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ABOUT US

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ASSESSING THE IMPACTS OF CLIMATE CHANGE ON BIODIVERSITY: AN EMPIRICAL STUDY

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ABSTRACT

Climate change represents a profound and escalating threat to the planet's biodiversity, driving an urgent need to evaluate its consequences and formulate adaptive conservation strategies. This study undertakes a thorough investigation into the multifaceted impacts of climate change on biodiversity, with a particular emphasis on critical dimensions including habitat degradation, the proliferation of invasive species, the identification of climate refugia, the role of local and indigenous communities, and the integration of policy frameworks. Drawing on a broad spectrum of empirical studies and theoretical insights, the paper explores the intricate relationships between climatic shifts and ecological responses. The findings reveal that building resilience in ecosystems requires a multifaceted approach, incorporating sustained ecological monitoring, cross-disciplinary scientific collaboration, and active stakeholder participation. The research concludes with a series of strategic recommendations aimed at guiding future inquiry and informing policy development to enhance biodiversity conservation amid accelerating climate change.

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1- INTRODUCTION

1.1 Introductory

Climate change stands as one of the most pressing global environmental challenges of our time, with far-reaching implications for the natural world. Among its myriad ecological consequences, the impact on biodiversity has emerged as a central concern for ecologists, conservation practitioners, and policy architects. As global temperatures rise and patterns of precipitation and extreme weather shift, it becomes increasingly imperative to unravel the complex interplay between climate dynamics and biological diversity. A robust understanding of these interactions is essential to inform sustainable environmental governance and long-term conservation efforts.¹

Biodiversity underpins the stability and functionality of ecosystems, contributing to the provision of critical services that support human livelihoods and planetary health. Yet, mounting scientific evidence reveals that climate-induced environmental changes are disrupting the delicate equilibrium of ecosystems. These disruptions manifest through altered species distributions, shifts in community composition, and changes in species interactions, all of which threaten the integrity of biodiversity on a global scale.²

This study seeks to systematically explore the wide-ranging effects of climate change on biodiversity. Key focus areas include phenological changes—such as alterations in the timing of reproduction, migration, and flowering—geographical shifts in species ranges, transformations in interspecies relationships, and modifications to ecosystem functions. Moreover, the research will delve into indirect pressures exerted by climate change, such as habitat loss, degradation, and fragmentation, especially when compounded by anthropogenic stressors like land-use change and environmental pollution.

Grasping the intricate and interconnected nature of these impacts is crucial for formulating adaptive and resilient conservation strategies. Through an integrative synthesis of current scientific literature, this review aims to provide a knowledge base that can support evidence-based decision-making by policymakers, conservationists, and other stakeholders committed to safeguarding biodiversity in an era of climate uncertainty.

¹ Dr. Bireshwar Bera, 'Investigating the Effects of Climate Change on Biodiversity' (2023), 10(1S) SFS 5924

² Dr. Bireshwar Bera, 'Investigating the Effects of Climate Change on Biodiversity' (2023), 10(1S) SFS 5924

1.2 Judicial Pronouncements

1. Lujan v. Defenders of Wildlife (1992):

-In this landmark case, the U.S. Supreme Court addressed the issue of standing in environmental cases. The Court held that plaintiffs must demonstrate concrete and particularized harm to themselves or the environment to have standing to sue. This ruling underscored the importance of legal standing in environmental litigation, including cases related to biodiversity loss due to climate change.³

2. MK Ranjitsinh et al. v. Union of India et al. (2019)

The Supreme Court of India addressed a writ petition concerning the protection of two endangered bird species, the Great Indian Bustard (GIB) and the Lesser Florican. This petition referenced an earlier Supreme Court judgment from April 19, 2021, which mandated the conversion of overhead power transmission lines to underground lines in specific territories to protect these birds. The Ministries of Environment, Forests and Climate Change, Power, and New and Renewable Energy requested a modification of this judgment, arguing that it would adversely affect the power sector and India's commitments under the Paris Agreement for renewable energy transition.

The Court had to balance two key issues: the modification of its previous directions and the preservation of the Great Indian Bustard alongside India's climate change commitments. The Court reviewed the threats to the Great Indian Bustards, actions by the Government of India such as the 'Habitat Improvement and Conservation Breeding of Great Indian Bustard' program, and the broader impacts of climate change.

The Supreme Court underscored the constitutional duties under Articles 48A and 51A for environmental protection and compassion for living creatures, linking these to Articles 21 and 14 which ensure the right to life, personal liberty, and equality before the law. It emphasized that the right to a clean environment and protection against climate change is embedded in these constitutional rights. Thus, the Court highlighted the intersection of conservation efforts for endangered species and the necessity of addressing climate change.⁴

³ *Lujan v. Defenders of Wildlife* (1992) 504 JUSTIA 555, SCOTUS

⁴ *MK Ranjitsinh et al. v. Union of India et al.*, Writ Petition (Civil) No. 838 of 2019

1.3 Emerging Areas

Climate change has emerged as one of the most urgent and complex environmental challenges confronting humanity in the 21st century. Its wide-ranging impacts are disrupting natural systems and human societies alike. Altered weather patterns are increasingly undermining food security, while rising sea levels are heightening the risk of widespread flooding and displacement. The scope and scale of these consequences are without precedent, underscoring the critical need for swift, coordinated, and ambitious action to reduce future risks and the economic costs of adaptation.

The scientific consensus attributes the primary cause of modern climate change to anthropogenic activities, particularly those dating back to the onset of the Industrial Revolution in the 1800s. The combustion of fossil fuels such as coal, oil, and natural gas has significantly elevated atmospheric concentrations of greenhouse gases (GHGs), especially carbon dioxide (CO₂). These gases trap infrared radiation, contributing to the greenhouse effect and driving global temperature increases. CO₂ alone is responsible for approximately two-thirds of all GHG emissions and is chiefly generated through energy production and industrial processes.

Recent analyses, including the United Nations Environment Programme's (UNEP) *Emissions Gap Report*, suggest marginal progress in emissions mitigation since the adoption of the Paris Agreement in 2015. Projections for 2030 GHG emissions have improved—from a previously anticipated 16% increase to a 3% rise. However, these improvements remain insufficient. To align with the Paris targets, emissions must be reduced by 28% for a 2°C warming trajectory and by 42% to remain within the 1.5°C threshold by 2030.

The current global temperature has already risen by approximately 1.1°C above pre-industrial levels, a direct result of over a century of carbon-intensive development and unsustainable resource exploitation. This warming is contributing to more frequent and severe extreme weather events, with dire implications for both human health and natural ecosystems. The intensification of heatwaves, storms, and heavy precipitation events underscores the vulnerability of socio-ecological systems. Climate-induced pressures on food and water security are projected to increase further, particularly when compounded by global challenges such as pandemics, political instability, and resource conflicts.

Addressing this crisis demands a rapid escalation in mitigation and adaptation efforts.

Emissions must begin to decline immediately and fall by nearly 50% by 2030 to stay on track for the 1.5°C limit. This target represents not only a scientific necessity but also a socio-political opportunity to transform global systems toward sustainability.

In its 2018 Special Report, the Intergovernmental Panel on Climate Change (IPCC) highlighted the profound benefits of limiting warming to 1.5°C. Doing so would reduce projected sea-level rise by approximately 10 centimeters by 2100 relative to a 2°C scenario. Additionally, the probability of experiencing an ice-free Arctic summer would decrease from once per decade to once per century. Perhaps most strikingly, coral reefs—vital marine ecosystems already under stress—would see losses limited to 70–90%, as opposed to the near-total collapse expected under a 2°C increase.

Achieving these goals will require transformational changes across all sectors of society, including energy, transportation, urban development, agriculture, and industry. Reducing net anthropogenic CO₂ emissions by approximately 45% from 2010 levels by 2030—and reaching net zero around mid-century—will be essential. This transition involves not only cutting emissions at the source but also investing in carbon removal technologies and nature-based solutions to restore atmospheric balance.⁵

1.4 Objectives

1. **To Understand Climate Change Impacts:** This paper aims to comprehensively examine climate change effects on biodiversity across ecosystems and scales, synthesizing empirical evidence to elucidate mechanisms and identify conservation priorities.
2. **To Identify Research Priorities:** Highlighting emerging areas and gaps in knowledge, the paper contributes to advancing scientific understanding and fostering interdisciplinary collaboration to address environmental challenges.
3. **To Raise Awareness:** Communicating scientific findings, the paper aims to raise awareness and foster public engagement for biodiversity conservation efforts at local, national, and global levels.

