American Journal of Biodiversity
https://biojournals.us/index.php/AJB
ISSN: 2997-3600

Climate Change and its Impact on Biodiversity: Adaptive Strategies for Conservation

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Received: 2024, 25, Jun
Accepted: 2024, 21, Jul
Published: 2024, 26, Aug

Annotation: Biodiversity refers to the variety and composition of life on Earth. From microbes to mammals, biodiversity affects all living organisms. Therefore, it is critical for human activities and for the development of policies oriented toward conservation and protection of natural heritage and the provisioning of ecosystem services. However, biodiversity is threatened: anthropogenic climate change is expected to promote species extinction and could push a significant percentage of living organisms to extinction by 2100. Climate change triggers a broad array of direct and indirect effects on organisms and ecosystems; among others, we can find temperature increase, changes in precipitation patterns, and increases in the frequency of extreme events. Therefore, in order to dampen the negative effects of climate change on biodiversity, a new proactive attitude in species conservation is needed. Current conservation strategies must allow species to increase ecological plasticity, adaptive capacity, and, in turn, the evolutionary potential of populations. Current conservation strategies applied within regional park and reserve management must be adapted to this new perspective.

1. Introduction

In addition, all conservation actions will be effective only if accompanied by effective, legally binding policies aimed at reducing major threats to the stability of global, regional, and local climates. Indeed, without the stability of the atmosphere and the climate, resilience and conservation will remain valid at a small scale, such as islands, sediment basins, and other systems where interaction with the atmosphere is limited and local geopolitical control can apply. In this way, a small range of species can coexist with an increasing human population. The present paper aims to highlight such a proactive attitude in order to provide an understanding of adaptive strategies in conservation. It would be naive to expect that small parks and reserves can withstand a rapid scenario of global change, resulting in the large-scale decline of many biodiversity components. The realization that current rotational zoning cannot cope with the accumulation of exploitative industries at continental and global levels suggests that conservation will have no sense – the maximalist scenario. [1][2][3]

2. Understanding Climate Change and Biodiversity Loss

Climate change is a scientifically observed and statistically significant variation in the Earth's climate over time, typically occurring progressively over many years. One of the most critical environmental challenges of the 21st century, climate change has been primarily driven by the ongoing rise in atmospheric carbon dioxide and other greenhouse gases, primarily due to human activities. Climate change is intrinsically linked to an increase in extreme events, such as heavy and intense precipitation events, coastal flooding, and heatwaves, among others. On the other hand, it has also been reported that rapid changes in climate have caused increased desertification, threatening the basic human needs of food, water, and shelter. Drought, violent cyclones, ice storms, unusual temperatures, and frequent wildfires are all among the extreme weather and climate change events currently jeopardizing human welfare and property worldwide. On a broader scale, climate change has undermined the long-term sustainability of human subsistence due to an increase in heat storage and retreats in glaciers and snow cover, while also pushing up sea levels and affecting the ocean.

Biodiversity is the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. Biodiversity and healthy ecosystems are inextricably linked to human health and agricultural productivity. Ecosystems, basically maintained by biological diversity, are able to provide a range of valuable services that are fundamental to our survival and quality of life. Ecosystem services include food and fuel supplies, nutrient recycling and pollination, regulation of water supply, flood and pest control, and absorption of pollutants. Further, these services also contribute to our capacity to adapt to change and resist shock, a feature known as resilience. Biodiversity will be affected, in large part due to shifts in temperature, precipitation, and relative humidity, as a result of climate change, with this vulnerability often varying across taxa and the nature of habitats. Therefore, the primary objectives guiding the effective management of rare species in the face of changing climate are to date based on those that are designed to maximize landscape diversity and to maximize the long-term resilience of species to climate change. [4][5][6]

2.1. Key Concepts in Climate Change

Various definitions are commonly used to explain different aspects of global environmental change involving climate change. The term "global warming" actually refers to a growing trend of average yearly temperatures. This trend is illustrated by instrumental measures that date back to the mid-1800s. The definitions of "greenhouse effect" are mainly related to the atmospheric capacity of several gases to capture the infrared radiation that results from the radiation of the Earth's surface. The involved gases are called "greenhouse gases." The phenomenon is called climate change when in compliance with the definition: "a change of climate which is deemed directly or indirectly to follow human activities that alter the composition of the global atmosphere and which adds to the natural variation observed over comparative periods."

