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RESEARCH ARTICLE

CLIMATE CHANGE IMPACT AT THREE DIFFERENT SCALES OF BIOLOGICAL DIVERSITY: A HOLISTIC REVIEW OF RESEARCH FINDINGS FROM ACROSS THE GLOBE

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Abstract

Impact of recent changes in global climate is evident through many scientific investigations using field observations and through modelling studies. The impacts are perceived to effect biodiversity at three different scales i.e. ecosystem diversity, species diversity and genetic diversity. Most findings indicate a notable widespread impact on tropical region and specific effects on some habitat specialists and species with no migration ability. The current review also highlights the need of more research efforts to investigate impact on genetic diversity across various taxa of flora and fauna.

Introduction:-

The conservation of the diversity of life we inherited is of immense importance, especially their degradation and depletion arelargely caused by anthropogenic actions, directly or indirectly (Venter et al. 2016). Among all causes of biodiversity loss, the global climate change phenomenon is one of the large and looming challengeof biodiversity conservation (Stern 2008). The global climate change not only threatens the existence of some individual species buthas already had an observed impact on natural ecosystems (Woodward et al. 2008).

Global average temperatures have risen by 0.7-0.8 ºC over the last century and are predicted to continue rising(IPCC 2007). With increasing temperature which is a sign of global climate change, it is pertinent that the areas of rare climates are likely to shrink, and that in turn may result in the loss of rare endemic species (Öhlemülleret al. 2008).It has been well recognized that there is a clear link among biodiversity, climate change and sustainable development as reflected in the various fora and frameworks such as Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC).

Three principal sources provide evidence for impacts of global climate change on biodiversity that are 1) field observations, 2) experimental outcomes and 3) predictions from the modelling studies. The first evidence come from the direct observation of biodiversity in nature where the changes in the different components of biodiversity over a period of time which can obviously linked with climatic variations.Parmesan and Yohe (2003) reported the phenological changes in bird arrival times and changes in distribution. In addition to the direct observations there are several experimental studies indicating the effect of increased CO_2 on plant communities (Morgan et al.2006; Bloor et al.2008), or effect of temperature rise on plant phenology (Hovenden et al. 2008). Additionally, modelling of changes in climatic variables which in turn help to project the impacts of climate change on future population distributions and changes. This may provide us with probable outcomes based on our current understanding of the requirements and constraints on the distributions of species and ecosystems in light of modelled changes in climatic

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variables (see Martinez-Meyer et al. 2004; Botkin et al. 2007; Heikkinen et al. 2007; Luoto & Heikkinen, 2008, Nogués-Bravo et al. 2008).

The impact of global change would affect biodiversity at three hierarchical levels i.e. at ecosystem level, at species level and finally at genetic level.

i. Climate Change impacts at ecosystem level

Climate change slowly alters the composition of particular ecosystem and that in turn affects the functioning of the same and ultimately to the spatial distribution of that ecosystem. Experimental evidences substantiated by the modelling studies provide evidence of significant change in the distribution of some ecosystems owing to rise in global temperature and shift in precipitation regimes. Such changes generally occur first at areas bordering different ecosystem types (Thomas et al.2008) as the actual occurrence of these changes in such areas largely depend on the ability of component species to migrate and to the availability of suitable substrates. Such changes are evident from previous studies such as by Beckage et al. (2008) which showed an upward shift of tree species. There are some field studies which reported the species turnover and attendant changes in species richness in terrestrial as well as aquatic ecosystems (see Daufresne& Boet 2007; Lemoine et al.2007; Moritz et al. 2008; Bunker et al. 2005; Bush et al. 2008; Phillips et al. 2008). Besides, there are several studies providing examples of likely species turnover through modelling and simulations (Levinsky et al. 2007; Buisson et al. 2008; Colwell et al. 2008; Trivedi et al.2008).