⁵ *Climate Change* [Welcome to United Nations], [https://www.un.org/en/global-issues/climate-change#:~:text=Climate%2Ddriven%20food%20and%20water%20insecurity%20is%20expected%20to%20grow&text=Each%20increment%20of%20warming%20results,for%20human%20health%20and%20ecosystems,\(accessed 27th May, 2024\)](https://www.un.org/en/global-issues/climate-change#:~:text=Climate%2Ddriven%20food%20and%20water%20insecurity%20is%20expected%20to%20grow&text=Each%20increment%20of%20warming%20results,for%20human%20health%20and%20ecosystems,(accessed 27th May, 2024))

1.5 Why Choose This Topic

Climate change poses a critical threat to global biodiversity, necessitating immediate attention. Research on this topic addresses a pressing environmental issue with profound implications for ecosystems and human well-being. Understanding the impact of climate change on biodiversity requires an interdisciplinary approach, incorporating insights from ecology, climatology, remote sensing, and conservation biology. This fosters collaboration across diverse fields, driving innovation and novel approaches to conservation.

The significance of biodiversity loss and climate change is global, with far-reaching consequences. Studying their effects on biodiversity informs policy and management decisions worldwide, advancing conservation efforts and sustaining ecosystem services on a global scale. Additionally, researching the intersection of climate change and biodiversity presents opportunities for innovation, from developing new modeling techniques to exploring innovative conservation strategies. Choosing this topic allows researchers to push scientific boundaries and creatively address complex environmental problems.

1.6 Hypothesis

Climate change is causing significant shifts in biodiversity patterns, leading to changes in species composition, distribution ranges, and ecosystem dynamics. We hypothesize that increasing temperatures and altered precipitation patterns will result in biodiversity loss, with certain species facing heightened extinction risk, while others may exhibit adaptive responses or range expansions in response to changing climatic conditions.

1.7 Research Questions

1. Are certain species becoming extinct due to climate change?
2. Is climate change affecting migration patterns of animals?
3. Does climate change impact the breeding habits of certain species?
4. Do we know if climate change affects the reproductive success of plant species?
5. Can climate change result in habitat loss for certain organisms?

1.8 Statement Of Problem

The intensifying threat that anthropogenic climate change poses to global biodiversity is both immediate and profound. As the Earth continues to warm at an unprecedented rate, the natural regulatory mechanisms of the climate system—such as glacial cycles and oceanic patterns—are unlikely to stabilize for centuries, even with aggressive mitigation. The persistence of

elevated greenhouse gas (GHG) concentrations in the atmosphere renders climate change an urgent present-day crisis rather than a distant environmental challenge. Observable ecological consequences are already widespread, including altered species phenology, shifts in geographic ranges, population declines, mass coral bleaching, increased wildfire incidence, and the collapse of entire ecosystems driven by glacial retreat and rising sea levels.

In response to these growing concerns, the conservation science community has significantly intensified its research efforts. Over the past decade, peer-reviewed publications addressing the intersection of climate change and biodiversity have grown at an average annual rate of 20%, reflecting a strong collective commitment to addressing this escalating challenge. Despite this surge in scholarship, a critical gap persists: most research remains narrowly focused on the direct ecological consequences of climate change, often neglecting the significant role of human adaptation strategies in shaping biodiversity outcomes.

Anthropogenic pressures such as habitat fragmentation, deforestation, and modified fire regimes have already compromised the resilience of many species, limiting their capacity to respond to climatic shifts. As human societies adapt to changing environmental conditions, these threats are poised to intensify or manifest in new forms, compounding the stress on ecosystems. For instance, the reduction of Arctic sea ice has enabled increased oil and gas exploration, exacerbating pressures on polar species and habitats. Similarly, changes in precipitation patterns in parts of sub-Saharan Africa have facilitated agricultural expansion into biodiversity hotspots like the Albertine Rift and Congo Basin, driving habitat loss and species displacement.

Moreover, extreme weather events, increasingly frequent under a warming climate, often provoke rapid and unanticipated human responses with severe ecological repercussions. Flooding, drought, and associated socio-economic displacement can result in the conversion of natural landscapes into agricultural or settlement zones, further degrading ecosystem services. In some regions, such crises have led to a surge in unsustainable practices such as poaching, as seen in southern and southeastern Asia, where flooding has undermined both local livelihoods and wildlife conservation efforts.

Even well-intentioned adaptive responses may inadvertently undermine biodiversity. For example, coastal defense measures such as seawall construction in Papua New Guinea, implemented to counteract sea-level rise, have resulted in the destruction of coral reefs—critical reservoirs of marine biodiversity. These examples highlight the complex and often overlooked interplay between human adaptive strategies and ecological degradation.

A paradigm shift is necessary in conservation science. Future research must expand beyond

projecting biophysical impacts to also anticipate how human behavioral responses to climate stressors will influence extinction risk and ecosystem resilience. Understanding how anthropogenic drivers of biodiversity loss will evolve—and identifying potential new threats—will be key to developing integrative, adaptive conservation strategies.

To achieve this, an interdisciplinary approach that unites ecology, climatology, and the social sciences is essential. Such collaboration will enhance our capacity to anticipate and mitigate the indirect effects of human adaptation on biodiversity. Without incorporating human behavior into conservation models, efforts to safeguard biodiversity under climate change risk being incomplete or misdirected.

Reflecting on past contributions in conservation literature, it becomes clear that a reorientation is necessary. Failure to consider the ecological ramifications of human adaptation may result in maladaptive conservation planning, missed opportunities for preemptive action, and avoidable biodiversity loss. Bridging this knowledge gap is imperative for crafting robust, future-proof strategies to conserve the planet's biological richness in a rapidly changing world.⁶

1.9 Limitations And Citations

1. The study's conclusions depend significantly on the availability and quality of data used in the analysis. If the data sources are limited, incomplete, or contain inaccuracies, this can impact the precision and reliability of the findings.
2. There may be selection bias in choosing which species, habitats, or ecosystems to analyze, potentially prioritizing certain taxa or regions over others. This bias could affect the study's comprehensiveness and representativeness.
3. Climate change projections and models are subject to uncertainties, such as assumptions about future greenhouse gas emissions, feedback mechanisms, and regional variations. These uncertainties can limit the precision of predictions about climate change's impacts on biodiversity.
4. Biodiversity is influenced by complex ecological interactions, including predator-prey relationships, competition, and symbiosis. The study may not fully account for these complexities, affecting the understanding of climate change's effects on biodiversity.
5. The study might focus on specific biodiversity indicators, like species richness or abundance, while overlooking other critical aspects such as genetic or functional

⁶ Watson, E. M. (2013), Human Responses to Climate Change will Seriously Impact Biodiversity Conservation: It's Time We Start Planning for Them, *Conservation Letters*, 7(1), (2013), 1-2, <https://doi.org/10.1111/conl.12083>, (accessed 27th May 2024)

diversity. This narrow focus could limit the study's overall comprehensiveness.

1.10 Citation

OSCOLA Citations

1.11 Data Collection

1. **PRIMARY DATA COLLECTION:** Primary data collection is conducted by distributing a Google form among university students to gather their opinions on the impacts of climate change on biodiversity.
2. **SECONDARY DATA COLLECTION:**
Secondary data collection is carried out by reviewing various research papers and articles authored by different experts in the field.
3. **TERTIARY DATA COLLECTION:**
Tertiary data collection is performed by examining information available on online webpages.

1.12 Chapterisation

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6. CONCLUSION

2- CLIMATE CHANGE AND INDIA

2.1 Observed Changes In Climate Over India

Temperature rise over India:

India has witnessed a notable warming trend, with average temperatures increasing by approximately 0.7°C between 1901 and 2018. This rise is largely driven by greenhouse gas emissions, although its full impact has been partially mitigated by anthropogenic aerosols and land use changes. Climate projections under the high-emission RCP8.5 scenario suggest that average temperatures could escalate by up to 4.4°C by the end of the 21st century, relative to the 1976–2005 baseline.

Over the past three decades (1986–2015), the annual temperature of the hottest days and coldest nights has risen by about 0.63°C and 0.4°C, respectively. These extremes are expected to increase further—by 4.7°C for the warmest days and 5.5°C for the coldest nights—by century's end. Correspondingly, the frequency of warm days and nights is projected to surge by 55% and 70%, respectively.

Summer heat waves (April–June) are anticipated to occur three to four times more frequently, with their average duration nearly doubling. This escalation in extreme heat events, combined with higher humidity levels, will significantly intensify heat stress, especially in vulnerable regions like the Indo-Gangetic and Indus river basins.⁷

⁷ Ministry of Earth Sciences and Government of India, *Assessment of climate change over the Indian region: A report of the Ministry of Earth Sciences (MoES), Government of India* Reliefweb, <https://reliefweb.int/report/india/assessment-climate-change-over-indian-region-report-ministry-earth-sciences-moes>, (accessed 25th May 2024)

Indian Ocean Warming:

The tropical Indian Ocean has undergone a pronounced rise in sea surface temperatures (SST), with an average increase of 1°C between 1951 and 2015—substantially exceeding the global SST average of 0.7°C during the same period. Concurrently, the ocean heat content in the upper 700 meters (OHC700) has exhibited a steady upward trend over the past six decades (1955–2015), with the most rapid warming occurring in the last two decades. Climate model projections suggest that both SST and ocean heat content in the region will continue to escalate throughout the 21st century, underscoring the Indian Ocean’s critical role in global and regional climate dynamic.⁸

Changes in Rainfall:

Between 1951 and 2015, India experienced an estimated 6% decline in summer monsoon rainfall, with the Indo-Gangetic Plains and Western Ghats witnessing the most pronounced decreases. This reduction is largely attributed to the cooling effects of anthropogenic aerosols over the Northern Hemisphere, which have offset the monsoon-enhancing influence of greenhouse gas-induced warming.