The term "climate resilience" refers to the utmost feasible tolerances and the realities of direct and indirect adverse effects of climate change. The realized amounts also involve non-technical obstacles, such as potentially an entirely irremediable condition. Predictions carried out on the basis of models that integrate the system of general circulation, as well as sub-models describing the physical, biological, and chemical transformations in various small overlapping spaces of the Earth's systems, forecast a broad range of changes that may occur, relating to one or several dozen degrees Celsius from about the 1800s until the end of the 21st century. [7][8][9]

2.2. The Importance of Biodiversity

Biodiversity or the variety of life is crucial. It has been described as an "insurance" against environmental stresses for key services provided by ecosystems, such as water provision or ecosystem balance. Additionally, biodiversity produces food and provides medicine, thereby contributing to the economic budget of a community. Moreover, genetic biodiversity is necessary to feed the growing human population and protect it from possible threats such as terrorism or natural disasters. On a completely diverse level, biodiversity is a key natural resource for people. Summarizing, "Variety is the paradigm of the organic world and earns value on several levels."

All these factors underline the significance of unimpaired biodiversity, not just for the conservation of nature as we know it and the welfare of future generations but for the day-to-day conditions under which humans now live. Nevertheless, the insurance value of biodiversity is often overlooked, compared with technological, physical, and financial options, and frequently dismissed in environmental policy. The current rate of biodiversity loss is considered a "preponderant resource" for scientific knowledge, food production, risk governance, and all life systems supporting society. A classic example of the impact of climate change on biodiversity is the Great Barrier Reef in Australia. This ecosystem is now chemically imbalanced; higher temperatures lead to coral bleaching and can occasion a degenerative cytological disorder called "Skeletolyn." The Great Barrier Reef can react to a series of stimuli by promoting acclimation strategies that necessitate energy expenditure. [10][11][12]

3. Impact of Climate Change on Biodiversity

Climate change is a major force of global change that exerts several modifications in species distributions, demography, physiology, and ecological interactions. The world is witnessing the consequences: warming temperatures, intensity of extreme weather events, rising sea levels, damage to crop production, extinction of plant and animal species, and increases in air and water pollutants. The direct effects of climate change on biodiversity and ecosystems include the alteration of natural systems, rises in alien species, and changes in diseases, as well as impacts on ecosystem services. This has recently posed the first threat to biodiversity, which is the transformation of natural habitats into anthropogenic ones. It is, therefore, increasingly obvious that many ecosystems are being altered profoundly by resource allocations to human societies carried out through domestication and translocated species. The second threat mentioned is the exposure, vulnerability, and resistance of biodiversity to climate change, which is mainly due to the alteration of ecosystems. With the changing climate and, in particular, more frequent fluctuations, many species are being challenged in a direct or indirect way by ecological degradation, diminution, or even elimination of their natural habitats. The impacts of climate change on biological resources are diverse, but in some cases, empirical evidence is available as a reflection of potential effects of combined resource factors and stress from a changing climate. [13][14]

3.1. Changes in Habitats

Changes in temperatures, precipitation patterns, and frequency of extreme weather events, which are expected to change with climate change, have several direct impacts on local habitats and ecosystems and thus on biodiversity. Globally, the highest temperatures measured today are generally rising and are expected to continue to rise into the future. At the same time, an increase in warming of the poles compared to the tropics can be observed due to climate change, the effects of which vary regionally. On the basis of this average temperature increase, it is to be expected that species will seek new areas of distribution through shifting migration or invasion fronts, and that vegetation zones will move.

Even today, essential associates, such as plants, fail to succeed, and acclimatization of existing areas of distribution is essential for their maintenance. These processes change the natural spatial structure of ecosystems. Often, they can no longer distribute themselves completely or they even disappear completely, resulting in a reduction in species populations in a habitat, and thus an increased risk of extinction. With the destruction of ever larger and more complex habitats, due to the increasing warming in the North and South Poles, the marginal regions inhabitable by the specific species are increasingly being subdivided and thus isolated into small and ever smaller 'islands'. This results in reduced migration possibilities and opportunities for occupation for these species. Since nature does not know any borders in terms of species associations, many migrants must take a detour to reach territories that are not as hot. Migratory species are therefore particularly affected by the growth and isolation of small and compatible habitats. Thus, the destruction of habitats gives better survival prospects to only a limited number of highly resilient species in the area of the smaller and connected habitats. In the few landscapes with large, connected habitats, species that correspond to the needs of many species are more likely to survive. This can counteract the loss of species from a habitat area and thus the region. For this reason, large, diverse, and intact habitats should also be the focus of efforts to preserve and restore wildlife — with regard to the optimization of landscape design and addresses, which should also maintain migratory animal routes as true as possible. [15][16]

3.2. Shifts in Species Distribution

Changes in species distribution have been proven in response to recent climate change. As extreme diurnal and yearly temperature changes increase at higher latitudes and altitudes, and among small seasonal ponds, we expect not only a poleward shift but also an altitudinal shift as boreal habitats change to temperate ones. As temperature increases, native species can also shift their range towards the poles in the Northern Hemisphere. A wide range of range shifts can occur due to not only the responses of an individual species to climate change but also to changes in habitat availability and interconnectedness with other closely related habitats in the landscapes surrounding the 'initial' and 'destination' habitat. Additionally, not all species can migrate or adapt fast enough to take full advantage of the new climate conditions. Consequently, we expect various changes in overall assemblage sizes.