Besides species turnover and distribution shifting caused by the change in climate in long run, there are studies showing the spread and establishment of invasive species and that have in turn major impacts on ecosystem composition (Hobbs et al. 2007b; Hellmann et al. 2008; Rahel & Olden 2008; Rahel et al. 2008). According to van derWalet al. (2008)climate change has been recognized as one of the key interacting factors which can enable a native species to become invasive.

ii. Climate change impacts atspecies level

Climate change seem to affect individual species through interfering with its performance which subsequently let species adjust with prevalent climatic condition or develop new adaptation for migrating to neighbouring ecosystem.There are some biological species or group of organisms which can not adapt or migrate fast enough to keep pace with the changing climate and therefore such species or organisms face increased risk of extinction (Menendez et al. 2006). The ecosystem in which such species or group of organisms are abundant are prone to lose function in its original form, e.g., coral reefs, rain forests, cloud forests (Hoegh-Guldberg et al. 2008).

At individual species level climate change affects either through species distribution or through change in its population status. We look into both one by one:

Climate change and population distribution of species

For successful survival of any species in a given habitat depends on various habitat factors. Suitability of such habitat factors are directly dependent on prevalent climatic conditions such as range and average of annual temperature as well as precipitation pattern. Climate change as manifested by the temperature rise and altered precipitation range would affect the suitability of a habitat for a particular species. In response to the altered habitat through rapid change in climatic conditions, a species is likely to change thegeographic extent of its distributions. The resultant species response would be eithera) latitudinaland/or b) altitudinal shifts and/or c) contractions ofspecies' distribution range.

Poleward shift

It has been observed that global climate change has caused drastic and harsh climatic conditions with extreme weather events in mid latitudes (IPCC 2007). There are several studies on different species and meta-analyses of observed impacts have found that there have been significant range shifts towards poles in recent years (Parmesan & Yohe 2003; Root et al. 2003). Besides there are several observational records for many species including plants (Colwell et al. 2008), invertebrates (Hickling et al. 2006; Franco et al. 2006; Mitikkaet al. 2008), and vertebrates (Gaston et al. 2005; Hickling et al. 2006; Hitch &Leberg 2007; Lemoine et al. 2007; Sorte& Thompson 2007; Schliebe et al. 2008) which corroborate the findings of significant latitudinal shift of range boundaries, change in their abundance and shift in the centres of their occurrence.

Altitudinal shift
In recent times, there are new observational evidences substantiating the findings that in condition with increasingtemperature many species tend to migrate to higher elevations. It has been observed that altitudinal shifts for species on mountains and in grasslands have been larger than species in other habitats (Lenoir et al. 2008). Many plant species in Europe (Kullman 2007; Lenoir et al. 2008) and North America (Kelly & Goulden 2008) have been observed migrating up-slope. In case of butterflies, their distribution ranges in Spain have shifted upwards by over 200 m within period of 30 years which is consistent with shifts in isotherms (Wilson et al. 2005;Wilson et al. 2007). Even in case of vertebrate fauna such as Madagascan amphibia and reptiles, birds in Southeast Asia and mammals in temperate region have shown a shift in their altitudinal distribution (Parmesan 2006; Peh 2007; Moritz et al.2008; Raxworthyet al. 2008). There are some studies in which upward shifts in tropical insect distribution have been modelled (Colwell et al. 2008) and as tropical ecotherms already exist close to their thermal optimum, change in temperature are likely to have very deleterious consequences (Deutsch et al. 2008).

Range contraction
Beside species ranges shifting latitudinally or altitudinally, distribution ranges of many species which are unable to migrate would respond by range contraction. Carroll (2007) finds that in case of mammalian species such as Martins and Lynx, interactions between climate change and landscape changes will impede the range shifting and therefore resulting in range contractions and potential extinctions. Another example of the range contraction is for Scandinavian land birds where the Arctic Ocean acts as a natural barrier restricting them from latitudinal shift (Virakkalaet al. 2008). Similarly, Franco et al. (2006) also observed the range contractions in case of butterflies in Britain. Jetzet al. (2007) have projected that 5 % of all land bird specieswill get affected by 50% range reductions by 2050.

The phenomenon of range contraction is much devastating and severe for organisms with limited dispersal abilities such as amphibians and reptiles (Hickling et al. 2006), plants (Huntley, 2007) and range restricted species such as mountain top specialists (for eg.Snow leopard) and species in polar region (for eg. Polar bear) as land area decreases with increasing elevation (Moritz et al. 2008).