Recent decades (1981–2011) have also shown a 27% increase in dry spell frequency during the monsoon season, alongside more intense wet spells. Globally, rising atmospheric moisture levels have contributed to a surge in localized heavy rainfall events. In central India, for example, extreme rainfall days—exceeding 150 mm—have increased by approximately 75% since 1950.

Future projections using CMIP5 models suggest that, as aerosol emissions decline and global warming persists, India is likely to see greater monsoon rainfall variability and intensity, with a marked rise in extreme daily precipitation events by the end of the century.

Drought:

India has witnessed a notable rise in drought frequency and spatial extent over the past six to seven decades, primarily driven by the decline in seasonal summer monsoon rainfall. From 1951 to 2016, regions such as central India, the southwest coast, the southern peninsula, and the northeast experienced an average of more than two droughts per decade. During this period,

⁸ Ministry of Earth Sciences and Government of India, *Assessment of climate change over the Indian region: A report of the Ministry of Earth Sciences (MoES), Government of India* Reliefweb, <https://reliefweb.int/report/india/assessment-climate-change-over-indian-region-report-ministry-earth-sciences-moes>, (accessed 25th May 2024)

the area impacted by droughts expanded at a rate of approximately 1.3% per decade.

Future projections under the high-emission RCP8.5 scenario indicate a continued increase in drought frequency, severity, and coverage across the country by the end of the 21st century. These changes are linked to heightened monsoon variability and increased atmospheric moisture demand in a warming climate, underscoring the growing vulnerability of India's water and agricultural systems.⁹

Sea Level Rise:

Sea-level rise, driven by thermal expansion and melting land ice due to global warming, has become an increasingly pressing concern. In the North Indian Ocean (NIO), sea levels rose at a rate of 1.06–1.75 mm per year between 1874 and 2004. Over the past 25 years (1993–2017), this rate has accelerated to approximately 3.3 mm per year, matching the current global average.

Looking ahead, projections under the RCP4.5 emissions scenario suggest that the steric sea level in the NIO could rise by about 300 mm by the end of the 21st century, relative to the 1986–2005 baseline. This projected increase is significantly higher than the anticipated global mean sea-level rise of around 180 mm over the same period, highlighting the heightened vulnerability of the NIO region to climate-induced coastal impacts.

Tropical Cyclones:

Between 1951 and 2018, the North Indian Ocean (NIO) has experienced a decline in the overall annual frequency of tropical cyclones. However, this period has also seen a marked rise in the occurrence of very severe cyclonic storms (VSCSs), particularly during the post-monsoon season, with an increase of roughly one additional event per decade since 2000. Although these shifts are evident, a definitive connection to anthropogenic climate change remains unconfirmed.

Looking ahead, climate projections suggest a likely intensification of tropical cyclones in the NIO throughout the 21st century, raising concerns about escalating impacts on vulnerable coastal regions.

⁹ Ministry of Earth Sciences and Government of India, *Assessment of climate change over the Indian region: A report of the Ministry of Earth Sciences (MoES), Government of India* Reliefweb, <https://reliefweb.int/report/india/assessment-climate-change-over-indian-region-report-ministry-earth-sciences-moes>, (accessed 25th May 2024)

Changes in the Himalayas:

From 1951 to 2014, the Hindu Kush Himalayas (HKH) experienced a notable warming of approximately 1.3°C. This rise in temperature has contributed to reduced snowfall and widespread glacier retreat across much of the region in recent decades. However, the high-altitude Karakoram range has shown a contrasting trend, with increased winter snowfall helping to stabilize its glaciers.

Future climate projections under the RCP8.5 scenario indicate a significant rise in annual mean surface temperature across the HKH, potentially reaching around 5.2°C by the end of the 21st century. While the CMIP5 models project an overall increase in annual precipitation, snowfall is expected to decline, although projections vary considerably between models, reflecting the region's complex climate dynamics.¹⁰

2.2 Impact Of Climate Change On Key Resources

Climate change poses a profound threat to critical natural resources and the structural and functional stability of ecosystems, with far-reaching implications for both biodiversity and human well-being. Acting as an intensifying force, it exacerbates existing environmental stressors, placing additional pressure on already fragile ecosystems and the species they support. The accelerated rate of climatic change limits the capacity of many species to adapt or migrate, increasing the risk of population declines or extinctions.

Particularly at risk are ecosystems such as coral reefs, alpine and arctic habitats, and tropical regions, where climate-induced alterations may become irreversible. These ecosystems are not only biodiversity hotspots but also crucial to the enforcement and effectiveness of conservation policies. The potential for permanent loss in such systems underscores the urgent need for integrated climate and biodiversity governance frameworks to safeguard ecological resilience.¹¹

India's assessment of climate change impacts on biodiversity remains limited and often

¹⁰ Ministry of Earth Sciences and Government of India, *Assessment of climate change over the Indian region: A report of the Ministry of Earth Sciences (MoES), Government of India* Reliefweb, <https://reliefweb.int/report/india/assessment-climate-change-over-indian-region-report-ministry-earth-sciences-moes>, (accessed 25th May 2024)

¹¹ Joint Global Change Research Institute and Battelle Memorial Institute, *India: The Impact of Climate Change to 2030*, Office of the Director of National Intelligence, dni.gov/files/documents/climate2030_india.pdf, (accessed 25th May 2024)

depends on extrapolations from global or regional studies, resulting in an incomplete understanding of local ecological vulnerabilities. Foundational reviews by Sukumar et al. (2000) and Ravindranath et al. (2003) raised early concerns, particularly regarding forest ecosystems. One notable instance highlighting climate sensitivity was the 1997 El Niño, which elevated sea surface temperatures in the Indian Ocean and triggered extensive coral bleaching. This event disproportionately affected the biodiverse southern reefs, whereas northern reefs in the Gulf of Kutch—adapted to extreme salinity and heat—were relatively resilient.

Moreover, the increasing frequency of El Niño events and associated droughts is contributing to intensified human-wildlife conflict. Severe droughts have driven wildlife, such as elephants, into agricultural and residential areas in search of food and water. Historical examples include the 1982–83 and 1986–87 droughts, which saw elephant migrations into regions like Andhra Pradesh and southern West Bengal—areas from which they had long been absent. These patterns of conflict, as documented by Sukumar (1996, 2016), persist today, underscoring the need for localized, data-driven conservation strategies that consider both ecological and social dimensions.

Agricultural Growing Periods

India is already grappling with water scarcity across various regions, particularly in agriculturally productive areas of the North that depend heavily on spring snowmelt to sustain water availability. Climate projections suggest that snowmelt will occur earlier in the season, potentially reducing soil moisture during critical crop-growing periods and posing risks to agricultural productivity.

The retreat of Himalayan glaciers is a growing concern, with clear evidence of significant ice loss in glaciers such as Naimona'ny, which feeds major river systems like the Indus and Brahmaputra. Some glacier surfaces now exposed were last covered in 1944, and overall, Himalayan glaciers are receding at an alarming rate of 10–15 meters annually. This accelerated melting may initially increase river flows and cause flooding, but over time is expected to reduce streamflow, threatening both drinking water access and irrigation-dependent agriculture.

Concurrently, evapotranspiration rates have declined in recent decades, likely due to reduced solar radiation reaching the surface—a result of increased atmospheric aerosols, cloud cover,

and pollution. Additionally, heightened sulfur dioxide emissions have led to rising sulfate deposition on Himalayan glaciers, altering meltwater patterns and river dynamics.

Findings from the Indian Ocean Experiment have revealed that black carbon aerosols from the Indian subcontinent significantly absorb solar radiation, masking nearly half of the expected surface warming due to greenhouse gas emissions. These aerosols also influence precipitation patterns, disrupting both regional and global hydrological cycles. While the combined impact of aerosols and climate change on water resources and agriculture is evident, further research is crucial to unravel the complex interactions and inform adaptive strategies.¹²

3- INTER-LINKAGES BETWEEN HUMAN INDUCED ENVIRONMENTAL DEGRADATION, CLIMATE CHANGE AND BIODIVERSITY

3.1 LAND DEGRADATION, CLIMATE CHANGE AND BIODIVERSITY

Land degradation exerts both direct and indirect pressures on biodiversity across terrestrial, aquatic, and coastal environments. In terrestrial ecosystems, physical disturbances and chemical alterations degrade soil quality, harming vital soil organisms such as earthworms and mycorrhizal fungi, while also diminishing vegetative cover. In aquatic and coastal zones, degradation disrupts sediment transport, negatively affecting key habitats like coral reefs, mangroves, and seagrass beds. Additionally, persistent organic pollutants (POPs) bound to soil particles can amplify these adverse effects on biodiversity.

