Impacts of Climate Variability on Wildlife, Fisheries and Ecosystems

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SUMMARY

This book chapter provides a comprehensive examination of the multifaceted impacts of climate change on wildlife, ecosystems, and fisheries. Through an extensive review of scientific literature and case studies, the chapter explores the interconnected web of consequences arising from global climate shifts. Changes in precipitation patterns, habitat disruption, and rising temperatures all have a powerful influence on the distribution and behavior of various species. This contribution elucidates the intricate connection among biodiversity loss and climate change, providing insights into the disruptions of migration patterns, shifts in phenology, and vulnerability of habitats that are vital for specific species to the impacts of extreme weather events. As an essential component of Earth's ecosystems, the oceans are confronted with unique difficulties including acidification and sea level rise. The alterations mentioned have an impact on marine life, specifically coral reefs, and fish species that are commercially significant. The chapter examines the cascading effects on fisheries, exploring the implications for global seafood supply and the livelihoods of communities dependent on fishing. Mitigation and adaptation strategies are crucial components of the discussion, emphasizing the need for coordinated efforts at various levels of governance which highlights the importance of sustainable resource management, habitat restoration, and international initiatives to curb greenhouse gas emissions. By providing a nuanced knowledge of the complex interactions between ecological systems and climate change, this chapter aims to contribute to a holistic approach to address the issues of wildlife, ecosystem, and fisheries due to climate change.

INTRODUCTION

Climate is derived from the Greek word "klima", which means "inclination" is the average of the weather over a lengthy period, usually 30 years (Muluneh, 2021). Climate change is a multifaceted and pressing worldwide problem that transcends beyond geographical limits, affecting ecosystems, weather patterns, and human societies (Wang et al., 2023). Although natural processes have historically contributed to climatic fluctuations, the current rapid and intense shifts are mostly ascribed to human activity. The fluctuation in temperature arises from both natural events and human activity on Earth, resulting in the accumulation of greenhouse gases (GHGs) (Braide et al., 2020).

Fossil fuels, deforestation, and human activities: catalysts of climate change

The combustion of fossil fuels is a major driver of climate change. The burning of coal, oil, and natural gas emits substantial quantities of greenhouse gases, including carbon dioxide (CO2), methane (CH4), and nitrous oxide, which contribute to ozone depletion (Malhi et al., 2021). Increasing atmospheric CO_2 concentrations (463-580 ppm) have the potential to influence soil microbial activities and water content, leading to an increase in methane gas release from upland soil and nitrous oxide emission from wetlands. This counteracts the estimated 16.6% reduction in climate change as predicted from the expansion of terrestrial carbon sink. An additional factor induced by human activities, deforestation, exacerbates this problem (Bhowmik et al., 2022). Trees serve as carbon sinks by holding CO2 from the atmosphere. However, extensive deforestation undermines this critical mechanism, thereby permitting the accumulation of additional greenhouse gases (Rodrigues et al., 2023). Further contributors to climate change include industrial operations, alterations in land use, improper waste disposal practices, permafrost thawing, and the emission of black carbon (Schuur et al., 2022).

Dual impact of climate change: Direct and indirect effects

Fundamentally, planet Earth is influenced by climate change in two ways: directly and indirectly. The primary consequences encompass an elevated temperature level and a decline in minimum temperature. Sea level rise results from the protracted maximum temperature-induced ice melting in the northern hemisphere (Griggs and Reguero, 2021). In addition, it enhances the temperature of the ocean and introduces a humid atmosphere. As a result of the ocean's

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elevated temperature, water evaporates into vapor, producing torrential rainfall. Conversely, the water crisis is triggered by the indirect influence of changes in climate, as evidenced by the daily fall in groundwater levels (Mehrim & Refaey, 2023).

