# Species response to climate change.

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***Received:*** *15-Jul-2022, Manuscript No. AAASCB-22-69322;* ***Editor assigned:*** *18-Jul-2022, AAASCB-22-69322 (PQ);* ***Reviewed:*** *01-Aug-2022, QC No. AAASCB-22-69322;* ***Revised:*** *13-Oct-2022, Manuscript No. AAASCB-22-69322 (R);* ***Published:*** *20-Oct-2022, DOI: 10.35841/2591-7366.6.11.151*

## Abstract

**The study aimed at narrative review of published literature to understand the response of mammals, birds, reptiles, fish, insects and microorganisms to climate change. Response of biodiversity to altitudinal gradient was also reviewed. It results into habitat loss, sea level rise and snow melting influenced species diversity and species extinction climate change affected biodiversity both positively and negatively at all scales and levels. The response of species diversity to climate change is a complex phenomenon. Literature search from 2000-2019 was carried out using key words, nature and climate change journals. More than 120 publications were obtained and key phrases in Google search engine. Elsevier, JSTOR, Googlescholar, Research gate and 69 were used for this publication. The study found that species diversity responds to climate change differently depending of their habitat, feeding habit and physiology. While some organisms are favoured by increased high temperature/rainfall, others are disfavoured by increased temperature/rainfall. The review concluded that the response of species to climate change is complicated since involving both negative and positive scenarios. Further studies were recommended to generate more knowledge and better understand the complex phenomenon for sustainable development and human wellbeing.**

**Keywords:** Temperature increase, Heavy rainfall, Extinction, Habitat loss, Plant phenology, Biodiversity

## Introduction

Biodiversity at all levels are differently affected by climate change across the globe. “Biodiversity is the variety of life on earth and includes variation at all levels of biological organisation from genes to species to ecosystems. Genetic, organismal, ecological and cultural diversity are all elements of biodiversity with each including a number of components” [1]. Biodiversity are found within the biosphere component of the Earth’s spheres due the favourable conditions that support life. “Climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer” [2]. Climate change and biodiversity are interdependent thus affect each other at both local and global scales. Climate change is one of the threats to biodiversity across the globe [3] and in certain instances; it leads to migration and even extinction of living organisms from the earth’s surface. Studies report that there is now enough evidence of the ecological impacts of recent climate change, from polar terrestrial to tropical marine environments [4,5] and this has an impact on species diversity. Climate models predict that species migration might not match with the speed at which climate is changing hence posing a threat of extinction in some regions [6]. A number of flora and fauna species have gone extinction because of changing environmental conditions that are unfavourable for their survival across the globe [7,8]. Previous studies on the Albertine Rift region show that 34 endemic species were predicted to lose >90% of their remaining suitable habitat because of climate change [9]. The impact of climate change has affected all types and classes of living organisms ranging from mega fauna, small mammals, birds, reptiles, fish, birds, insects, planta and microorganisms at different rates in different regions. It has been reported that more than 26,500 species are threatened with extinction, which are more that 27% of all assessed and documented taxa at the global level [10]. How different species responds to climate change is not well documented hence the need for this review [11].

## Literature review

### *Methodology*

A systematic literature search was done from 2001 to 2019 using key words and relevant phrases. This was done from Elsevier environmental and ecological journals, JSTOR journals, Google web browser, Googlescholar, Research gate and nature and climate change journals. Out of 120 scientific articles, books and reports retried, 69 were selected and reviewed during the preparation of this manuscript. Narrative review guidelines were followed while preparing this manuscript [12] and other relevant e-books, conference proceedings, government and farmer group reports at local, national, regional and International levels from both developing and developed countries were consulted for additional information on the response of species diversity to climate change.

