Climate Change and Biodiversity – Insights from the Royal Society Global Environmental Research Committee

This paper is an output of a discussion on climate change and biodiversity science at a Royal Society Global Environmental Research Committee (GERC) meeting held in May 2020 (see 'context' on page 3). It seeks to highlight science issues of interest to researchers, funders and government.

Executive summary

GERC identified five areas where further research and/or investment is needed to improve our understanding of the impacts of climate change on biodiversity, and ultimately to be able to address these issues in an integrated way. These five areas are:

1) The causes and consequences of variation in the susceptibility and adaptation of species to climate change.

2) The effects of climate extremes and local variations in climate change on biodiversity.

3) The need to improve monitoring to fill knowledge gaps on, for example, how biodiversity in freshwater, the deep sea, and tropical and polar regions are responding to climate change.

4) How interactions of climate change with other stressors, such as land-use change, impact biodiversity.

5) The consequences of climate induced biodiversity change for ecosystem functions and human wellbeing.

Introduction

Climate change has a range of impacts on biodiversity through factors such as rising temperatures, changing rain and snowfall patterns and extreme weather events. These factors affect the performance, survival, distribution and behavior of species, which ultimately alters the key functions and services that biodiversity provides. Consequently, understanding the effects of climate change on biodiversity is critical for predicting the impacts of climate change on nature's benefits to people and human wellbeing.

Climate change affects all areas of the planet, regardless of the local presence of humans. Yet, the effects of climate change are heterogeneous, with some regions changing much faster than others.

There are striking differences in the pace of climate change across latitudes, altitudes (on land) and depths (at sea), which leads to differences in impact in these areas. For example, the Arctic is warming at twice the rate of the rest of the planet, causing rapid change in local species and their traits. Climate change also affects marine, freshwater and terrestrial realms differently, and the impacts on biodiversity may differ in aquatic ecosystems relative to those on land. Finally, biodiversity in some regions is naturally more sensitive to climate change than in others. For example, tropical biodiversity is thought to be the most sensitive to climate change, because the climate in tropical areas has historically been more stable, and there is little seasonal variation in climate and so the species there are likely less able to adapt to rapid climate change. Tropical regions are also entering climatic configurations not experienced elsewhere on the planet, and hence there are no species known to be adapted to these new conditions.

Research Priorities

1) Understanding the causes and consequences of variation in susceptibility and adaptation of species to climate change

Understanding the causes and consequences of differences in susceptibility of species to climate change is a critical area of investigation. The consequences of climate change for biodiversity depend on the interaction between the susceptibility and exposure of organisms to conditions outside their limits. Developing a better understanding of the tolerances of species to warming and other climate change related factors, and of the climate dimensions that trigger biodiversity change, will help to identify those species and regions most at risk. Some organisms exposed to conditions outside their historical range are able to respond by adapting to novel local conditions, or by changing their distributions by moving to, for example, cooler microclimates or colder ecosystems. However, other species have no cooler locations to move to (eg high-latitude and montane species) and are unable to adjust, and therefore are at risk of becoming locally or globally extinct. This variation in susceptibility leads to the emergence of 'winners' and 'losers'. If 'loser' species played a critical role within ecosystems, then their loss will have adverse effects on ecosystem functioning, ecosystem services and ultimately human wellbeing, unless newly arriving 'winner' species replace these roles.

2) Understanding the effects of climate extremes and local variation in climate change on biodiversity

Variation in local climate conditions and specifically climate extremes drive biodiversity change more than global averages. Climate is experienced by species at a local level, and local climatic extremes are known to cause losses of species. Understanding the thresholds of climate change at which the most profound biodiversity effects occur is a vital area of research to anticipate potential ecosystem change. Species may be confined to refuges as the climate warms, for example, in colder or moister microclimates and habitats, highlighting the importance of local variation, combined with species-specific responses that we are only now beginning to resolve. Yet, recent widespread dieback of coral reef ecosystems with warming waters highlight how vulnerable ecosystems can be when refuges are limited.

3) Improving monitoring to fill key knowledge gaps

Representative monitoring that reflects all life on Earth is critical for capturing and understanding biodiversity responses to climate change. Species that currently suffer from under-representation in monitoring include large groups of invertebrate and microbial species, diversity in soil, freshwater and deep-sea ecosystems, and in tropical and polar regions of the world. These knowledge gaps prevent a complete understanding of the consequences of climate change for biodiversity. For example, the recent interest in insect population trends despite data limitations, highlights the growing need for more comprehensive global monitoring of biodiversity. Monitoring could among other things be improved by using new technological solutions (eg drones, satellites, eDNA) to improve data collection that harness new perspectives on ecological change, and the importance of landscape connectivity.