The consequences of land degradation extend beyond ecosystems: reduced agricultural productivity often compels farmers to convert more natural landscapes, further eroding biodiversity. Moreover, shifts in species composition, including the proliferation of invasive species, can accelerate land degradation processes.

Climate change compounds these challenges by altering vegetation patterns, soil conditions, and hydrological cycles. Adaptive responses to climate variability—such as shortened fallow periods, expansion of cultivation into fragile rangelands, and intensified irrigation—particularly in arid and semi-arid regions, can intensify land degradation. These intertwined dynamics underscore the complex feedback loops between climate change, land management

¹² Joint Global Change Research Institute and Battelle Memorial Institute, *India: The Impact of Climate Change to 2030*, Office of the Director of National Intelligence, dni.gov/files/documents/climate2030_india.pdf, (accessed 25th May 2024)

practices, and biodiversity loss.¹³

3.2 Water Degradation, Climate Change And Biodiversity

Water management practices—including withdrawals and flow alterations—significantly influence biodiversity and land productivity, particularly in agricultural landscapes and watershed regions. Degradation of water quality through pollution, siltation, canalization, and over-extraction disrupts critical ecological parameters such as natural flow regimes and water clarity, adversely impacting native aquatic species. These altered conditions often favor invasive species, which can outcompete or prey on indigenous populations, especially within marine and coastal ecosystems.

Eutrophication in freshwater and coastal waters presents a serious threat to biodiversity and fisheries, with overfishing and extractive industries like mining further contributing to declines in marine and coastal species diversity worldwide.

Climate change is intensifying the global hydrological cycle, altering the availability and quality of water resources crucial for domestic use, agriculture, industry, and hydropower. Variations in precipitation patterns, alongside an increase in extreme events such as floods and droughts, disrupt aquatic habitats and their biological communities. Additional climate-driven factors—including rising temperatures, changes in evapotranspiration, shifts in biogeochemical cycles, increased sediment loads, and altered fire regimes—compound pressures on water quality and ecosystem health. The escalation of extreme weather events is already evident and is projected to exacerbate these impacts, disrupting water flows, degrading quality, and elevating risks from invasive species.

Coastal zones are particularly vulnerable, facing threats from increased flooding, shoreline erosion, degradation of coral reefs and mangroves, and seawater intrusion into freshwater aquifers. These changes jeopardize critical habitats for migratory and resident species, such as birds and fish, potentially leading to population declines. Rising sea levels further threaten freshwater wetlands in low-lying coastal areas. Collectively, climate change poses profound direct and indirect challenges to aquatic ecosystems and their biodiversity, emphasizing the

¹³ Lokesh Chandra Dube and Dr Subodh Sharma, 'Climate Change and India: Impacts on Biodiversity', in AK Bhatnagar and Rupam Kapoor, (ed.), *Plant Diversity in India*, India, I.K. International Publishing House Pvt Ltd, 2018, p. 502-525

urgent need for integrated water resource and ecosystem management strategies.¹⁴

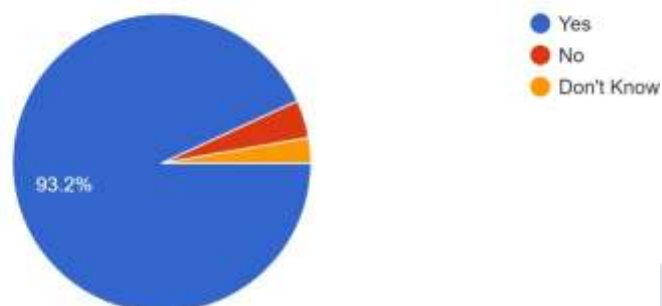
4- DATA COLLECTION

4.1 Data Collected And Explanation For The Data Collected

The following data were collected through Google Forms circulated among university students.

1. Are certain species becoming extinct due to climate change?

73 responses



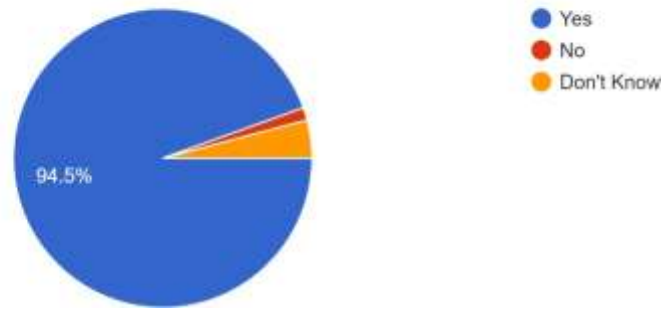
The fact that the majority of students voted 'yes' to the question indicates a high level of awareness among students regarding the impacts of climate change on biodiversity.

These responses indicate not only awareness of the situation but also suggest that students understand the severity and direct impact of climate change on global ecosystems. It reflects their recognition of the threat to various species and the broader implications for ecological balance and human societies. Furthermore, their responses indicate a concern for the environment and a recognition of the urgency to address climate change to mitigate further biodiversity loss.

¹⁴ Lokesh Chandra Dube and Dr Subodh Sharma, 'Climate Change and India: Impacts on Biodiversity', in AK Bhatnagar and Rupam Kapoor, (ed.), *Plant Diversity in India*, India, I.K. International Publishing House Pvt Ltd, 2018, p. 502-525

2. Is climate change affecting migration patterns of animals?

73 responses

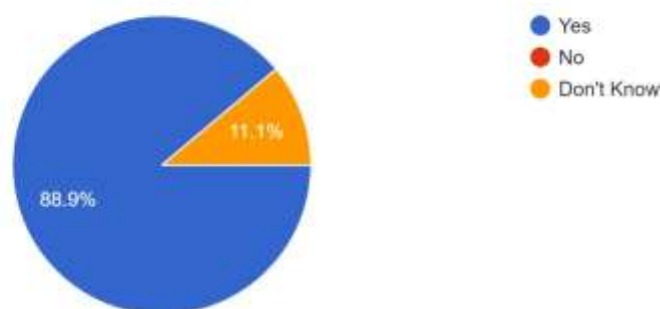


The fact that the majority of students voted 'yes' indicates a high level of awareness among students regarding this issue. It suggests that students are informed about the impacts of climate change on biodiversity and understand that it is influencing the migration patterns of animals.

Beyond awareness of the impacts of climate change on biodiversity, these responses also indicate that students recognize the broader ecological implications of climate change. They understand that changes in animal migration patterns are a direct consequence of climate change, which can lead to shifts in ecosystems, changes in species distributions, and potential disruptions to ecological processes. This level of understanding suggests that students are aware of the interconnectedness of environmental systems and the cascading effects of climate change on biodiversity and ecosystems.

3. Does climate change impact the breeding habits of certain species?

72 responses



The responses indicate more than just awareness of the impacts of climate change on biodiversity. They suggest varying levels of understanding and engagement with the topic among students:

1.Awareness of Impacts: The majority of students voting "yes" indicates a general understanding among students that climate change affects the breeding habits of certain

species. This suggests awareness of the ecological impacts of climate change on wildlife.

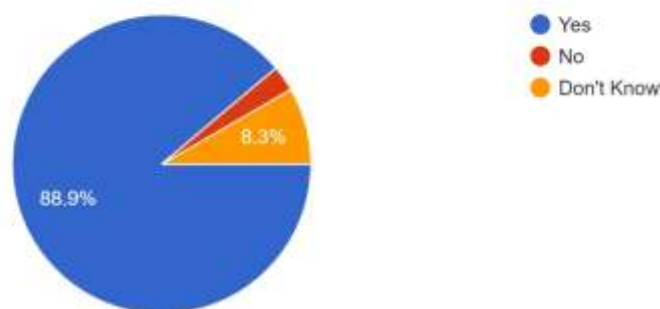
2. Uncertainty and Need for Education: The students who voted "don't know" indicate a lack of awareness or uncertainty about the specific impacts of climate change on breeding habits.

This highlights the need for further education and information dissemination on the subject.

In summary, the responses not only reflect awareness of the impacts of climate change on biodiversity but also highlight areas where further education and engagement can lead to increased understanding and advocacy among students.

4. Can climate change lead to shifts in ecosystems?

72 responses



These responses indicate more than just students' awareness of the impacts of climate change on biodiversity. They suggest a range of attitudes and understanding levels among students regarding climate change:

1. Awareness and Concern: The majority of students who voted 'yes' likely demonstrate awareness and concern about the potential for climate change to cause shifts in ecosystems. They recognize that climate change can alter habitats, disrupt species distributions, and impact biodiversity.