**Response of fish to climate change:** Climate change affects fish habitat and phenology and the fish species migrate to look for suitable habitat. The most recent climate impact on fish diversity was coupled with increased acidification of marine ecosystems resulted change in pH and affected the survival of a number of fish species. Zhang predicted that warm water habitat favour fish spawning and survival but high increase in temperature has a negative effect on fish and associated biodiversity. Canadian researchers predicted that global flatfish catches have been declining since the 1970's and suggest that climate change may further exacerbate the declining trends and threaten the long-term variability of some flatfish populations in the 21$^{st}$ century [13]. Similarly, climate change was predicted to be responsible for the high levels of Mercury, which has a negative effect on fish and humans [14]. At the same time, researchers in USA predicted that increasing temperature has a serious negative effect of reducing rare color morph in fish species and some may go extinct by 2100 [15]. Climate change affects the foodstuffs of fish, their phonology, habitat and diversity. Moreover, this also affects the aquaculture and the entire fish value chain thereby affecting the livelihood of all the fishermen and government revenue hence increasing household poverty and malnutrition.

**Amphibian's response to climate change:** Climate change affects amphibians mostly because they spend part of their lifecycle in water and part on land. They bleed in water and when they mature, they move to land where they spend most of their life and obtain food. Previous studies predict a decline in species diversity of amphibians in both the present and the future centuries [16]. Previous studies show that climate change affects the physiological performance in amphibians: 1) Temperature increase, 2) The increase of the dry season length, 3) Decrease of soil moisture (due changes of precipitation and temperature rise) and 4) Increase in rainfall variation. This would affect organisms at population and community levels [17]. Studies conducted in the USA reported that frogs and toads are highly sensitive indicators of biotic response to climate change. Climate variability affects the critical eight months of amphibian gametogenesis (overwintering, emergence, courtship and spawning). Frogs, especially those that breed early in the spring season, are especially sensitive to increases in winter and spring temperatures [18]. Climate change affects the reproductive behaviour and might enhance amphibian chytridiomycosis disease among the among amphibian species [19] that affects their health. Changes in climate may affect survival, growth, reproduction and dispersal capabilities of amphibians. It can alter their habitats including vegetation, soil and hydrology. Climate change can influence food availability, predator prey relationships and competitive interactions which can alter community structure and result into extinction of amphibian populations [20]. Amphibians are poiquilothermic, the thermoregulatory performance are related to the water balance, digestion, oxygen supply, vision, hearing, emergence from hibernation, development, metamorphosis, growth and immune response. Increased temperature may strongly influence on amphibian species' geographic distribution so that the species with broad tolerance to thermal regimens are able to expand their ranges and then colonize new habitats. Based on the above authors, amphibians are indicators of environmental and ecosystem health. Climate change has resulted into reduction of water levels for many lakes and some have gone dry in many regions across the globe. This poses a great threat to the amphibian and some have gone extinct as a result.

**Response of reptiles to climate change:** Reptiles are much sensitive to climate change and most of them are vulnerable. Studies in USA reported that 80.5% of reptiles are highly sensitive to climate due to habitat specialization, 48% had low adaptability and 58% have high exposure and some may go extinct due to climate change. The range for reptiles, coral reefs amphibians were reported to have shrink leading to population decrease in polar regions due to climate change. Previous research shows that 80.5% of species of reptiles are highly sensitive to climate change due to habitat specialization, 48% had low adaptability and 58% had high exposure ability. At the same time conducted on 1918 species among 49 reptile families revealed that climate change affects their distribution, thermal biology, reproduction and genetics. Zhang found that one week of exposure to a simulated heat wave significantly shortened telomere length and decreased the overwinter survival of lizards in China hence climate change might have a significant effect on these reptiles. Similarly, studies conducted by American scientists on 25 species of herpetofauna (7 amphibians and 18 reptiles) revealed that most of these herpetofauna species were vulnerable to impact of climate change. Studied in Himalaya mountains predicted a significant decrease of -15% to -64% of Amphibian species by 2080 due climate change. Models projected extinction risks for a tropical heliothermic teiid lizard (*Kentropyx calcarata*) from 52.8% to 92.8% in Amazon forest, Brazil due to climate change. Models predicted a decrease of 15-84% by 2018 of the four *Scutiger* species including: *S. boulengeri*, *S. glandulatus*, *S. sikimmesis* and *S. tuberculatus* in India due to climate change. Most reptiles like to live and reproduce in dump places or near water bodies. High temperature deprives them of suitable habitats for their reproduction and survival.