IMPACTS OF CLIMATE CHANGE ON FISHERIES

Climate change has direct and indirect effects on aquaculture production. The physiology of shellfish and finfish stocks in aquaculture production systems are the direct effects while indirect effects are the alterations in the primary and secondary productivity and structure of the ecosystems, input supplies or by altering product costs, prices of fishmeal and fish oil and other goods and services required by producers of fisheries and aquaculture (Adhikari et al., 2018). Indirect effects can arise through changing the ecosystem structure, primary and secondary productivity, input supplies, or the cost of fishmeal, fish oil and other products and services required by fishermen and aquaculture producers. Direct effects comprise impacting the physiology and physical characteristics of stocks of shellfish and finfish in production systems (Adhikari et al., 2018).

The complex effects of climate change on the ocean environment are felt by fish populations, fisheries, and fisheries management organizations. Fish are rich in important nutrients such Fe, Zn, Omega-3 fatty acids, and vitamins, which promote human health and supply a major channel for addressing micro-nutrient shortages in most countries (Gaikwad et al., 2020). However, ocean warming, and acidification have the ability to affect concentration of fish nutrients via both direct (metabolism, nutrient absorption efficiency) and indirect (nutritional quality and composition of basal food sources) mechanisms (Nagelkerken et al., 2023). These factors also relate to each other and to other human pressures, such as over-exploitation and pollution. Commercially significant marine fish species (such as Atlantic cod) have reduced body size, which is associated with changes in ocean conditions, which could affect fishery catches worldwide (Ahti et al., 2020). Many marine and freshwater species depend on estuarine ecosystems for part of their life cycle, and these ecosystems are also more affected by extreme weather events like droughts and floods.

Rising temperature

Growth and development of aquatic species and fish which are poikilothermic, is significantly influenced by temperature, and these species are especially vulnerable to temperature fluctuations produced by climate change (Adhikari et al., 2018). The 1.5°C increase in average temperature led to higher mortality rates among fish, especially those in colder water and inter-tidal shellfish. As a result of warming, the ocean's ability to absorb carbon dioxide is gradually declining, which in turn causes changes to the appearance of red tides and the hydrography and hydrology of water bodies. Additionally, immune responses, cardio-respiratory performance, aerobic scope, and the function of the osmoregulatory system can all be altered by chronic stress in many economically significant species (Zhang et al., 2019). The physiological processes, feeding habits, and developmental outcomes of the majority of shellfish and finfish species are also likely to be impacted (Lemasson et al., 2019).

Ocean acidification

Ocean acidification happens when atmospheric CO_2 is absorbed by the ocean and causes a long-term decrease in ocean pH levels, typically over decades (Bahri et al., 2019). Worldwide, the oceans are believed to be able to store fifty times more carbon dioxide than the atmosphere. Several aquatic species suffer with negative impacts on their abundance, calcification, survival, growth, and development due to the anticipated increase in carbon dioxide absorption by oceans at 1.5-degree celcius or elevated global warming. The environmental viability of aquaculture production systems is at risk because of degradation of water quality and poor productivity caused by an increase in CO_2 accumulation in water, which could lead to higher water acidity levels (a decrease in pH). Ocean acidification also makes it harder for shell-forming organisms like corals, shrimp, mussels, and oysters to calcify the building block of their skeletons (Maulu et al., 2021).

Sea level rise

Sea level rise is the capability to harm various coastal habitats, such as salt marshes and mangroves, which are critical for supporting supplies of wild fish and seed for aquaculture production. This will negatively impact aquaculture breeding programs and the sector’s economic sustainability. This will have a detrimental impact on aquaculture breeding programs and the sector's economic sustainability. Higher sea levels are expected to impact aquaculture facilities for production such as ponds, cages, tanks, and pens, particularly in lowland areas, due to the intrusion of salty water (Khalid, 2022). Groundwater salinization is thought to be detrimental to agricultural output, freshwater fisheries, and aquaculture (Iber & Kasan, 2021). Consequently, salinization makes aquaculture an unfeasible production method, which in turn increases production costs and decreases economic benefits. As an outcome of increasing sea levels, changes in composition of species, distribution and abundance, phenological shifts and productivity of ecosystems could endanger both marine and inland aquaculture production (Muruganandam et al., 2023).