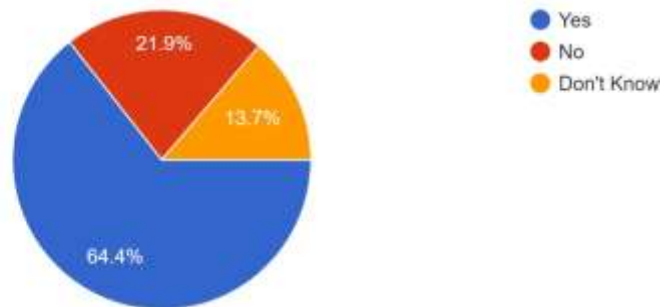
2. Uncertainty and Lack of Information: Students who voted 'don't know' may indicate uncertainty about the specifics of how climate change affects ecosystems. This could suggest a need for more information and education on the topic.

3. Skepticism or Disbelief: Students who voted 'No' might indicate skepticism or disbelief in the connection between climate change and ecosystem shifts. This could be due to misinformation, lack of understanding, or skepticism towards climate science.

4. Need for Education and Awareness: Overall, the responses highlight the importance of education and awareness campaigns about climate change. There is a need to further educate students about the impacts of climate change on ecosystems, biodiversity, and the environment as a whole.

5. Are some species able to adapt to climate change?

73 responses



The responses from the students indicate several things:

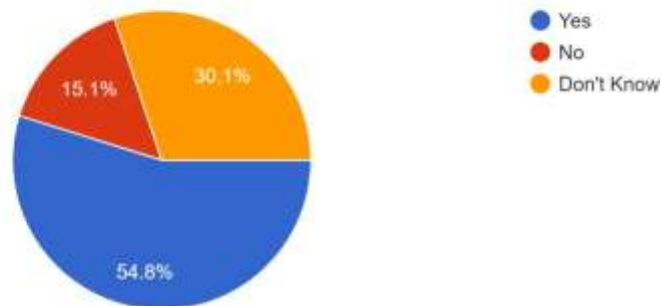
- 1. Awareness of Adaptation Potential:** The majority of students (64.4%) believe that some species are able to adapt to climate change. This suggests that these students are aware or at least optimistic about the adaptive capacity of certain species to cope with changing environmental conditions.
- 2. Uncertainty and Lack of Knowledge:** A significant portion (13.7%) of students responded with "don't know". This indicates a level of uncertainty or lack of knowledge about whether species can adapt to climate change, possibly reflecting a need for more education or information on this topic.
- 3. Concern and Pessimism:** About 21.9% of students voted "No", suggesting a belief that species are not able to adapt to climate change. This response could indicate concern or pessimism about the ability of biodiversity to withstand or adapt to the ongoing changes.

Apart from awareness of the impacts of climate change on biodiversity, these responses also indicate the students' perceptions regarding:

- **Scientific Understanding:** The level of understanding about the ability of species to adapt to climate change.
- **Educational Needs:** The need for further education and information on biodiversity and climate change adaptation.
- **Attitudes and Values:** Their attitudes and values regarding environmental resilience and the future of biodiversity in a changing climate.

6. Does climate change contribute to the spread of invasive species?

73 responses

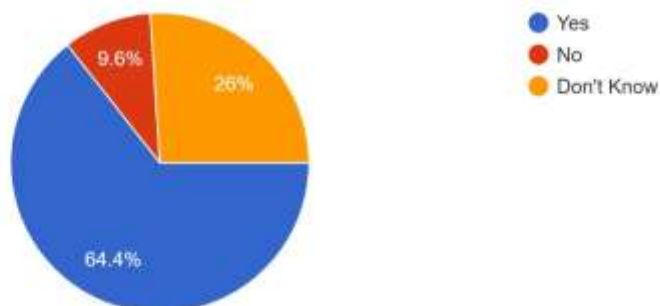


The responses to the question "Does climate change contribute to the spread of invasive species?" indicate varying levels of awareness among students. The majority (54.8%) acknowledging that climate change does contribute to the spread of invasive species suggests a significant awareness of this issue among students. However, the 30.1% who responded with "don't know" may indicate a lack of knowledge or uncertainty about the specific link between climate change and invasive species spread. Additionally, the 15.1% who voted "No" may suggest a misunderstanding or lack of awareness about the scientific consensus regarding this relationship.

Beyond awareness of the impacts of climate change on biodiversity, these responses may also indicate students' understanding of ecological concepts, their engagement with scientific literature or educational materials on climate change and invasive species, and their ability to critically evaluate environmental issues. Additionally, it may reflect the effectiveness of educational initiatives or campaigns aimed at raising awareness about the intersection of climate change and biodiversity conservation.

7. Do we know if climate change affects the reproductive success of plant species?

73 responses

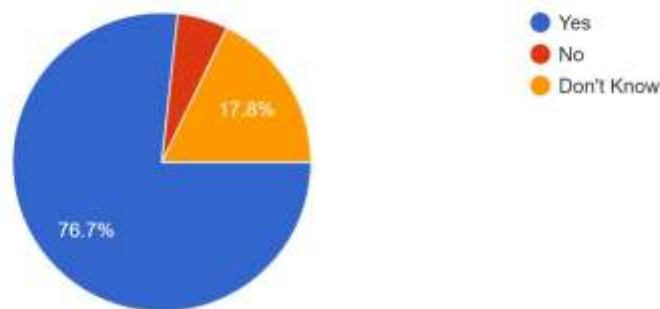


The responses to the question regarding the awareness of students about whether climate

change affects the reproductive success of plant species indicate several things:

1. **High Awareness about Climate Change Impacts:** The fact that 64.4% of students voted 'yes' suggests a significant level of awareness among the student population regarding the impacts of climate change on the reproductive success of plant species. This indicates that a large majority of students recognize the link between climate change and its effects on plant biology.
2. **Uncertainty and Knowledge Gaps:** The 26% of students who voted 'don't know' highlights some uncertainty or lack of knowledge among a considerable portion of the student body. This suggests that there are gaps in understanding about the specific impacts of climate change on plant reproductive success.
3. **Misconceptions or Lack of Awareness:** The 9.6% of students who voted 'No' may indicate a smaller group of students who are either misinformed or lack awareness of the scientific consensus regarding climate change impacts on plant species.
4. **Overall Awareness Levels:** Collectively, these responses indicate a mixed level of awareness among students regarding the specific impact of climate change on plant reproductive success. While a majority understand this impact, there is a notable percentage that either does not know or holds misconceptions.

8. Is it known whether certain plant species will thrive or decline due to climate change?
73 responses



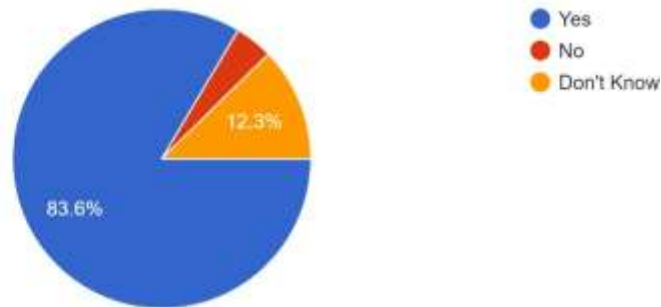
The responses from the students indicate a fairly high level of awareness regarding the impacts of climate change on plant species:

- 76.7% voted 'yes': This indicates that a significant majority of students are aware that certain plant species are likely to either thrive or decline due to climate change. This awareness suggests that they understand the potential impacts of climate change on biodiversity, specifically regarding plant species.
- 17.8% voted 'don't know': While this portion is smaller, it suggests that there is still a segment of students who are uncertain about the impacts of climate change on plant species. This could indicate a need for further education or information on this topic.

- Rest voted 'No': This minority suggests that a small portion of students do not believe that climate change will have any impact on certain plant species. This could reflect differing beliefs or a lack of understanding about the potential effects of climate change.

9. Is climate change affecting the availability of food sources for wildlife?

73 responses



The responses indicate a high level of awareness among students regarding the impact of climate change on the availability of food sources for wildlife. Specifically:

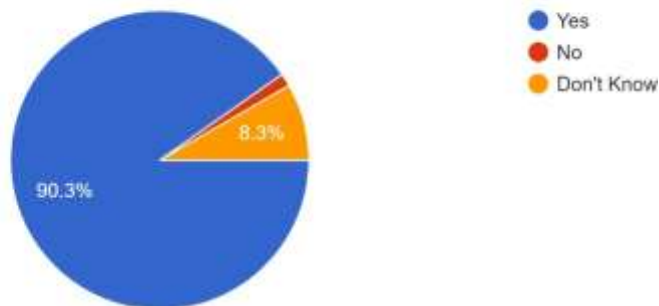
- 83.6% voting 'yes': This shows that a significant majority of students believe that climate change is affecting food sources for wildlife. This indicates a strong awareness of the environmental consequences of climate change, particularly in relation to wildlife and biodiversity.

- 12.3% voting 'don't know': While a smaller percentage, this group represents students who are unsure or may need more information about the issue. It highlights the need for further education and awareness-building regarding the impacts of climate change on biodiversity.

- Remaining students voting 'No': This small percentage suggests that there is a minority of students who do not believe climate change is impacting food sources for wildlife. This could indicate varying levels of understanding or skepticism about the issue among the student population.