**Response of birds to climate change:** "Global warming is the greatest threat to birds and other wild life in human history. The rate of global warming is already impacting birds, their prey and their habitat. Those impacts will become more severe over the coming decades, leading to the loss of one-quarter to one-third of all species on earth, including many bird species". Birds respond to climate change in different ways. Migratory birds were reported to be climate sensitive and respond to changes in temperature and their populations vary depending on the environment migratory bird species spend much of their time in water bodies and high temperature affects their habitat and when the water dries in one area, they have to migrate to look for another habitat for their survival. Many bird community composition 38% of the breeding species were observed at higher altitude due to favourable temperature that support their survival. Studies show that 145 bird species suffered significant declines in abundance and species richness between two time periods between 1997-1998 and 2012-2013 in China due to climate change and habitat loss. Additionally, 14 species were reported to have moved to different directions driven by climate and habitat change in China. Climate change affects the phenology of plants and this affects the fruiting period that provides food for the birds resulting into shifting of birds to look for other habitats where they can get food from. Climate change is affecting birds' behaviour, distribution and population dynamics and is implicated in complete breeding failure in some population. Climate change affects their habitats, phenology, timing of migration and nesting. It can also lead to increased pressure from competitors, predators, parasites, diseases and disturbances like fires or storms. Studies conducted in Finland 1981-2017 revealed that increase in temperature of 1.1°C resulted into 28.5 km to 1.8 km/year northward range shift for the migratory birds and population decline up to 10%. Related studies in China predicted the increased spread of avian influenza ($H_5N_1$) outbreaks among migratory birds due to increased temperature. Studies in Germany predicted that increasing winter temperature is expected to lead to declines in the proportion of migratory species, whereas increasing spring temperature and decreasing spring precipitation may lead to their increase. Migratory water birds are severely affected by climate change. This is partly the cause for their migration to look for suitable habitats where they can find feed and breeding places. Other aquatic birds depend on aquatic zooplanktons, phytoplankton and fish. Increased temperature and rainfall affect aquatic ecosystems hence affecting fish either directly or indirectly. Climate change also affects plant phenology for production of fruits that feed terrestrial bird species.

**Mammal's response to climate change:** Mammals respond differently to climate change depending on mammal type and their habitat. Previous studies show that small mammal's population decreased with increasing altitude due to the effect of increasing minimum temperature of 30°C in Yosemite national park, California, USA. Related studies in the USA predicted species decline, reduced range and threat of extinction based on the climate changes over the years. At the same time, polar bears have decreased in size and declined in numbers due to receding snow habitat resulting from climate change in polar regions. About 80% of species have been reported to have shifted 6.1 km pole ward per decade and 87% had advancement in phonological events including breeding and flowering in polar regions. Decreased sea level has been reported to be responsible for disappearance of some aquatic diversity. Models predicted that nine threatened mammal species will lose more than 50% of their range in Altai mountains, China due to climate and land use change in the region. Similarly, extreme climate events such as increased precipitation affected small mammals for example; *Oryzomys melanotis*, an invasive and opportunistic species, benefited from extreme events and two populations were harmed by them: *Peromyscus perfulvus* and *Liomys pictus*, the small mammal with the most abundant population of the upland forest, which was extirpated for over 16 months in Mexico. USA scientists reported that mammals may be affected by alterations in pathogen transmission due to a variety of factors, effects on body condition due to shifts in the prey base/food web, changes in toxicant exposures and factors associated with increased human habitation in the Arctic marine mammals. Related studies in United States of America predicted loss of some species of mammals 4 million years ago as a result of global warming. As the global warming is increasing the rate at which mammals extinct was much increased and now 25% of mammals are threatened with extinction at the global level. Climate change affects food and water availability of mammals which are the most important parts of their lifestyle. Buffalos, elephants, cows, zebras, etc. cannot survive in absence of water. Many of such species have died in the present century in semi-arid countries including Kenya, Ethiopia, Tanzania, etc. due to water shortage. Loss of domestic animals affects livelihood of those people that depend on livestock for instance the Borana of Ethiopia and the Karamojong of Uganda. Loss of wildlife causes a great loss of the government tourism revenues.

