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Sanjai Kumar Gupta
Department of Zoology,
Government Degree College,
Barakhal, Sant Kabir Nagar,
Uttar Pradesh, India

Rajesh Kumar Dubey
Department of Zoology,
Government Post Graduate
College, Chunar Mirzapur,
Uttar Pradesh, India

Corresponding Author:
Sanjai Kumar Gupta
Department of Zoology,
Government Degree College,
barakhal, Sant Kabir Nagar,
Uttar Pradesh, India

Impact of COVID climate on global crisis and biodiversity

Sanjai Kumar Gupta and Rajesh Kumar Dubey

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Abstract

Climate change has created potential major threats to global biodiversity. The multiple components of climate change are projected to affect all pillars of biodiversity, from genes over species to biome level. Of particular concerns are “tipping points” where the exceedance of ecosystem thresholds will possibly lead to irreversible shifts of ecosystems and their functioning. As biodiversity underlies all goods and services provided by ecosystems that are crucial for human survival and wellbeing, this paper presents potential effects of climate change on biodiversity, its plausible impacts on human society as well as the setting in addressing a global crisis. Species affected by climate change may respond in three ways: change, move or die. Local species extinctions or a rapidly affected ecosystem as a whole respectively might move toward its particular “tipping point”, thereby probably depriving its services to human society and ending up in a global crisis. Urgent and appropriate actions within various scenarios of climate change impacts on biodiversity, especially in tropical regions, are needed to be considered. Foremost a multi sectored approach on biodiversity issues with broader policies, stringent strategies and programs at international, national and local levels is essential to meet the challenges of climate change impacts on biodiversity.

Keywords: Biodiversity, ecosystem functioning, ecosystem services, tipping point, forests

Introduction

Climate change poses major threats to biodiversity [1-3]. Although a certain variation of climate is compatible with the ecosystem survival and its function, the very rapid shift is detrimental to the variety of life. Climate change is expected to exacerbate biodiversity loss in the future [4]. Many species might simply be unable to adapt to the rapidly changing, probably unsuitable conditions and thus will be threatened by extinction [5]. As atmospheric CO_2 upsurges over the next century, it is predicted to become one of the major drivers of global biodiversity loss [6]. Global average temperatures increased by 0.2 °C per decade since the 1970s, global average precipitation increased by 2% in the last 100 years [7]. Moreover, climate alterations are spatially assorted. Tropical forest ecosystems for example experience much greater changes than global means, while other ecosystems and regions of the world are exposed to secondary effects. In addition to changes in averages of temperature, precipitation or sea level, anthropogenic climate change is also linked to changes in the frequency and intensity of extreme events, which can also affect biodiversity [8, 9].

Climate change may have already resulted in several recent species extinctions. Many species ranges have moved poleward and upward in elevation in the last century [10] and this is likely not to cease. Local communities are disaggregating and encompassing more warm-adapted species [11]. Phenological changes in populations, including shifting breeding cycles or deferred peaks of growth periods, are decoupling species interactions. Phenological shifts in flowering plants are potentially initiating the incompatibilities between plant and pollinator population. This may lead to the extinctions of both the plants and the pollinator with expected consequences on the structure of such mutualistic networks [12]. The multiple components of climate change i.e., temperature, rainfall, extreme events, CO_2 concentrations and ocean dynamics are anticipated to affect all levels of biodiversity: gene, species and habitat-diversity. At the very basic level of biodiversity, climate change is able to lessen genetic diversity of populations due to directional selection, genetic drift, population differentiation and rapid migration. As a consequence, the probability of population adaptation to new environmental conditions is reduced and thus the risk of extinction increases. Furthermore, altered species compositions and interactions are considered to directly affect ecosystem functioning and resilience [11].