Not all species will be lucky enough to shift their distribution. Species interactions are shaped by their biotic and abiotic environment. A range shift may place a species in a novel environment, which may allow for the spread of invasive species. Such factors make an obvious need for the development not only of new data on current species assemblages but also of new methods of generating these data and integrating them into a coherent biodiversity monitoring framework. Local changes in species distribution have different consequences for conservation. Any decrease in species richness, of any spatial extent or any group of species, must be evaluated in the context of the needs and societal goals of the focal regional and local habitat. [17][18][19]

4. Adaptive Conservation Strategies

Conservation strategies designed to preserve ecosystems under climate change are likely to face an uncertain future. Adapting to climate change requires a paradigm shift in conservation, from a traditional approach that relies on protecting only pristine natural areas to one that seeks to protect the ecological continuum or networks necessary for the continued functioning of ecosystems and biodiversity. Several strategies have been proposed to ensure that taxa and ecosystems are able to respond, adapt, move, or change in response to climate change and to promote species- and ecosystem-level resilience to climate change. Such strategies differ depending on spatial scale, from the smallest conservation areas to the largest ecoregions.

Protected Area Management: Conservatively, conservation biologists often advocate for the management of entire ecosystems or the protection of existing biodiversity.

Protected Area Design - Wildlife Corridors: Connectivity is widely believed to increase the chances of species surviving and responding to climate changes and can help to counteract the reduced flow of genes and dispersers currently observed as a result of habitat fragmentation. Therefore, climate change conservation plans generally suggest the design and implementation of wildlife corridors to enhance connectivity. Research on the effect of corridors has largely focused on dispersal and movement or demographic effects, and research into gene flow conservation values is uncommon. Gene flow levels species genetic variability among populations, which is positively linked to population extinction risk. Behavior, individual ability, phenology, and the physical characteristics between habitat and matrix are all factors that influence functional connectivity between habitat and matrix. Because these variables relate to each other in ways that influence gene flow in a linear fashion, they work together to affect ecological connectivity. Management of ecological and functional connectivity between habitat areas can result in a stepped flow of organisms and genes. In conclusion, increased connectivity can increase climate change chances, but few case studies exist for gene flow between populations. Additional research and monitoring are required to determine effective strategy. [20][21]

4.1. Protected Areas Management

Managed protected areas and natural reserves are considered critical tools for biodiversity conservation in the face of rapid climate change. Protected areas are generally expected to be refuges for biodiversity as organisms move to higher elevations and latitudes where local conditions are similar to those found at present; resources should remain stable if the area is well managed. However, in many situations, species may need to move large distances to reach protected areas and will be unable to do so without safe passages. Thus, managing protected areas effectively is crucial.

Potential strategies to enhance protected areas' abilities to buffer climate change impacts include habitat restoration and increasing habitat connectivity. Critical to this effort is an understanding of how predicted altered species distributions outside of protected areas may affect species inside. For smaller, more genetically isolated areas, managing for the evolutionary potential to adapt, such as planting "maladapted" plants that may introduce new genetic variation, may also be appropriate. However, the most important tool is likely to be adaptive management, based on sound ecological principles and evidence-based decisions with a focus on climate change projections. Such adaptive territory-based planning is currently underway for protected area management in Panama and has been developed for the Springbrook National Park in Australia. Key to all this is the engagement of stakeholders in assisted decision-making processes. Costa Rica provides a case study of a country with an established set of policies and legal frameworks already in place to support the role that protected areas can play in maintaining species diversity and ecosystem functioning while also continuing to meet local human needs. This experience can focus on the social benefits associated with mappings and how this information can help resource managers in identifying new areas for protection, as well as in the subsequent management of these parks. [22][23][24]