10. Can climate change result in habitat loss for certain organisms?

72 responses

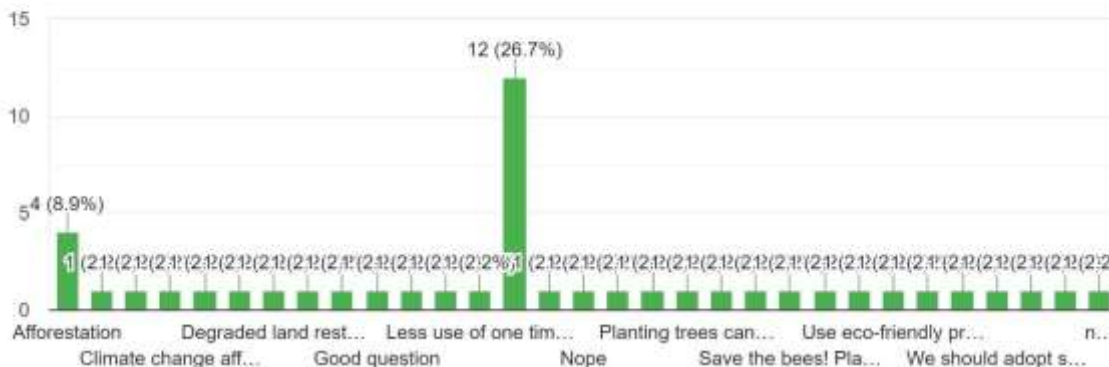


The responses indicate a high level of awareness among students regarding the impacts of climate change on biodiversity. Specifically:

- High Awareness of Habitat Loss: The overwhelming majority (90.3%) of students recognize that climate change can result in habitat loss for certain organisms. This shows that a significant portion of students are aware of the direct impact of climate change on habitats and ecosystems.
- Recognition of Uncertainty: A small proportion (8.3%) of students responded with 'don't know', indicating an acknowledgment of the complexity and uncertainty surrounding some aspects of climate change impacts. This suggests an understanding that there are still uncertainties in scientific knowledge and the need for further research.
- Low Denial Rate: A very small percentage of students (1.4% based on the provided numbers) voted 'No', indicating a low level of denial or skepticism about the impacts of climate change on habitat loss. This reflects a generally accepted understanding among the student population that climate change is indeed affecting habitats.

11. Any suggestions?

45 responses



4.2 Answers For Research Questions

1. Are certain species becoming extinct due to climate change?

Answer 1. Introduction:

The world hosts a remarkable diversity of plants and animals, making it crucial to protect these ecosystems from the harmful impacts of climate change. Unfortunately, for some species, our efforts come too late, as they have already become extinct. According to the International Union for Conservation of Nature (IUCN), 882 plants and animals are confirmed extinct, but this number doesn't tell the whole story.

Extent of Extinction:

The Bramble Cay melomys, declared extinct in 2019, marked the first recognized mammalian extinction. These small creatures were known to inhabit a tiny island near Papua New Guinea's coast, but rising sea levels have reduced their habitat by nearly 97%. The Torres Strait, where they lived, experiences sea level rise at almost twice the global average rate, endangering many habitats and the species that depend on them.

The Bramble Cay melomys represents a sad milestone in documented extinctions. However, tracking extinctions is challenging, and many species go extinct before being officially identified. The IUCN has identified over 2.15 million species so far. Additionally, there are many species categorized as 'extinct in the wild' (EW) by the IUCN, indicating they survive only in cultivation, captivity, or naturalized populations far outside their original range, which is the last category before extinction.

Currently, more than 80 animals are classified as EW. Examples include Père David's deer, Hawaiian crow, Franklin tree, and Wyoming toad.

Causes of Extinction due to Climate Change:

Historically, extinction is a natural process, but current extinction rates are 1,000 to 10,000 times faster than the natural rate, and these rates continue to accelerate. The primary drivers of biodiversity loss are overfishing, pollution, and climate change, with habitat destruction being the most significant factor. Overfishing leads to unsustainable fishing practices, causing declines in fish populations and affecting entire marine ecosystems, including unintended catches like turtles and dolphins. Over a third of fish stocks are being harvested at unsustainable levels, and live coral cover on reefs has decreased by over 50% since 1870.

Climate change contributes to extinction by raising global temperatures, making traditional habitats unsuitable for species. Many species are forced to adapt or move to survive, putting them under severe pressure.¹⁵

In addition to these causes, scientists have identified proximate causes directly resulting from climate change, such as heat avoidance behaviors, loss of host and pollinator species due to climate change, and the positive impacts of climate change on pathogens and competitors.

Habitat Loss:

Pollution, overfishing, and climate change contribute to habitat loss, the biggest driver of declining biodiversity and rising extinction rates. Human activities have severely altered 75% of the earth's land surfaces. Deforestation, particularly in the Amazon, is a clear example of habitat destruction.

To Combat This:

Nature-based solutions are effective in combating habitat loss. They involve nurturing and protecting ecosystems and habitats to mitigate the impacts of enhanced greenhouse gas emissions. By preserving and restoring ecosystems, we can sequester carbon more efficiently and sustainably while protecting biodiversity.

Threat to Humanity:

The natural world is interconnected, so the extinction of one species directly affects others. Habitat destruction and land clearance can increase the spread of diseases like COVID-19. The close interactions between humans and animals due to land clearances are becoming more common, facilitating the spread of infections and diseases across species. Many scientists and ecologists agree that endangering other life on Earth amplifies the effects of climate change, endangering humanity itself.

Conclusion:

As of now, the IUCN Red List notes over 900 extinct species and more than 80 species extinct in the wild. Additionally, over 16,000 species are labeled as vulnerable, over 17,000 as endangered, and over 9,000 as critically endangered. While these numbers may be surprising,

¹⁵ Tom Haddon, *How Many Species Extinct Due to Climate Change*, Earthly, <https://earthly.org/how-many-species-are-extinct-due-to-climate-change>, (accessed 1st June 2024)

they underscore the importance of protecting all species, not just flagship or popular animals, for thriving ecosystems.

Nature-based solutions offer a holistic approach to protecting ecosystems and preventing extinctions. When all plants and animals are valued for their role within their habitats, they are more likely to survive and thrive. It's crucial to recognize that we have the power to shape the future of our planet and its biodiversity to prevent extinctions.¹⁶

2. Is climate change affecting migration patterns of animals?

Answer 2. Movement is a critical aspect of animal ecology, influencing individual fitness and population persistence through activities such as foraging, predation, behavioral interactions, and migration. Migration, in particular, plays a significant role in biodiversity at regional and global scales, affecting ecosystem processes. Animals rely on predictable environmental cues for the timing and navigation of migration, which are crucial for their phenology and migration extent. For instance, the timing of arrival and hatching in migrating birds, influenced by global warming, has been integrated into a recent mathematical model.

Elevated temperatures lead to earlier emergence of insect prey for hatchling birds, compelling birds to breed earlier to coincide with peak prey abundance. This advanced breeding depends on the arrival of adults at the breeding site and the interval between arrival and the start of breeding. These traits can change synchronously or asynchronously, and a mismatch between prey abundance and hatching can cause population declines. A mathematical model explores these interactions and their evolutionary pathways, explaining patterns observed in European flycatchers.

Conversely, migratory birds from the Palearctic departing their non-breeding grounds in Africa also appear to be departing earlier. Consequently, there is a global shift in arrival and departure times affecting migratory bird movement and local abundance due to climate warming.

Changes in the phenology of migration in endothermic birds are connected to the abundance of their ectothermic prey. While endotherms are directly affected by temperature changes, impacting their metabolic demands for thermoregulation, these effects are more pronounced in ectotherms. Ectotherms like invertebrates and fish have body temperatures and physiology

¹⁶ Tom Haddon, *How Many Species Extinct Due to Climate Change*, Earthly, <https://earthly.org/how-many-species-are-extinct-due-to-climate-change>, (accessed 1st June 2024)

closely linked to environmental temperatures. Climate warming thus influences their metabolism and physiological processes directly, affecting movement and migration.

The proximate mechanisms enabling movement include physiological functions providing energy to muscles and the muscles themselves converting chemical energy (ATP) into work. Temperature influences all physiological processes, with optimal rates typically achieved within a narrow temperature range. Extreme temperatures, either low or high, can halt physiological functions, leading to mortality. Even at more moderate temperatures diverging from the optimal range, decreased physiological performance increases the risk of ecological failure by impairing movement. Therefore, changing environmental temperatures, including those resulting from anthropogenic global warming, impact migration and other ecological processes through the thermal sensitivity of physiological processes.¹⁷

A new theoretical model suggests that metabolic constraints exacerbate the effect of temperature on the metabolic costs of migration in Chinook salmon. These salmon migrate hundreds of kilometers from their natal riverine areas to the ocean and back for spawning. Salmon prefer relatively cool water, and rising water temperatures compromise their cardiovascular and metabolic physiology. However, the need to replenish metabolic substrates, particularly glycogen, during their migration exacerbates the effects of warm water. This necessity to rest in tranquil warm water to replenish substrates increases migration times, exposing them to warm waters longer. The replenishment of substrates and increased exposure to warm water reduce metabolic scope, the energy available for migration, as metabolic maintenance costs rise in warmer water. These physiological dynamics indicate that climate warming along the North American west coast has already impacted salmon migration.