**Insect's response to climate change:** Increased ticks and tick borne diseases and other vector borne diseases and human diseases have been reported to come after biodiversity loss. Pests and diseases have shifted their ranges across the globe thus affecting humans and wildlife. High altitude regions like Kabale, western Uganda and Kitabi south Rwanda where malaria was not a problem are now experiencing severe malaria due to the invasion of anopheles mosquitoes. This was caused by degradation of wetlands and cutting down forests which increased the temperature hence favouring the survival of vector borne diseases. Increased temperature up to 43°C increase bee's mortality and decrease their performance. Models predict that crop pest species will increase in distribution due climate change across the globe. This could have more profound impacts on the species distributions of those regions where species richness increases are expected, by altering the species' community compositions. Similarly, studies conducted in SWISS Alps predicted a large number of plant species shift to higher altitudes due to the impact of climate change. Climate change in the USA was predicted to increase habitat fragmentation and reduce breeding habitat patch size by 2090. Models predicted increased global distribution of poikilothermic invasive pest species due to

climate changes associated with decreased temperature and precipitation. Studies in France show that increased temperature of 40°C-43°C decreased growth of deformed wing virus but increased bee mortality in laboratory experiments indicating that high temperature due to climate change has a negative effect on bee's performance. Insects are pollinators and make a great contribution to peoples' livelihood by enhancing crop production. Particularly, the bees produce honey which is important peoples' income and nutrition and climate change affects their health and productivity.

**Microorganisms, diseases outbreak and climate change:** Majority of vectors and microorganisms thrive with increasing temperature due to climate change. This is because high temperature favours multiplication of most microorganisms thus enhancing diseases spread in humans, plants and animals. For instance, previous studies in Eurasia predicted that *Haemaphysalis concinna* Koch, 1844, a proven vector of Tick Borne Encephalitis (TBE) virus and *Francisella tularensis*, the causative agent of tularaemia will increase to up to 87.3% in warm temperature with precipitation all year round. Related studies in Argentina projected more spread of armadillo (*Chlamyphorus truncatus*) and particularly the Chacoan fairy armadillo (*Calyptophractus retusus*) due to current climate change. Similarly, studies report that certain emerging disease events are preceded by biodiversity and climate changes. Studies in the USA predict that water borne diseases are expected to increase as water temperatures rise due to the impact of climate change, in their study predicted that climate change and increased temperature will enhance spread of chikungunya fever in northern Italy, the sudden appearance of West Nile virus in North America, the increasing frequency of Rift Valley fever epidemics in the Arabian Peninsula and the emergence of Bluetongue virus in northern Europe. At the same time, scientists reported that disease outbreak and increased mortality of coral reefs and marine mammals were associated with high El Nino temperatures. It is reported that climate change will continue to limit the transmission of certain pathogens and create opportunities for others to spread diseases based on host-pathogen relationship and life cycle. Recent outbreak and spread of six strains of bluetongue, a devastating disease of ruminants, across 12 countries and 800 km further north in Europe has been attributed to global warming. Additionally, 51% of waterborne disease outbreaks were preceded by precipitation attributed to extreme precipitation. Nevertheless, host pathogen and climate change relationship is still a puzzle among scientists and gaps need to be filled by additional studies to find out how climate change modulate both directly and indirectly, host-parasite and disease persistence. Climate change has enhanced flourishing of microorganisms and diseases among humans and wildlife, especially increased temperature. Emergency of some diseases such as Ebora and pests like armyworm might be due to climate variability. Climate change has also increased pest resistance to pesticides and ticks' resistance to acaricides, which in turn undermine farmer's income and enhance household poverty.