At a higher level of biodiversity, an altered climate could induce changes in vegetation communities that are projected to be large enough to affect biome integrity as a whole. The Millennium Ecosystem Assessment predicted shifts for 5-20% of Earth's terrestrial ecosystems [13]. The particular concerns are "tipping points" where ecosystem thresholds will possibly lead to irreversible shifts in biomes. Such thresholds exist because of the ecological understanding of hysteresis as alternative states of ecosystems. The shift between them is characterized by passing a certain threshold or "tipping point". The potential for hysteresis (parameter perturbation or changing environmental drivers) implies that communities and ecosystems might be easily pushed into some configurations from which it may prove much more difficult for them to recover [14, 15]. Past examples include e.g., effects of invasion by exotic species [16], and undesirable vegetation changes in terrestrial ecosystems [17]. Pressures on biodiversity can shove ecosystems beyond what might be termed "safe functioning space". Once an ecosystem enters the peril zone it is in danger of crossing a threshold which will tip it into an alternative state. Actions to increase the resilience of ecosystems, *i.e.*, by conserving biodiversity, are critical to prevent the "tipping point" being surpassed. Meanwhile the precise location of tipping points is difficult to define. Recent "tipping points" analyses indicate that rising atmospheric CO_2 concentrations and climate change could lead to major biodiversity transformations. Especially in tropical regions [18]. levels near or below the 2 °C global warming, are defined as "dangerous" by the Intergovernmental Panel on Climate Change (IPCC). The change eventually becomes self-perpetuating through what is known as "positive feedback" for example, deforestation may reduce regional rainfall, leading to greater fire risk, further drying and dieback of forest. As a result of lags in the socio-economic, biological and physical systems, these transformations will be irreversible over the next several centuries [14], creating great difficulties in ecological management. With biodiversity as the basic fundament in providing ecosystem functions and services to human society, its loss induced by climate change might disturb these functions and services and might reduce human benefits. Reduced provision of ecosystem services can be expected for all types of land uses: agriculture, forestry, fisheries, infrastructure, urban agglomerations and tourism. Beside the complex approaches of conservation in situ there also exist artificial alternatives of biodiversity conservation such as assisted migration or ex-situ conservation.

With the magnitude of climate change expected in the current century and in combination with other human activities (*i.e.*, transformation of forest into agricultural land, expanding or creating settlements) biodiversity will be pressured far beyond the changes caused by natural global climate change [2]. Projected rates of climate change are also faster than they were in the past. Thus, *in situ* genetic adaptation of most populations to new climate conditions is not likely nor is migration likely to be fast enough for many species [2, 9].

Ecosystems can be considered as a fund of natural capital stocks generating flows of intermediate and final ecosystem goods and services through time, which will be disturbed by the scenarios aforementioned. These natural capital stocks include renewable and non-renewable resources such as biotic, geologic, water, atmosphere, and land resources. Flows of ecosystem services are classified by the Millennium Ecosystem Assessment [19], as supporting (e.g., nutrient cycling, primary production), regulating (e.g., natural hazard mitigation, water quality), cultural (e.g., spiritual values, recreation), and provisioning (e.g., food, fresh water) services. Stocks and flows are highly interdependent. Depreciating stocks jeopardize the future yields of flows. If beyond a possibility of adequate replacements, this interferes with the viability of natural capital stocks [20] and finally creating a possible crisis at a global scale.

Review and Discussion

Responses of species to a rapidly changing climate

Sullivan and Clark in 2007 define that the impacts of global climate change on biodiversity are not merely concerns of a far-off "worst-case" future [21]. Following their statements, global climate change has both direct and indirect effects on biological systems. Direct effects include those arising from increased temperature and increased CO_2 levels associated with global climate change. These direct effects give upsurge to numerous potentially serious indirect effects, such as changes to hydrologic cycles (precipitation and evaporation) and an increasing frequency of extreme weather events. These changes can influence biodiversity in many ways (whether positive or negative), such as changing the timing of critical events that affect the reproduction and survival of species.

In their publication in 2007 Sullivan and Clark in general describe three possible responses of affected species to global climate change, which can be recapitulated as "change, move, or die." Either species can adapt by altering life cycles or by shifting habitat ranges to a more suitable, generally cooler climate, or finally can become extirpated from a region or extinct altogether. There is evidence that all three responses are occurring around the world; as plant and animal species are already on the move toward the poles or to higher elevations [10, 11, 13, 22], hatching earlier, blooming earlier, or exhibiting other phenological changes [23] or even evolving rapidly [24]. Species-specific differences in the reaction to climate change can become particularly important when interacting species, such as plants and their pollinators, are considered. Hence, climate change has the potential to disrupt trophic interactions, having important consequences at ecological and evolutionary time scales [25].