Reproduction

Alterations to the physicochemical properties of both saltwater and freshwater such as changes in pH/CO_2, temperature, O_2 content, and salinity, have the potential to affect vital physiological processes, including reproduction, in fish (Gallo et al., 2020). Sex differentiation, also phenology and timing of the reproductive period, can be significantly influenced by fluctuations in temperature and photoperiod regimes across numerous species of fish. Temperature primarily functions at the gonad level by affecting steroidogenesis and the process of gametogenesis (Kumariya et al., 2021). The development and quality of released gametes of embryos are both directly impacted by temperature. Sperm quality and fertility are particularly impacted by changes in water acidity or salinity. The availability of the steroid's precursor cholesterol or aromatase action can be affected by hypoxia events, which in turn affect gonad steroidogenesis and, by extension, gamete quality and reproductive success. The influence of climate change on water parameters extends to their influence on fish reproductive behavior (Loda et al., 2022).

Loss of biodiversity

The loss of biodiversity and the crises in ecosystems may be associated directly to climate change. Climate change is responsible for disturbances in ecosystems worldwide. Species undergo the necessity of adapting to altering environments, and some may encounter difficulties in their survival (Kattel, 2022). Coral reefs, major marine ecosystems, are very vulnerable to increasing sea temperatures and ocean acidification, leading to coral bleaching and the depletion of species. The biodiversity impacted by climate change encompass several factors like species over-exploitation, soil deterioration, deposition of nitrogen, pollution, invasive or non-native species introduction, diversion of water resources, landscapes fragmentation, urban development, and industrial expansion (Thirukanthan et al., 2023). Although climate change interaction with pre-existing biota concerns recently emerged as the most critical and pressing issue. Biodiversity loss, on the other hand, is caused by a complex interplay of many other variables. Among these include overpopulation and overconsumption (Muluneh, 2021). One of the main causes of the worldwide decline in biodiversity is the destruction of natural habitats, which is accelerated by climate change (Habibullah et al., 2022).

CLIMATE CHANGE EFFECTS ON WILDLIFE

Climate change is a major threat to global biodiversity, affecting a diversity of species and habitats. Global biodiversity is under unprecedented threat from invasive species, land use change, over-exploitation, pollution, and climate change. Extensive research has been conducted in response to these risks, to assess the consequences of global climate change on biodiversity at various taxonomic, temporal, and spatial scales. Over the last two decades, vulnerability evaluation has uncovered the broad ecological impacts at the individual, population, and community levels as well as the direct and indirect effects of changing climate on species and population (Foden et al., 2018).

Changes in migration patterns

Phenology or the seasonal timing of biological processes, is vital for ecological relationships and key index of species reaction to climate change. Many studies demonstrate that migratory birds migrate and breed earlier due to higher temperatures and altered precipitation patterns (Staudinger et al., 2019). Migratory birds arrive sooner at nesting sites due to higher global temperatures. Longer-distance species arriving later in spring have less progressed their arrivals than shorter-distance species arriving earlier. Thus, compared to migrants with more flexible arrival dates, individuals who cannot accelerate their spring migration and modify their breeding cycles are more susceptible to decrease in population. Environmental variables and species richness may affect bird arrivals to nesting locations. When a species is in large numbers, viewers can spot a species early and more easily. Population abundance is affected by variables such as inter-specific competition, land use change, and hunting pressure rather than climate, resulting in variations in apparent arrival dates (Kolecek et al., 2020). The distance a species migrates impacts its arrival date, abundance, and relationships. Longer migration distances lead to smaller arrival dates and negative population trends, as species are less adaptable to climate change (Prytula et al., 2023).

Habitat loss and fragmentation

Many species are facing extinction and decline due to habitat loss, fragmentation, and climate change on a local, regional, and global scale. In contrast, land-use change causes habitat fragmentation, which diminishes biodiversity, affects ecosystem processes, and increases wildlife competition, particularly in small, isolated fragments. This arises as it becomes more difficult for species to alter their ranges in response to changing climate circumstances when appropriate habitat is scarce and fragmented within progressively hostile terrain (Synes et al., 2020).

