane vegetation. Future decreases in mountain-top plant species may result due to competition from species of lower altitudes. Although potential exists for mismatches between flower production and peak pollinator availability, there is considerable flexibility in which species pollinate most plants; this could buffer the majority of plants from mismatches (at least in diverse communities).These shifts can disrupt ecological interactions. For instance, if plants bloom earlier than their pollinators emerge, both the plants and pollinators suffer, impacting the entire food web.

Temperature increase, increased frequency of droughts and floods and increased carbon dioxide will all result in significant changes in many plant communities. Some tree species are more sensitive to drought and rise in temperature. The increase in severity or frequency of climate change events such as warming and drought may lead to a change in structure and composition of different communities. A range of experiments has shown that changes in climatic factors affect the growth rates of plant species, altering interactions between species and also community composition. Climate change can alter the impact of plant-eating insects

on vegetation by increasing the insect population or changing the relative timing of insect emergence; for example, higher temperatures appear to increase the aphid population, with subsequent impacts on vegetation. Range shift and species colonization are likely to give rise to novel combinations of species and complex changes in food web interactions between, for example, plant species and herbivores, parasites and hosts. Changes in climatic conditions alter the way that different species compete for the same resources (e.g. food or living space) in an ecosystem, leading to shifts in species composition. Further changes in climate increase the risk of a breakdown in the synchrony between different species' life-cycle events. Food chain mismatches are most likely in highly seasonal species that depend on a synchronized food peak

Populations of many species are genetically adapted to local conditions, including climate. Climate-driven changes in phenology, species distributions and population sizes are already altering the amount and distribution of genetic diversity (i.e. the variation of genes found within a population or species, which represents the raw material for natural selection). Rapid genetic adjustments to warming have been observed in zooplankton and fish in freshwater systems, and are also likely to be occurring in other invertebrates and microorganisms. Genetic variation in some populations is enabling adaptive responses to environmental change. Genetic diversity is being reduced in many species. This increases the risk of inbreeding depression, reduces survival of individuals and restricts opportunities for evolutionary adaptation to changing conditions. These factors can exacerbate extinction risk. The rate of evolution will be unlikely to match climate change where genetic diversity is low, gene flow between populations is restricted, reproduction rates are low or generation times are long. Evolutionary (genetic) adaptation to climate change allow some populations to persist where the climate would otherwise become unsuitable, or to colonize new areas. Heavily fragmented landscapes that reduce gene flow between populations hamper genetic adaptation to new conditions even in some widespread species

THE WAY FORWARD

Protecting and restoring the habitats can enhance the ecosystem resilience. Establishing protected areas, restoring degraded ecosystems and implementing sustainable land-use practices are crucial steps in climate change scenario. Assisted migration, where species are relocated to more suitable habitats, can also help preserve biodiversity. Combating global warming by reducing greenhouse gas emissions through renewable energy, energy efficiency and reforestation efforts are essential to limit the extent of climate change. Supporting the carbon sequestration projects in forests, wetlands and agricultural lands also crucial in this regard. Importance of global cooperation and commitment to global agreements for biodiversity conservation is vital. Policies that integrate climate change and biodiversity considerations can foster more effective conservation strategies and international agreements and commitments to limit global temperature rise and address climate impacts on biodiversity is the key. Since the climate change is a global phenomenon, joint research, data generation, data analysis, predictions and modeling are essential to understand the future climate scenario and to develop conservation and restoration strategies. Raising awareness about the importance of biodiversity and the impacts of climate change can drive public support for climate action and will also bring community based conservation efforts.

CONCLUSION

The future of our planet's rich tapestry of life hinges on our ability to curb climate change. Mitigating greenhouse gas emissions is crucial, but so are efforts to protect and restore the

habitats. By creating corridors for migrating species and safeguarding remaining natural areas, we can help biodiversity adapt to the changing climate. The loss of biodiversity isn't just an environmental concern; it has significant consequences for human well-being and economy. Healthy ecosystems provide us with clean air and water, regulate climate, and offer essential services like pollination. As biodiversity declines, these services become compromised; threatening food security, water resources and even human health. By recognizing the gravity of the situation and taking decisive action, we can ensure a world teeming with life for generations to come. As International Day for Biological Diversity (2024) suggests, "Be part of the plan" which is a call of action for all stakeholders to implement the Kumming-Montreal Global Biodiversity Framework, also known as 'The Biodiversity Plan'.

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