Bellard and colleagues stated in 2012 that because of climate change, species might not acclimate through plasticity to the set of environmental conditions in a given region and could therefore fall outside their respective climatic niche. To persist, individuals, populations or species must develop adaptive responses, which can be several mechanisms [13]. The first would be that a given species will be able to acclimate fast enough to keep up with the rapid pace of changing climate through plasticity which provides a measure of short-term responses within individual lifetimes. This may involve intraspecific variation in morphological, physiological or behavioral traits, which can occur at varying temporal scales within the spatial range of the populations. Another type of response is a genetic one, where micro-evolution takes place. In such case species can genetically adapt to new conditions through mutations or selection of existing genotypes. Evolution can be very rapid through mutation and selection and could allow species with short life cycles to adapt successfully to severe environmental changes. However, many plant species show a unique and often slow response to environmental changes, which is related to specific plant life history traits, such as long generation times or potential for clonal growth [26]. It may take many generations for genetic drift to have a significant impact on population genetic structure [27]. Hence, it is not clear how the non-synchronization of the evolution of different species will affect their performance and thus ecosystem functions and services.

Although there are multiple possible responses at temporal and spatial scale to cope with a changing climate, nowadays species have to cope with additional threats. Those threats can somehow act in “synergy” with climate change [28] as for example habitat loss and destruction [2, 29]. Thus, as we are already facing an irrefutable biodiversity crisis, the possible increasing number of species that are threatened by climate change has become a major concern during the last decade.

Climate change impacts on biodiversity examples from tropical ecosystems

The following examples are summarized from the detailed appendices of the Global Biodiversity Outlook 3 by the Secretariat of the Convention on Biological Diversity [30].

Extensive dieback of humid tropical forest like the Amazon as modeled through various climate projections would lead to a substantial reduction in precipitation. Combined with rising temperatures this would lead to significant reductions in species abundance in this region than foreseen in previous global biodiversity assessments. Extensive fires and forest dieback could also result in a massive degradation of sustaining and regulating ecosystem services. The release of carbon, for example stored in vegetation and soils would be large enough to significantly influence atmospheric CO_2 concentrations and global climate. There is still uncertainty concerning the Amazon “tipping point”. However, if an extensive dieback of the Amazon Forest would occur within the next several decades a negative feedback loop regarding biodiversity, regional and global climate will be a possible scenario [31].

The West Africa “tipping point” for land degradation has already been passed several times with dramatic consequences for human well-being [31, 32]. Social and political instability promotes the unregulated use of natural resources and drives human migrations to regions already under environmental stress, often triggering further social and political disruption. Many studies found that a reduction in species richness harms the functioning and services of ecosystems. The short-term adaptability is to a decisive degree a function of species diversity. Therefore, one crucial service of species-rich ecosystems, such as the Sudanian savannas and woodlands, is the capability to mitigate the effects of climate change respectively. This and further ecosystem services such as pollination, seed dispersal, natural pest control–thus are the basis for continued regeneration of natural biodiversity, allowing for continued use of many vital natural goods and services by the local inhabitants [34]. This also applies to the Guinean Forest, which is characterized by a high level of endemism. Land degradation is considered as one of the main reasons in the semi-arid areas of this region, as well as the great difficulty of restoring lands once they have been degraded due to soil compaction, erosion and salinization [33].

The “miombo woodlands” belt, a moist savannas formation, is elongating south of the Congo rainforests from Angola to Tanzania as one of the largest remaining near-intact ecosystems in the region. Instead of direct impacts of climate change, here land use change (which might be an indirect effect of local climate change) is projected to cause high rates of extinctions of vertebrates and vascular plants, thus changing the species composition and therefore the characteristics of this woodland by more than 20% by 2050 [34, 35].