Changes in reproductive behaviors

Climate change impacts the reproductive activities of many species. Climate variations can impact the ability of organisms to survive, grow, reproduce, and disperse. Climate change can impact the availability of food, the relationships between predators and prey, and the competitive interactions among species, leading to changes in community structure. Temperature has a direct impact on the rates at which predators attack and manage their prey, which in turn influences the size of the prey they target. For example, a moderate temperature rise amplifies the size-specific per capita consumption rates of predators and enhances top-down regulation. However, the availability of nutrients does not directly impact the per capita rates of predation. Increasing nutrition availability can indirectly reduce predation rates by enhancing the abundance of alternative prey. Climate change has the capability to modify the interactions between pathogens and their hosts, leading to significant impacts on the occurrence of diseases (Weiskopf et al., 2020).

CLIMATE CHANGE EFFECTS ON ECOSYSTEMS

Ecosystems are habitats that support and sustain various forms of life. The ecosystems encompass a variety of environments such as freshwater, saline water, forests, peatlands, terrestrial-coastal systems (such as salt marshes and mangroves), wetlands, estuaries, deserts, cities and agricultural regions. The heating climate is exerting various effects on all these habitats (Loucks, 2021). Ecosystems are undergoing rapid transformations caused by many global factors and climate change. These changes are not solely driven by shifts in temperature, but also by alterations in patterns of precipitation, CO2 levels in the atmosphere, H2O distribution, ocean chemistry, and the occurrence and intensity of extreme events (Upadhyay, 2020). Worldwide biodiversity is at risk due to alterations in natural ecosystems, which also have consequences for global food production (Malhi et al., 2020). Ecological circumstances can change due to warming, leading to the expansion of infections, parasites, and diseases. Global warming can induce plant and animal species migration to areas that are more suitable for their viability. Numerous factors can impact the food availability, breeding, migration, pests and avoidance behavior of animals and plants in diverse manners. Various species exhibit variations in their capacity to acclimate and evolve. The geographical distribution and life cycle of numerous species are significantly impacted by the temperature of their environment. With the decreasing duration and intensity of winters, the timing of these biological activities can be altered.

With rising temperatures, the geographical areas where many species can live are moving to higher altitudes that are cooler. For certain species, this entails migration to less favorable environments, heightened competition, and/or a decrease in their geographical range. For several species, it has resulted in the disappearance of local populations. Escalating temperatures and modified patterns of precipitation contribute to heightened occurrences of severe droughts and wildfires, which significantly impact the structure and functioning of ecosystems, especially those in forested areas. In the past twenty years, forest drought severity has escalated in response to rising temperatures and unpredictable rainfall patterns. This has resulted in a decline in tree growth and an increase in tree mortality. Nevertheless, the reactions can differ and may experience delays in species with longer lifespans. Drought diminishes the resilience of trees, making them more vulnerable to various forms of damage, such as insects, pathogens, invasive species, and wildfires. Drought impacts have long-term effects, but drought-facilitated disturbances can change forest ecosystem structure and function immediately (Loucks, 2021).

MITIGATION AND ADAPTATION STRATEGIES

Addressing the response to climate change requires a focus on adaptation and mitigation. Scientists study the concept of mitigation to climate changes, while also examining how adaptation strategies can directly influence phenomena such as floods. It is noteworthy that mitigation plays a significant role in reducing or moderating greenhouse gas emissions. This aspect has gained considerable importance from both economic and environmental perspectives (Vale et al., 2021). There is significant concern among researchers regarding the methodologies used for adaptation and mitigation in different sectors and geographical areas. Land use, industries, transport, forests, and agriculture are the primary sectors that require adaptation and mitigation policies (Karkkainen et al., 2020). Adaptation and mitigation are important considerations that need to be addressed at both the national and global levels. In recent decades, climate change has emerged as an important global issue, necessitating an urgent need for societies to adapt to foster economic and social progress. Developing policies and strategies at the international level is crucial for climate change adaptation and mitigation (Hussain et al., 2020).