4.2. Corridor Design and Restoration

Introduction Corridors, strips of protected habitat that can facilitate movement between habitat fragments, have long been considered important to the conservation of biodiversity. Their primary goal is simply to help animals move between larger habitat fragments; this has many potential consequences, but one of the most frequently mentioned involves maintaining and enhancing the genetic diversity of fragmented subpopulations. Three principles should be considered when planning wildlife corridors. First, the objectives of the conservation and of each species present in the concerned area must be defined to choose the regions and the concerned areas. Second, it is essential to be informed about the biology, ecology, and behavior of the species which are focal to decide which corridor is suitable. Before deciding on the land purchase, the characteristics of it must be analyzed, such as the physical and natural landscape and the land use. Third, attention must be paid to understanding the context of ecological corridors in a larger landscape plan to analyze and understand the potential constraints and opportunities present and future. Restoration is also important to ecological corridors. Indeed, without a sufficient level of habitat quality, the existence of corridors becomes an issue of some debate. The geographical character of wildlife management has also changed. It was a human-centered regulation of forests that gradually modified to an ecological basis. Restoring the corridors has many advantages, such as reducing or preventing damage caused by soil erosion and land degradation or natural disasters, and regenerating the flora in highly eroded areas. The restored corridors are also good habitats and shelters for troops of gelada baboons when they travel between different pockets of hills. Some forests are the sole source for activities of the population. The project revolves around wildlife conservation and is essentially about working to link fragmented forests together, thus providing part of a corridor. Conclusion The establishment of corridors may prevent habitat loss and biodiversity deterioration. Climate change will affect many ecosystems and habitats. It may disrupt the next decade of biodiversity conservation in some places. And so, in many ecosystems and habitats, looking to the next 100 years, we cannot prevent or avoid climate change. We are unable to predict how ecosystems will respond to changed climates. Therefore, possibly the best way of conserving biodiversity is to plan for the inevitable and conserve it in an adaptive way. One of the foremost approaches that benefit the species of a continent and individual ecosystems is to establish corridors that cut wide strips across the continent's ecosystems from coast to coast, or from near-coast to near-coast, north-south, at various latitudes on the land. Instead of isolating species in a single-reserve ecosystem, as is the current model of most conservation practices, it is possible to place a few countries and international organizations in partnership to purchase ecosystem land strips dividing neighboring countries. Following an adaptive conservation model, the priority might be to search for funding, so important to convince as many ecologists and other members of the larger community of the value of the concept of corridors and the need to dedicate the world to saving its living resources. If owning and thus controlling the land in the corridor, it is possible to switch animal species from one ecosystem to another by moving them within the planned wildlife corridors. Moving them would also remove a potential source of conflict of interest. Control would have to include a ban on all such farming schemes. And if the international partners that we aim to bring could join the governments, individual groups, and organizations, they could purchase and control a reasonable part of the mountain ecosystem. [25][26][27]

5. Conclusion and Future Directions

Throughout this essay, we have described some of the many ways that contemporary climate change presents new challenges to biodiversity. We are already committed to planetary warming that will likely remove a substantial number of specialized, endemic, and insider populations and species, and that will substantially disrupt even large and cosmopolitan meta-populations over the next century. If all goes well, we can ensure that few species will go completely extinct due to climate change alone, and, given our record on past investments, we can certainly save many threatened species using other means. Hence, while very far from easy, adapting to new climates is something that biodiversity can potentially do relatively well; certainly better than it can do when subject to direct human exploitation via habitat destruction or the introduction of large numbers of effective competitor species.

What we cannot afford to do, however, is remove the context within which this new climate-driven rebuilding of biodiversity could happen because of some vague hope that we can wander blithely away from current resource management and conservation challenges and instead engage in large-scale, global-scale tinkering of the earth’s climate. There is an urgent need to integrate adaptation strategies that might minimize climate biodiversity impacts into more conventional strategies for either direct conservation of species or more indirect conservation of biodiversity features. To do so, we need to know the sorts of impacts we ought to be concerned with and the responses we ought to be planning on. We also need to know what changes to current conservation strategies we need to consider, not just under various future climate changes, but in potentially quite different future states of nature, some of which may not yet exist. In short, much more research and thought should be going into developing and refining adaptation/conservation strategies than so far appears to be the case. This difficulty is only compounded by the evidence suggesting that adaptation’s capacity to offset climate impacts may not be constant, nor predictable, nor potentially increasing for given levels of impacts and within given taxonomic and habitat concerns, and this too requires more research to resolve. The typical response of many to the issues raised herein is to flee into discussing mountains, marine reserves, population viability, novel ecosystems, and ecosystem-based management. Yet all of these applications of “more of the same” strategies need re-evaluation not just under climate change but also in the light of exploiting them to encourage conservation of populations that maintained viable populations in a broader range of environmental conditions than do most today. Meanwhile, humanity is developing collective aspirations towards a brighter future, and the idea that such visions must include conserving the natural world in all its wild and domesticated glory is fast becoming a cultural norm that people can get passionate about. We do have a good sense of what works today to conserve biodiversity. A sustained and increased effort to translate these same values into a positive, adaptive vision for all things natural and evolutionary will succeed. We can save all aspects of biodiversity from the consequences of climate change; indeed, we are morally and ethically committed to doing so.

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