4) Understanding how interactions of climate change with other stressors impact biodiversity

The effects of climate change are occurring in tandem with many other stressors for biodiversity. Land-use change in particular is a prevalent stressor, which is likely interacting with climate change in complex ways. Climate change mitigation is often achieved through measures that require land-use change, with potential consequences for biodiversity. Understanding the consequences for biodiversity of these interacting stressors is an important area of investigation, because stressor interactions are complex and poorly studied, and may lead to unanticipated and larger-than-expected biodiversity changes, or indeed help buffer effects of climate change.

5) Understanding the consequences of climate induced biodiversity change for ecosystem functions and human wellbeing

Understanding the consequences of biodiversity change for ecosystem function is a critical knowledge frontier because biodiversity and functioning ecosystems underpin human wellbeing in ways that we are only beginning to understand. The mix of different species' responses to climate change (adaptations, changing distributions, changes in abundance, local extinctions and species replacements) can lead to mismatches between different components of ecosystems that undermine a specific ecosystem function. Losses of ecosystem functions or specific groups of species that support human wellbeing will have important consequences to human society. For example, climate change is expected to have a strong negative effect on crop pollination through its effects on insect biodiversity. Insect populations have been reported to be in steep decline by some studies, but many gaps remain in our knowledge of insect abundance trends and their consequences. Understanding these broader consequences of biodiversity loss is urgent because climate-driven biodiversity change is accelerating, and we still have a very poor understanding of its consequences for human societies.

Conclusion

The understanding of the interface between climate change and biodiversity is rapidly advancing with UK scientists providing key expertise. Future UK science in the five above mentioned research priority areas could provide substantial scientific progress and inform national and global policy development. This would be best done by creating a balance between continuing to develop scientific understanding and focusing efforts on informing policy.

The context for Global Environmental Research Committee reports

The Royal Society's Global Environmental Research Committee (GERC) is charged with advising the Royal Society, and interacting with research councils, the environmental science community and other relevant bodies. To do this, it is undertaking a rolling series of reviews of areas of science within its remit. The areas it has identified are (in alphabetical order): Air quality, Biodiversity, Carbon and other biogeochemical cycles, Climate, Natural resources (including land use) and food, Oceans and polar science, and Water. In each area, GERC uses both its own expertise, and that of a small number of invited experts to consider the questions:

1. What are the hot research topics in this area at present?
2. What is the status of UK science within this area?
3. What are the most pressing research needs in the next 5-10 years?
4. Are there specific areas where UK science should be focused to meet these needs?
5. How should priority topics be incorporated into multidisciplinary (funded across research councils) issues?

This paper results from the discussion on climate change and biodiversity, organised by Dr Tim Newbold and Dr Maria Dornelas and held in May 2020. In addition to contributions from its regular and ex-officio members, the committee was advised in person by Professor Michael Burrows (Marine Scotland), Professor Nick Graham (University of Lancaster), Professor Jane Hill (University of York), Dr Michelle Jackson (University of Oxford), Dr Isla Myers-Smith (University of Edinburgh) and Professor Yadvinder Malhi FRS (University of Oxford). The resulting paper represents a snapshot of issues and is not a comprehensive survey of the science area. It does not represent the view of the Royal Society but aims to advise the Royal Society Council. The absence of a topic from this document does not negate its importance, and many areas that are already under intense research are not highlighted here. However, we hope that this document will put a spotlight on some trends that will inform future activity by the Royal Society, UKRI, and UK Future Earth.

Membership of GERC (including ex-officio members) at the time this topic was discussed was: Dr Maria Dornelas, Professor Peter Smith FRS (Chair), Professor Martin Solan, Professor Louise Heathwaite, Professor Roy M. Harrison, Professor Harry Bryden, Professor Gabi Hegerl FRS, Dr Tim Newbold, Professor John Croxall, Professor Kate Heal, Dr Sarah Webb, Professor Pierre Friedlingstein, Professor Alessandro Tagliabue, Professor Mike Bentley, Dr Kirsti Ashworth. Helene Margue, Senior Policy Advisor, acted as GERC Secretary.