Similarly to birds, a recent study showed that the phenology of aphid migration in the UK has changed due to climate change. Data collected over 770 trap-years in the past 50 years indicated that over 55 species of aphids started flying progressively earlier in the year, with most species showing an increasing duration of their flying season. The severity of the previous winter best predicted the onset of the subsequent flying season, and the number of days above 16°C predicted flying behavior later in the year. Correlations between phenological changes

¹⁷ Frank Seebacher and Eric Post, Climate Change Impacts on Animal Migration, *Climate Change Responses*, no. 2, 2015, pp. 1-2, <https://climatechangeresponses.biomedcentral.com/articles/10.1186/s40665-015-0013-9#citeas>, (accessed 1st June 2024)

and climate change are essential starting points that require follow-up with experimental approaches to determine cause-and-effect relationships between climate change and animal responses. The strength of salmon studies lies in the identification of at least some mechanistic bases for climate-dependent changes in migration patterns, making it possible to experimentally determine the thermal sensitivity of cardiovascular function and metabolism and use this data to predict the effects of future or regional climate change.

In addition to shifts in the phenology of migrating animals, some species have reduced their migratory behavior or even formed sedentary populations due to anthropogenic environmental changes. A recent study also demonstrated that changes in migratory behavior alter the incidence and transmission of infectious diseases. Migration can reduce disease incidence by periodically removing individuals from contaminated habitats, increasing spatial separation during migration, and causing infected individuals to succumb to demanding long- distance movements. Monarch butterflies in the US have significantly altered their migratory behavior in recent years due to habitat changes, with an increasing incidence of sedentary, non-migratory populations. Non- migratory populations have a significantly higher infection rate with the protozoan *Ophryocystis elektroscirrha* compared to migratory populations, resulting in significantly reduced lifespans. Changes in animal movement and migration due to habitat modification and climate change may therefore alter individual lifetime fitness in addition to regional and global biodiversity and ecosystem processes.¹⁸

3. Does climate change impact the breeding habits of certain species?

Answer 3. The environment plays a crucial role in the health and reproductive success of animals, affecting their physiology and behavior. Among the various environmental factors, climatic conditions such as temperature, humidity, radiation, and wind are particularly influential. Extremes in these climatic factors disrupt the exchange of energy between animals and their surroundings, which can have detrimental effects on reproduction.¹⁹

Seasonal variations in environmental conditions, as well as changes in nutrition and

¹⁸ Frank Seebacher and Eric Post, Climate Change Impacts on Animal Migration, *Climate Change Responses*, no. 2, 2015, pp. 1-2, <https://climatechangeresponses.biomedcentral.com/articles/10.1186/s40665-015-0013-9#citeas>, (accessed 1st June 2024)

¹⁹ F.C. Gwazduaskas, Effects of Climate on Reproduction in Cattle, *Journal of Dairy Science*, no. 68, 1985, pp. 1568-1578, [https://www.journalofdairyscience.org/article/S0022-0302\(85\)80995-4/fulltext#:~:text=Animal%20environment%20is%20affected%20by,and%20can%20affect%20deleteriously%20reproduction](https://www.journalofdairyscience.org/article/S0022-0302(85)80995-4/fulltext#:~:text=Animal%20environment%20is%20affected%20by,and%20can%20affect%20deleteriously%20reproduction), (accessed 1st June 2024)

management practices, significantly influence the reproductive cycles of animals. For instance, changes in the duration and intensity of daylight (photoperiod), which vary with the seasons, can impact the timing and duration of estrous cycles in females. The estrous cycle refers to the recurring physiological changes that occur in sexually mature female mammals, which are necessary for reproduction.

High temperatures (hyperthermia) and low temperatures (cold stress) both adversely affect reproductive outcomes. Heat stress, for example, reduces adrenal function, which can help animals cope with environmental challenges due to reduced calorogenic effects of glucocorticoids. Glucocorticoids are a class of steroid hormones involved in various metabolic processes, including stress response. During periods of heat stress, lower levels of estrogens are observed, particularly during the proestrus to metestrus period of the estrous cycle and late gestation. This can result in shorter estrus duration and lower birth weights of calves, impacting reproductive success.

In males, seasonal variations and exposure to extreme temperatures can alter endocrine profiles, affecting fertility. Spermatogenesis, the process of sperm production, is particularly vulnerable to heat stress, leading to impaired sperm production. Testosterone levels, crucial for male reproductive function, can also decrease during early exposure to hyperthermia.

While environmental modifications can mitigate some of the effects of heat and cold stress, further research is necessary. Experimental studies using environmental indices are essential to understand the interactive effects of climatic factors on animal reproduction. These studies can help in developing strategies to optimize animal management practices and mitigate the adverse effects of climate change on animal health and reproductive success.²⁰

4. Do we know if climate change affects the reproductive success of plant species?

Answer 4. Climate change can affect plant populations both directly, by influencing their fitness, and indirectly through changes in biotic interactions. For example, climate change can directly impact plant reproduction by altering the availability of resources needed for flower, fruit, and seed production (Eckert et al., 2010; Hedhly et al., 2009; Koti et al., 2005; Takkis et

²⁰ F.C. Gwazduaskas, Effects of Climate on Reproduction in Cattle, *Journal of Dairy Science*, no. 68, 1985, pp. 1568-1578, [https://www.journalofdairyscience.org/article/S0022-0302\(85\)80995-4/fulltext#:~:text=Animal%20environment%20is%20affected%20by,and%20can%20affect%20deleteriously%20reproduction,\(accessed 1st June 2024\)](https://www.journalofdairyscience.org/article/S0022-0302(85)80995-4/fulltext#:~:text=Animal%20environment%20is%20affected%20by,and%20can%20affect%20deleteriously%20reproduction,(accessed%201%20st%20June%202024))

al., 2015). In temperate grassland ecosystems, water availability is often the most critical abiotic factor affecting plant fitness (Lambers & Oliveira, 2008), and climate change is expected to alter precipitation patterns, which vary in space and time across different regions and seasons (Dore, 2005; Hundsdoerfer & Bárdossy, 2005; IPCC, 2014; Kudo & Cooper, 2019; Stocker et al., 2013). For instance, in Central Germany, climate models project drier summers and wetter falls in the future (Döscher et al., 2002; Jacob & Podzun, 1997; Rockel et al., 2008; Wagner et al., 2013).²¹

Indirectly, climate change can influence plant reproduction by affecting the services provided by animal pollinators, upon which 87.5% of flowering plants depend (Ollerton et al., 2011). There is evidence linking climate change to declines in pollinator abundance and diversity, as well as shifts in their flight periods (Giannini et al., 2017; Knight et al., 2018; Scaven & Rafferty, 2013; Settele et al., 2016).

According to the multiple limitation theory, plants are thought to evolve to be equally constrained by pollen and resources (e.g., water; Haig & Westoby, 1988). In a given environment, their traits should lead them to allocate optimal amounts of resources to attract pollinators to maximize seed production, which also requires resources for seed maturation. Therefore, an increase in precipitation (and thus water resources) might lead to pollen limitation in plant reproduction if pollinators cannot provide adequate pollination relative to the available resources. Conversely, decreases in precipitation might make plant reproduction more resource-limited, meaning that adding more pollen would not necessarily increase reproductive success. Thus, under extreme precipitation events, we might expect a positive relationship between precipitation and pollen limitation, and a positive but saturating relationship between precipitation and offspring production. However, extremely high precipitation could physiologically stress plants, resulting in a hump-shaped function where increased water resources lead to a decrease in the number or quality of offspring.

Pollen supplementation experiments, which measure how plant reproduction responds to experimental pollen addition, often find that plants are significantly pollen-limited (Bennett et al., 2020; Burd, 1994; Knight et al., 2005; Larson & Barrett, 2000). This limitation could arise

²¹ Andrzejak, M., Korell, L., Auge, H., & Knight, T. M., Effects of climate change and pollen supplementation on the reproductive success of two grassland plant species, *Ecology and Evolution*, 12(1), 2022, pp. e8501, <https://doi.org/10.1002/ece3.8501>, (accessed 1st June 2024)

from natural variation in resources and pollen availability across space and time, or from anthropogenic factors such as climate change that push plants away from their evolved optima (Ashman et al., 2004; Bennett et al., 2020; Knight et al., 2018). However, to date, no studies have quantified pollen limitation within the context of changing climate and resource availability, manipulated according to regionally realistic climate change scenarios projected by regional climate models (Korell et al., 2020).