## Discussion

**Plants response to climate change:** Plant physiology, phenology, pollination and dispersal are among the survival strategies much affected by climate change. Most plants fail to reach maturity during high temperature due to climate change. Snow ice has melted considerably since 1976 resulting into 35-75% decline of sea algae due to climate change. Some plants have increased in abundance because of increased temperatures while coral reef species reduced in numbers due to unfavourable conditions. A number of reports indicated that invasive plan species were much favoured that the native plants in the natural ecosystems due to climate change. Plant species distribution has been reported to occur in USA due to variations in climate. Research predicted that majority of flora species might have gone extinct during the Permian mass extinction due to environmental changes. Studies show that heat stress reduces fruit set of fruiting vegetables and speeds up development of determinate vegetables, shortening their time for photo assimilation resulting into yield losses, an impaired product quality, thereby increasing production waste. Studies in France predicted early spread of leaf rust diseases in wheat crops due to climate change suggesting the possible food insecurity in the region. Related studies in Spain revealed that elevated $CO_2$ in combination with high temperature (climate change scenario) reduced IVDMD and CP content and enhanced fibre content, which means that animal production, will be negatively affected. Benlloch-Gonzalez in Spain found out that exposition of the root system of young olives to 37°C for several hours inhibited K+ (Rb+) transport from root to shoot and growth of all parts of the plant suggesting that climate change may have a negative effect on plant growth and development. Plant productivity has been affected by extreme temperature and this increase food insecurity among many populations. Some crops die and do not reach maturity resulting into decreased crop production culminating into hunger in most developing countries. Malnutrition and under nutrition have increased in most developing countries due to climate change. Climate change undermines attainment of sustainable development goals for most countries across the globe.

**Response of biodiversity along the altitudinal gradient:** Increasing altitude is associated with decrease of both temperature and atmospheric pressure with the troposphere. This decrease has an impact on species diversity in the biosphere. Butterfly species richness and abundance were highly correlated with altitude, temperature and relative humidity in India but the density and richness of Oribatid mites decreased with elevation in Mount Kinabalu, Malaysia. Low species diversity of the family Araceae was found at the lowest and highest altitude in Thailand implying that there are other factors affecting their distribution other than pressure and temperature. Studies in Nepal predicted steep species increases altitude until 1,500 m above sea level, little change in species diversity between 1,500 and 2,500 m and an increase in species diversity above 2500 m above sea level suggesting various factors affecting species distribution along the altitude while studies conducted in China predicted a significant decrease in

above ground biomass in alpine meadow, Qinghai-Tibetan plateau Chang, China suggesting a decrease of plant diversity at higher altitude. Similarly, previous studies predicted a decline of arthropod species with decreasing glacier levels in Almajallojekna glacier, Sweden. However, studies in Switzerland revealed that thermal and nutrient demands drive species distribution along the altitude; thermophilic species tended to expand, while those of cold adapted species tended to contract suggesting that temperature and nutrients are key determinants of species distribution. Although majority of species diversity decrease along altitudinal gradient, some species increase suggesting that there are various factors that affect species diversity along the altitude. These include edaphic factors, nutrient availability, humidity, pressure, etc. No single factor can explain species diversity along the altitudinal gradient.

## Conclusion

The response of biodiversity to climate change is a complex phenomenon. Different species respond to climate change differently based on their phenology, geographical location, habitat and species type. Some species are favoured by warm temperatures and increased rainfall while others are disfavoured. Models predict extinction of some species by 2100 if climate continues to change at the current rate. The majority of global data and climate change models indicated alarming consequences for biodiversity, with the worst-case scenarios leading to the highest extinction rates than favour biodiversity. More multidisciplinary and synchronized studies need to be conducted in this complex subject to generate better knowledge for sustainable development, effective biodiversity conservation and human welfare.

## Acknowledgement

I thank the African centre of excellence for climate smart agriculture and biodiversity conservation management for the funding support they provided through world bank which enabled me pursue my PhD study at Haramaya university. Special thanks go to Dr. Anteneh Belayneh Desta for teaching the course and the time he spent reviewing this publication. I thank the professor Maud Kamateni-Mugisha for giving me a study leave to pursue PhD. God bless you all, Our god reigns!

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