Threats, opportunities, and solutions to climate change and ecosystems

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Abstract

The health and functioning of the biosphere are inextricably linked to the rapid anthropogenic climate change that we are witnessing in the early twenty-first century. Ecosystems are being impacted by climate change due to changes in mean conditions and variability, as well as other changes such as increased ocean acidification and atmospheric carbon dioxide concentrations. Other stresses on ecosystems, such as degradation, definition, and fragmentation, interact with it. Understanding the ecological dynamics of these climatic impacts, identifying hotspots of susceptibility and resilience, and identifying management measures that can help the biosphere adapt to climate change are all necessary. At the same time, ecosystems can help with both climate change mitigation and adaptation. The methods, possibilities, and limitations of such nature-based climate change solutions must be investigated and measured. The relationship of climate change and the biosphere is the subject of this study, which introduces a thematic concern. It examines new ideas on how ecosystems respond to climate change, how to improve ecosystem resilience, and how ecosystems may help meet the problem of a changing climate. It is based on a November 2018 Royal Society-National Academy of Sciences Forum in Washington, DC, where these topics and issues were explored. In order to maximize the potential for preserving a diversified, robust, and well-functioning biosphere under the tough conditions of the twenty-first century, we end by suggesting certain academic research and practical implementation goals.

Keywords: Weather • Climate • Adaptation • Mitigation • Biosphere • Nature-based solutions

Introduction

The biosphere, the thin living film of life on Earth that is integrally linked to the atmosphere and hydrosphere and supplies the nourishing fabric within which human societies exist, can be severely affected by changes in the atmosphere and oceans. As a result, the deterioration or restoration of portions of the biosphere is likely to have regional or global implications. The sustainability and resilience of natural ecosystems, as well as the human cultures that rely on them, are increasingly threatened by anthropogenic greenhouse gas emissions [1], which drive both climate change and ocean acidification. The consequences of these dangers can be severe, and they have become more visible in recent years. Earth has already committed to a significantly warmed climate, with greater warming expected in the future unless carbon emission paths alter radically. The understanding of the Earth's climate system and its dependent on the biosphere is still being refined through scientific studies. Climate change is expected to have more severe repercussions for ecosystems and people, according to most predictions. Climate-related repercussions are already being felt, and they appear to be becoming more severe and frequent [2]. A number of possible climatic tipping points are already showing symptoms of activation in the Earth system. As a result, the 2018 Special Report on 1.5°C by the International Panel on Climate Change (IPCC) cautions that permitting the earth to warm beyond 1.5°C will result in climate change impacts such as drought, floods, heat waves, and sea-level rise that are harmful to mankind and wildlife. While the previous international goal was 2°C, this half-degree differential could lessen the likelihood of widespread ecosystem deterioration in the Arctic and coral reefs. A 1.5°C maximum warming objective suggests that the world has roughly 12 years to cut global net carbon emissions in half to avert the worst effects, but even if this goal is met, the effects of warming are likely to last for decades, if not centuries.

We present contributions in this topical issue that are the result of talks during the 2018 Royal Society-National Academy of Sciences Forum on Climate Change and Ecosystems. The Forum's goals were to create new opportunities for international collaboration, showcase the most recent research findings on the focal issue, identify research gaps and future research objectives, and debate how research in this field might affect international policy. The Forum looked at the most recent research on how climate change affects terrestrial, aquatic, and marine ecosystems, as well as how it interacts with other elements [3]. It focused on research areas such as the effects of climate variability and extremes, interactions among numerous stressors, thresholds and the potential for abrupt change, and multi-trophic interactions in a variety of terrestrial, aquatic, and marine ecosystems. By looking at a variety of science and policy perspectives, the Forum looked at ways to help and manage ecosystems in order to improve both ecological and societal resilience to climate change. This included discussing how ecosystems may be best managed to improve their resistance to climate change, their potential to transform in the face of climate change, and how ecosystem management can be used as a strategy for more general change adaptation [4]. The resulting thematic issue, as well as our introduction to it, is organized around I the threats that climate change poses to ecosystems, (ii) opportunities to improve ecosystem resilience to climate change. (iii) How ecosystems and ecosystem restoration can help with climate change mitigation and adaptation. We outline the subjects in our introduction, introduce the papers in the thematic issue, and conclude with a summary of the Forum's principal results. In doing so, we emphasize the importance of research in order to better understand climate change and ecosystem dangers, opportunities, and solutions [5].