Climate change induced species loss and altered ecosystem functioning

Global estimates predict major losses of biodiversity due to global climate change, which are generally higher than current rates of loss and also much higher than rates of species extinctions documented in fossil records [37]. One of the first global studies estimated that by 2050, 15-37% of species are committed to extinction under intermediate climate warming [36] Malcom and colleagues stated in 2006 that the extinction rate of endemic species could reach up to 39-43% under worst-case scenarios, which represents a potential loss of 56,000 endemic plant species and 3,700 endemic vertebrate species [38]. Biodiversity hotspots for conservation priorities are particularly vulnerable because they are not only characterized by their endangerment, but also by their high level of endemism [39]. The majority of those hotspots are located within tropical regions.

There is robust understanding that biodiversity in biogeochemical functioning of an ecosystem depends on the combined, interrelated activities of its organisms, *i.e.*, the ways and rates at which ecosystem processes are carried out (e.g., respiration, CO_2 fixation, nitrification, litter decomposition). If such processes are disrupted by the loss of species and therefore by the loss of essential links within the system, ecosystem functions are affected, including impacts on goods and services provided by ecosystems to human benefit and prosperity [40, 41]. Therefore the issue of climate induced biodiversity loss is of major concern, especially in the environment of vulnerable developing countries in the tropics.

How to face a lingering crisis?

A global setting facing a lingering global crisis has been formulated in the institutional frameworks on governing biodiversity and climate change: e.g., the establishment of the Convention on Biodiversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC). The framework then is specialized through the construction of various global networks as well as through national and local initiatives.

Recommendations on biodiversity management in the face of climate change, out of initiatives by the aforementioned institutions and others, were reviewed by Heller and Zavaleta in 2009 [1]. They differentiated between general and actionable principles, whereas most recommendations offer general principles for climate change adaptation but lack specificity needed for implementation. Throughout the recommendations it appears increasingly important to protect the heterogeneity of habitats as well as the genetic diversity within a species to sustain a sufficient capacity to adapt. Furthermore, conservations efforts should be prioritized for sites, which are capable of a minimization of the effects of climate change e.g., tropical forest ecosystems, which not only contribute essentially to local climatic conditions, but also are suitable as climate refuges for biodiversity. Another important strategy is to enhance landscape connectivity to enable species to move through a matrix of interconnected habitats to support possible escapes from unsuitable climatic conditions and to provide gene flow. Data-driven, demographic assessments in conservation biology are particularly needed to predict abundance responses and to identify areas that can serve as biodiversity refugia under climate change [29]. In this regard it is of increased interest to avoid a somehow conventional view of climate change as a single threat, but rather see the interrelation between additional and potentially synergistic factors like land-use change or pests [29, 30].

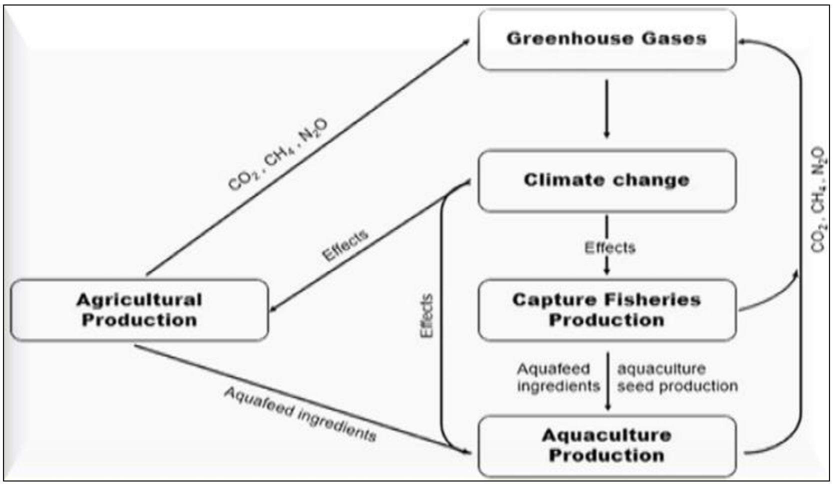

Fig 1: Shows the agriculture production & biodiversity facing different culture.