In addition to direct impacts on species as discussed above, shifts in species distribution would potentially disrupt biotic interactions and networks within particular ecosystem especially when interacting species respond differently to new weather conditions and that have important ecological and evolutionary consequences (Parmesan, 2006; Lenoir et al. 2008). Resultant new biotic interactions among species within an ecosystem could also lead to decline in overall biodiversity in future (Shuttle et al. 2007; Liow &Stenseth 2007) or impede more complex ecological responses (Tylianakiset al. 2008) owing to some important factors such as dispersal ability (Brooker et al. 2007).

Climate change effects on population status
Climate change through a range of mechanisms acts upon the performance of different species and therefore many species population have declined as well as reduced their distribution. Whereas, some other species have responded to the climate change with an increase in their population as well as range expansion over a period of time. For example, some of the European birds have declined while some others have increased(Gregory et al. 2008). Another similar example is of butterflies in Britain and Germany where their range has expanded (Menendez et al. 2006; Patrick et al. 2007). Major threats on biodiversity from global warming has been recognized in tropical regions which are rich in biodiversity (Deutsch et al. 2008; Tewksbury et al. 2008; Williams & Middleton 2008). It has also been observed that species from tropics and polar region as well as few habitat specialists are at receiving end of global climate change (Wake 2007; Laidreet al. 2008; Wake &Vredenburg 2008). Among all affected organisms, endemic species where migration is not assumed are predicted to be the most adversely affected species. Some modelling studies have projected that in simulated climate and land use scenario by 2100, 400-900 species out of 8750 species of land birds would suffer from the range reduction (Jetzet al. 2007; Sekerciogluet al. 2008). Globally, it has been predicted that increase in global warming by every degree would trigger the non-linear increase in bird extinction of about 100-500 species (Sekerciogluet al. 2008).Interestingly, 79% of such bird species are not even considered threatened today (Sekerciogluet al. 2008).

iii. Climate change impacts at genetic diversity level
Genetic diversity is as important as other form of biodiversity. Additionally, it is far more important as it determines the resilience of a species to the impacts of climate change and other threats (Botkin et al.2007). However, very little effort has yet been made to comprehend the impacts of climate change on genetic diversity. One of the visible

impacts is through habitat fragmentation by climate change which in turn fragments the population in small sub-populations; eg.wet mountain ecosystems surrounded by dry lowlands. There have been some studies showing higher resilience in eelgrass communities to increased temperature due to high genetic diversity (Ehlers et al. 2008). In case of polar bears, Crompton et al. (2008) has shown that reduction in sea ice cover also reduces the gene flow. The similar case would be of other marine mammals where gene flow may get affected by reduced sea ice cover (O'Corry-Crowe 2008).

Genetic diversity besides of affecting the species own survival in light of climate change scenario, it has strong implications for human well-being. As it is well known fact that wild relatives of cultivated crops are an important source of gene pool diversity for further crop improvements. Several modelling studies have shown that the survival of over 20 relatives of peanut, potato and cowpea may get affected by climate change, as most would lose their range size by 50% as well as their distribution would become highly fragmented (Jarvis et al. 2008).

In addition to above discussed three hierarchical levels, climate change also exertsits impact on ecological interactions within and between ecosystems (Cleland et al.2006; Klanderud &Totland 2007; Memmott et al.2007; Bloor et al.2008)as well as through the significant positive feedbacks to the climate systems (IPCC 2007). It is generally agreed that one of the main feedbacks to theclimate system will be through the increase in soil respiration under increased temperature, especially in theArctic region (Chapin et al.2008).

Conclusion:-

Despite long drawn debate on impact of global climate change on earth system and especially on biological diversity, it seems the impacts are slow but sure and eventually may create a cascade effect to disrupt the functioning of major ecological system. Although a good amount of research effort has been made after landmark report by Intergovernmental Panel on Climate change (2007), more research is required to comprehend the climate change effects on genetic diversity of critical elements withindifferent taxa of wild and cultivated flora and fauna.

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