Understanding threats and challenges of climate change

The current biodiversity is confronting a fundamental threat caused by several human-induced stresses, with climate change being the most widespread (Halsch et al., 2021). Climate change has already influenced twenty-seven million km2 (18.3% of land) across all biomes and has a detrimental impact on the distribution of 47 percent of 873 terrestrial non-volant endangered mammal species and 23.4 percent of 1.272 threatened bird species. The influence of changing climate on biodiversity and the ecosystem has been comparatively limited in comparison to the detrimental consequences of direct anthropogenic actions, such as habitat loss caused by land use change and over-harvesting. The relative significance of this matter is already undergoing a shift, and the unfavorable ecological effects of changing climate are becoming increasingly evident and very likely to escalate in the next few years (Ohashi et al., 2019).

Opportunities for improving ecosystem and societal resilience

Climate change is actively contributed by ecosystems, particularly by participating in C, H2O, and other bio-geochemical cycles. Ecosystems, when managed effectively using reliable ecosystem and biodiversity research, can serve as a substantial source of human resilience and facilitate the adjustment of human communities to quick changes in the ecosystem. To clarify, ecosystems are not only susceptible to climate change but also can serve as valuable collaborators in addressing the problems of mitigation and adaptation to climate change (Malhi et al., 2020).

Nature-based solutions (Nbs)

Biodiversity can be viewed as a crucial component in addressing climate change, as opposed to being portrayed as its victim. Climate change mitigation and adaptation may be significantly aided by rigorous, evidence-based restoration and stewardship of ecosystems as well as ecosystem management. Ecosystem-based strategies, however, will not be adequate, and the main strategy for stopping climate change still needs to focus on solving the fossil fuel emissions issue (Wudu et al., 2023). However, NbS frequently provides numerous additional benefits to human civilizations (Debele et al., 2023). The co-benefits of several techniques, such as restoration and protection of forests, urban ecosystems, high-latitude biomes, trophic rewilding and tropical forests, have been demonstrated in the contributions to this issue (Norton et al., 2020).

Need for academic research

Diverse academic research can enhance our knowledge of environmental response to climate change and support the implementation of ecosystem-focused strategies for adaptation and mitigation (Malhi et al., 2020). Particular areas of focus for both natural and social scientists: Enhance the communication of existing scientific knowledge to decision-makers and stakeholders in a manner that is constructive and useful, thereby generating political support and informing actions. Identify and resolve significant but manageable gaps in knowledge within the field of environmental science.

Several forms of intricate ecological systems will be difficult to solve for many years to put evidence-based solutions into practice. To address this, it is important to identify the critical aspects of complexity that increase adaptability and resilience and find ways to support and spread them. Additionally, it is crucial to establish and sustain management for longer period, only then can patterns in critical situations be completely understood and management action's efficacy evaluated (Roy et al., 2023).

FUTURE OUTLOOK

Over the last 150 years, global systems have developed rapidly, resulting in overexploitation of natural resources and disturbance of biogeochemical cycles. Fossil fuels have accelerated climate change, prompting actions to modify agricultural and socioeconomic systems. New scientific and technical advancements, as well as existing theories, can all contribute to the combat against climate change. However, obstacles remain in obtaining a greater quality of life and economic growth while minimizing the environmental effect of energy usage. Agriculture's fast expansion adds to global GHGs emissions, while environmental deterioration and pollution provide new issues. Collaborative efforts are required for a sustainable future.

CONCLUSION

Climate change's impact on wildlife, ecosystems, and fisheries underscores the need for comprehensive and cooperative strategies to cope with the challenges presented by climate change. The complex interconnections between climate change and biodiversity decline, such as disturbances in migration patterns, biological event timing, and habitat susceptibility, highlight the complexity of the ecological network. The effects extend beyond terrestrial ecosystems to oceans, with rising sea levels and acidification posing significant risks to marine life and fisheries. Comprehensive strategies, mitigation and adaptation methods, sustainable resource management, habitat restoration, and global attempt to lessen GHG emissions are crucial. Interdisciplinary collaboration and knowledge-sharing are essential for managing climate change implications and enhancing informed decision-making. Collaborative efforts centered on our current and future demands are needed for a viable future for coming generations as well as ourselves.

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