It is also essential to shift from a species centered focus to a holistic view; encompassing species interface networks and other facets of biodiversity such as functional and phylogenetic diversity. Beyond numerous different sectors Fig: 1 there is an emergent demand to go past the predictive focus and start aiming for an integrated and united framework to identify species vulnerability and adapt biodiversity management interventions. In addition, reducing other global change drivers could increase overall resilience of biodiversity in the face of climate change.

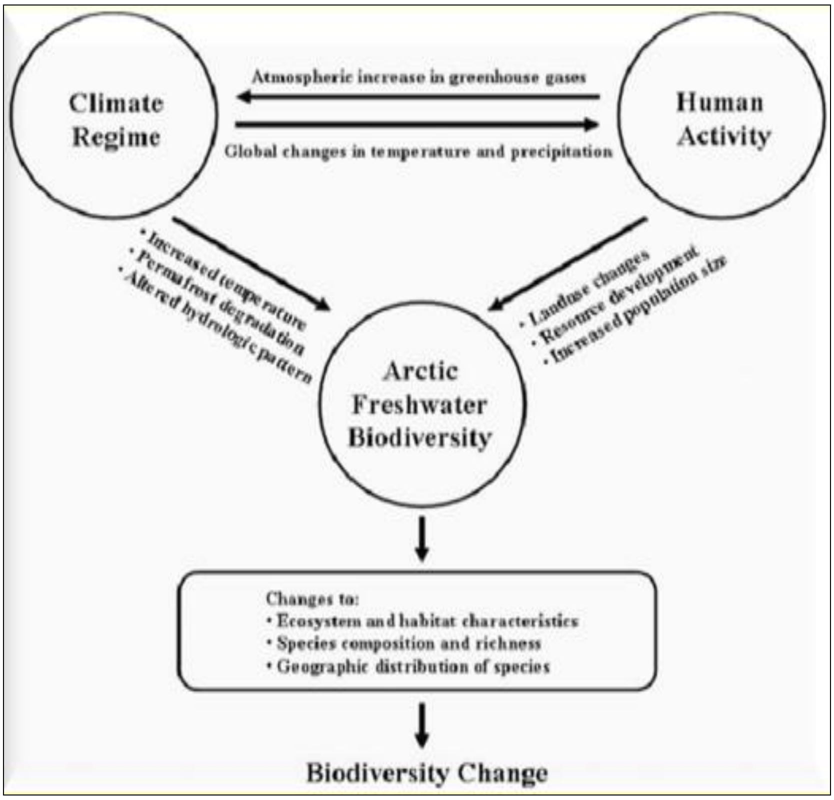

Fig 2: Distribution of given recommendations regarding biodiversity management in the face of climate change among different sectors.

Conclusions

Scenarios related to the impact of climate change on biodiversity are made up continuously, often predicting fast paced extinction of species, loss of natural habitats and shifts in the distribution and abundance of species during the first decade of this 21st century. In this matter "Climate Change" may be a familiar term by now, but further attention and action is urgently needed. Even a modest and slow warming of the climate will have complex consequences in terms of species numbers and distributions, thus potentially disrupting ecosystem functioning and services. This will be exponentially severe in highly diverse ecosystems like tropical forests comprising highly specialized organisms. This causality is particularly relevant for developing countries where often the majority of local livelihoods depend on goods and services provided by ecosystems like tropical forests.

Drivers of biodiversity loss have not yet been addressed significantly. Furthermore, there is a paucity of works dealing with the interaction between different drivers of global change. So far, most studies only focus on particular ones (mostly either climate change or habitat loss) and the mentioned interactions are largely neglected in assessments under global change scenarios. Hence, it is necessary to consider those interactions among different drivers of environmental change in the future.

Biodiversity issues suffer from insufficient integration into broader policies, and stringent strategies and programs at international, national and local levels are mostly far from being functional. Future initiatives must start to overcome the lack of connections between the regarding sectors. They must be able to adapt in an appropriate way towards increasing knowledge, raising public awareness and responsibility and thus towards changing conditions. The recent establishment of an institution like the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), which has to complement to existent structures like the Intergovernmental Panel on Climate Change (IPCC), might be a first step into this direction.

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