Discussion

The Forum looked at a variety of recent scientific findings on how climate change affects terrestrial, freshwater, and marine ecosystems, sometimes in conjunction with other variables. It focused on current research frontiers such as the effects of changing climatic variability and extremes, connections between climate change and other human-induced stressors, thresholds and the possibility for rapid and irreversible change, and multi-trophic interactions. Ecosystems are quickly altering in response to climate change and other global change drivers, including changes in precipitation, atmospheric carbon dioxide concentration, water balance, ocean chemistry [8], and the frequency and amplitude of extreme events, among other things. Because of complex interactions among organisms, disturbance, and other stresses, ecosystems differ in their sensitivity and responsiveness to climate change. Long-term warming and increasing atmospheric water deficits are raising physiological and hydrological stress and ecosystem flammability, while climate change is increasing precipitation variability and the likelihood of extreme dry and wet events. Heat waves are becoming more often in the ocean, and long-term trends of acidity are putting many creatures and ecosystems under stress [6]. Other anthropogenic stressors, such as deforestation, overfishing, invasive species, habitat fragmentation, and direct habitat degradation, interact to increase ecosystem susceptibility to climate change. Both the subtle effects on individual species within complex multi-trophic ecosystems and the more sudden consequences of ecosystem degradation make predicting the patterns and probability of biodiversity loss extremely difficult. In light of ecosystem complexity and a significant gap in our knowledge of how specific species and interspecific interactions will respond to climate change, an adaptive ecosystem research strategy, in addition to adaptive ecosystem management, is required. There are many topics of ecosystem science about which we will not have enough knowledge in a reasonable amount of time. Ecosystems are changing so quickly in response to global change drivers that actual, system-altering changes have surpassed our research and modelling frameworks. It is necessary to implement new frameworks for modelling and monitoring highly dynamic complex systems. Improved methods for implementing adaptive ecosystem management in the face of uncertainty are required. Long-term surveillance is also very important. It can reveal long-term changes that are difficult to detect due to shifting baselines, as well as providing early warning of species-specific vulnerability, ecosystem-wide loss, or tipping points. Long-term forest monitoring, for example, has produced valuable information about the biosphere carbon sink, which serves to decrease the rate of climate change, as well as its potential future route [7].

Ecosystems have an important role in the climate system, particularly through their contributions to the carbon, water, and other biogeochemical cycles. Ecosystems may be a major source of human resilience and promote the adaptation of human societies to fast environmental change if they are sustainably managed in a way that draws on rigorous ecosystem and biodiversity science. In other words, ecosystems are not only sensitive to climate change, but they also have the potential to be valuable partners in addressing climate change adaptation and mitigation difficulties. Ecosystems have complicated responses to climate change, which are poorly understood and only partially accounted for in future ecosystem function and dynamics estimates [8]. Habitat variety can produce micro-islands of resilience that can be sources of recovery following extreme events, and genetic variability can allow robust subpopulations to adapt and expand. Ecosystems in biodiversity hotspots may benefit from multi-trophic interactions and trophic redundancy to recover from disturbances. Strategic conservation of critical sites in a protected area network, particularly those that maintain biodiversity in present and future climates, can improve landscape and seascape scale resilience and ecosystem services, including climate change mitigation.

Ecosystem management and restoration, as well as thorough evidence-based restoration and stewardship, have the potential to play a significant role in climate change mitigation and adaptation. Ecosystem-based solutions, on the other hand, will be insufficient, and the primary method to slowing climate change will continue to be to address the fossil fuel emissions problem [9]. NbS, on the other hand, frequently has numerous co-benefits for human society. The contributors to this issue have used tactics ranging from restoring hydrologic function to forest conservation and restoration to trophic rewinding to demonstrate these co-benefits in urban ecosystems, tropical forests, and high-latitude biomes. These publications also reveal that some climate mitigation activities based on ecosystems that aren't well-suited to the environment can have negative consequences for terrestrial biodiversity and resilience. Scalability is a fundamental barrier to understanding and implementing nature-based approaches to climate change adaptation and mitigation. Despite the fact that climate change is a worldwide issue that necessitates multi-jurisdictional and multinational governance, many of the NbS examples include proof-of-concept research on rather modest spatial scales. Additional benefits of solutions can be substantial, and they may be enough to outweigh the opportunity costs. The problem, as well as the costs and rewards of remedies, are inequitable among social groups [10].

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