While the understanding of how resources and pollen influence plant reproductive success has a long history (Bierzychudek, 1981; Haig & Westoby, 1988), this topic is increasingly relevant for predicting and understanding plant responses to climate change. A few studies have experimentally manipulated both resources and pollen, expecting interactive effects on plant reproductive success (Brookes & Jesson, 2007; Campbell & Halama, 2012; Ne'eman et al., 2006). However, these factorial studies did not find significant interactions, possibly due to heterogeneity across studies in the types of resources considered and the methods used for resource manipulation. As a result, there is currently no comprehensive understanding of how pollen and resources jointly influence plant reproductive success.²²

5. Can climate change result in habitat loss for certain organisms?

Answer 5. The loss of habitat is one of the most significant consequences of climate change on wildlife. Rising temperatures and shifting rainfall patterns are causing profound changes in many ecosystems, resulting in habitat loss for numerous species. For instance, as temperatures increase, polar ice caps are melting, leading to the disappearance of habitat for animals like polar bears, walruses, and seals.

This loss of habitat can have serious repercussions for wildlife populations. Many species depend on specific habitats for essential activities such as finding food, shelter, and breeding grounds. Changes in these habitats can disrupt these critical functions. If a species loses its habitat due to climate change, it may be compelled to migrate to a new area where it might struggle to find sufficient food or suitable shelter.

Moreover, habitat loss can result in fragmentation, where a habitat is divided into smaller,

²² Andrzejak, M., Korell, L., Auge, H., & Knight, T. M., Effects of climate change and pollen supplementation on the reproductive success of two grassland plant species, *Ecology and Evolution*, 12(1), 2022, pp. e8501, <https://doi.org/10.1002/ece3.8501>, (accessed 1st June 2024)

isolated fragments. This fragmentation can make it harder for species to locate adequate food, mates, and shelter, and can increase their vulnerability to predators and other dangers. It can also lead to genetic isolation, reducing genetic diversity and potentially raising the risk of inbreeding depression.

Beyond its direct impact on wildlife populations, habitat loss can also have broader implications for ecosystems and the services they provide to humans. Ecosystems are intricate networks of species and processes that offer vital services like pollination, nutrient cycling, and water purification.²³

5- ACTIONS TO PROTECT BIODIVERSITY FROM THE ADVERSE IMPACTS OF CLIMATE CHANGE

5.1 International Actions

Decision IX/16B of the Conference of the Parties to the Convention on Biological Diversity (CBD) established the Ad Hoc Technical Expert Group (AHTEG) on Biodiversity and Climate Change as part of the COP initiative. The AHTEG's purpose is to provide scientific and technical advice on integrating biodiversity considerations into climate change mitigation and adaptation efforts. This includes:

- i. Proposing ways to enhance the integration of biodiversity and traditional knowledge into impact and vulnerability assessments, especially for communities and sectors vulnerable to climate change.
- ii. Identifying opportunities and potential negative impacts on biodiversity, its conservation, sustainable use, and the livelihoods of indigenous and local communities related to reducing emissions from deforestation and forest degradation.
- iii. Identifying options to ensure actions to reduce emissions from deforestation and forest degradation support the objectives of biodiversity conservation and sustainable use.

Due to advancements in scientific understanding of the relationship between biodiversity and

²³ DrishtiIas, The Impact of Climate Change on Wildlife, *Drishti IAS Blog*, [https://www.drishtiias.com/blog/the-impact-of-climate-change-on-wildlife#:~:text=As%20temperatures%20rise%20and%20rainfall,bears%2C%20walruses%2C%20and%20seals,\(accessed 1st June 2024\)](https://www.drishtiias.com/blog/the-impact-of-climate-change-on-wildlife#:~:text=As%20temperatures%20rise%20and%20rainfall,bears%2C%20walruses%2C%20and%20seals,(accessed%201%20st%20June%202024))

climate change, a second AHTEG was convened to provide biodiversity-related information to the Climate Change Convention. Building on the first report, the second AHTEG's report emphasizes the interactions between biodiversity and climate change, highlighting the impacts of climate change on biodiversity. It notes that observed climate changes have already adversely affected biodiversity at the species and ecosystem levels, with further impacts expected as climate continues to change. Particularly vulnerable are aquatic freshwater habitats, wetlands, mangroves, coral reefs, arctic, and alpine ecosystems. The IPCC's Fourth Assessment Report estimates that approximately 10% of species assessed so far face increasingly high risks of extinction for every 1°C rise in global mean temperature. Assessing risks to biodiversity from climate change can be initially done using existing vulnerability and impact assessment guidelines, although further development and validation of tools are needed to project climate change impacts on biodiversity and ecosystem services.²⁴

5.2 National Initiatives

According to India's 4th National Report to the Convention on Biodiversity (MoEF, 2009), India has developed a comprehensive strategy for conserving and sustainably using biodiversity. This strategy is primarily driven by the Ministry of Environment and Forests (MoEF), the central focal point for biodiversity conservation, with support from other ministries and departments such as Agriculture, Health, Water Resources, Rural Development, Power, Industry, New and Renewable Energy, Urban Development, and Science and Technology.

The conservation and sustainable use of biological resources in India are deeply rooted in local knowledge systems and practices, which are integral to the Indian ethos and are protected under the Constitution of India (Article 48A and Article 51 A(g)) as part of environmental protection. Recent policy frameworks, legislations, and action plans have been instrumental in guiding India towards achieving the three objectives of the Convention on Biological Diversity (CBD). These include the Biological Diversity Act (BDA), 2002; the National Wildlife Action Plan (NWAP) (2002-2016); the National Environment Policy (NEP) 2006; the National Biodiversity Action Plan (NBAP), 2008; and the National Action Plan on Climate Change (NAPCC), 2008.

²⁴ Lokesh Chandra Dube and Dr Subodh Sharma, 'Climate Change and India: Impacts on Biodiversity', in AK Bhatnagar and Rupam Kapoor, (ed.), *Plant Diversity in India*, India, I.K. International Publishing House Pvt Ltd, 2018, p. 502-525

India's efforts on vulnerability assessment and adaptation to climate change and desertification are diverse, including the establishment of the National Clean Development Mechanism Authority for approving projects on biomass-based cogeneration, energy efficiency, and municipal solid waste. The implementation of the NAPCC is pivotal in this regard. India ensures the integration of biodiversity concerns and social development through various mechanisms, such as greater participation of community groups in Forest Development Agencies (FDAs) and Joint Forest Management Committees (JFMCs), technology dissemination through a network of Krishi Vigyan Kendras and Agricultural Technology Management Agency, and the implementation of the National Rural Employment Guarantee Scheme (NREGS), which promotes economic and social enrichment while encouraging people's participation in environmental conservation.

The NAPCC outlines several steps to advance development paradigms and achieve climate change-related objectives of adaptation and mitigation. Eight national missions underpin the NAPCC and represent long-term, integrated strategies for achieving key goals. Notably, missions such as the National Water Mission, National Mission on Sustainable Agriculture, National Mission on Himalayan Ecosystem, and Green India Mission are particularly focused on the preservation and conservation of biodiversity in the context of climate change.²⁵

6- CONCLUSION AND SUGGESTIONS

While ecosystems have historically adapted to changing conditions, current changes are occurring at unprecedented rates. The faster the climate changes, the greater the impact on people and ecosystems will be. Reductions in greenhouse gas emissions can alleviate these pressures, allowing ecosystems more time to adapt. However, it is crucial to develop climate change adaptation plans because activities such as deforestation, overgrazing, and water degradation can exacerbate the consequences of climate change. In many countries, more people, particularly those with lower incomes, are now living in exposed and marginal areas like floodplains, hillsides, and arid lands, increasing their vulnerability to the negative impacts of climate change. Minor changes in climate can have devastating effects on lives and livelihoods in these areas. Similarly, many species are adapted to specific climatic conditions, and even small changes could lead to their permanent loss.

²⁵ Lokesh Chandra Dube and Dr Subodh Sharma, 'Climate Change and India: Impacts on Biodiversity', in AK Bhatnagar and Rupam Kapoor, (ed.), *Plant Diversity in India*, India, I.K. International Publishing House Pvt Ltd, 2018, p. 502-525

Although there is still much to learn about climate change, we already have enough knowledge about the range of impacts, the magnitude of risks, and the potential for adaptation to take action now. Traditional adaptation mechanisms such as conservation, preservation, and the creation of buffer zones have been used to combat the impacts of environmental degradation on biodiversity. However, climate change requires additional steps to address impacts such as changes in species distribution, increased extinction rates, shifts in reproductive timing, and changes in the length of growing seasons for plants.

Given the interconnections between climate change and biodiversity, it is essential to:

- Identify and conserve biodiversity components that are especially sensitive to climate change,
- Preserve intact habitats to facilitate the long-term adaptation of biodiversity,
- Enhance our understanding of the linkages between climate change and biodiversity, and
- Fully integrate biodiversity considerations into climate change mitigation and adaptation plans.

Examples of activities that promote climate change mitigation or adaptation include:

- Maintaining and restoring native ecosystems,
- Protecting and enhancing ecosystem services,
- Managing habitats for endangered species,
- Creating refuges and buffer zones, and
- Establishing networks of terrestrial, freshwater, and marine protected areas that consider projected changes in climate.²⁶

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