Journal of Climate Change, Vol. 8, No. 1 (2022), pp. 37-43.
DOI 10.3233/JCC220003

Fingerprints of Climate Change from the Indian Himalayan Environment: Need to Inculcate in Environment Education for Schools and Colleges

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Received January 1, 2022; revised and accepted February 1, 2022

Abstract: Himalayas are the youngest mountain range in the world that are experiencing the implications of climate change occurring at the local and regional levels. This does not only affect the ecologically diverse natural landscapes in the Himalayan region but also disrupts the natural habitats and distribution of species. The synthesis of the available literature indicates that abrupt changes in climate, especially at higher elevations are affecting the natural distribution of plant and animal taxa. The unpredictable movement of wildlife beyond their natural ranges underpin disturbances under micro climatic conditions and alteration of environmental niches. Though upslope movement of quite a few species has been observed, the extent to which these can be attributed to climate change is not clearly known. Considering the fingerprints of climate change in the Indian Himalaya, which has been considered as an ecological fragile landscape, there is a need to revisit and restructure our priorities for wildlife conservation. Moreover, monitoring species' responses over time and documenting indigenous knowledge of local communities would strengthen our actions in addressing the impacts of climate change. Furthermore, by adding climate change education in the school system, considering it to be mandatory, can be remedied only by providing appropriate knowledge and through a structured training programme on climate change mitigation and adaptation process.

Keywords: Himalayas; Climate change; Wildlife; Species; Conservation; Education; Schools.

Introduction

It is now widely acknowledged that the recent climatic changes have affected a wide range of species with diverse geographical distributions (Hughes et al., 2000; Wuethrich et al., 2000; Mc Carty et al., 2001; Walther et al., 2002; Root et al., 2003; Parmesan et al., 2006; Bickford et al., 2010; Kosanic et al., 2018). Although it has been presumed that climate change will impact a wide array of flora and fauna, a pole-ward (north-ward) extension of species has been observed during the past few decades (Parmesan et al., 1999, 2003; VanderWal et al., 2012; Cavanaugh et al., 2014; Fei et al., 2017). Climate change is significantly impacting the distribution of European flora and fauna, with distribution changes of several hundred kilometers projected over the 21st century, which include northwards and uphill range shifts, as well as local and regional extinctions of species (European Environment Agency). It has been estimated that Southeast Asia will bear the brunt of

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sweeping climatic changes with potential results ranging from shrinking individuals, declining population sizes, and altered community structures to widespread trophic cascades, extinctions, and loss of ecosystem services (Bickford et al., 2010).

Such abrupt changes may have wider consequences for the territorial wild animals and on the migration pattern of species. Threatened endemic species with specific requirements of the ecotope will generally be at the greatest risk, in particular, if they face migration barriers (Dirnbock et al., 2011). The report of a Working Group of the Intergovernmental Panel on Climate Change (IPCC) authenticates the fact of changes in the distribution of species across a wide range of taxonomic groups and geographical locations during the 20thcentury. Similarly, one of the reports of Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) says that shifts in species distribution, changes in phenology, altered population dynamics and changes in the composition of species assemblage or the structure and function of ecosystems are evident and accelerating in marine, terrestrial and freshwater systems (Diaz et al., 2019). The World Conservation Union-Conservation Measures Partnership (IUCN-CMP) unified classification of direct threats to biodiversity lists that 'climate change and severe weather' also includes habitat shifting and alteration as one of the threats to species. Considering the global impact of climate change on ecosystems and species, revisiting and restructuring our priorities for wildlife conservation would be a conservation challenge in the near future, which includes the restructuring of management plans of protected areas.

A report of the Ministry of Earth Sciences, Government of India revealed that India's average temperature has risen by around 0.7°C during 1901–2018, which is largely on account of greenhouse gases-induced warming, partially offset by forcing due to anthropogenic aerosols and changes in land use and land cover (Krishnan et al., 2020). A study pointed out that human-induced climate change has led to accelerated warming of the Himalayas (in parts of Hindu Kush Himalaya) and the Tibetan Plateau at a rate of 0.2°C per decade during 1951-2014, which also led to the significant decline in wintertime snowfall and glacier retreat in recent decades (Sabin et al., 2020). Similarly, another study indicated that the rate of warming in the western and eastern Himalayas and the plains of the Ganges basin over the past 25 years have been lower (0.01-0.03°C per year) (Kulkarni et al., 2013). It has been estimated that the sea level rise recorded in the Sundarbans (UNESCO's World Heritage Site) over the past 40 years is responsible for the loss of 28% of the mangrove ecosystem (Kaeslin et al., 2012).

The Fifth Assessment Report of the IPCC reported large inter-model spread in the climate change response of the Indian monsoon precipitation, Indian Ocean regional sea-level rise, Himalayan snow cover, and other aspects of the regional climate system (Christensen et al., 2013). In the year 2008, recognising climate change as a global challenge, the Indian Government has set eight ambitious goals for the country by launching the National Action Plan on Climate Change programme. 'National Mission for Sustaining the Himalayan Ecosystem' was set with the aim to protect the Himalayan ecosystems. India's National Wildlife Action Plan 2017-2031 also acknowledges the impact of climate change on global biodiversity through latitudinal and altitudinal shifts in the distribution of species and altered community interactions resulting in changes in species distribution (National Wildlife Action Plan 2017-2031).

Today when the entire world is struggling with various environmental issues, Environment Education (EE) has become a more important component of education in terms of minimising the catastrophic environmental crisis. The importance of fostering both environmental knowledge and connectedness to nature as complementary drivers of ecological behaviour, as offered by nature-based environmental education, should be researched further as a highly promising approach to fostering ecologically-motivated individuals (Otto and Pensini, 2017). There is empirical evidence suggesting a positive link between direct experiences in nature and people's environmental attitudes and behaviours (Rosa and Collado, 2019).

Environmentalists are seeing a huge change in the awareness levels through education while others are not convinced that education is generating anything beyond general nature lovers (Tandon, 2018). EE received wide attention from the stakeholders and specialised subjects were also initiated by several universities, which dealt in subjects like 'Environmental Microbiology', 'Biodiversity Conservation', 'Natural Resource Management', 'Wildlife Biology', 'Marine Biology/Sciences', 'Environmental Impact Assessment', etc. Considering broadly the status of EE at the school and college level, it is clear that EE is only a vocational subject, which needs to be read and cleared by every student. At the school level (up to the class 5), EE is a separate subject which is basically a science discipline and class 6 onwards is a science subject

under which students read some of the contents related to the environment. At the college level, EE is being taught in the first year or semester of the technical and professional courses.

Unpredictable Movement of Wildlife

In the recent past, some cases of unpredictable movement of wild animals were reported from different parts of Uttarakhand, India, wherein the species were found moving in higher elevations beyond their defined range (Table 1), which were never been reported as the natural range of the species. Whether such unpredictable movement of the species in higher ridges is indicating towards a shift in their natural ranges, or some small resident and isolated population exist in the area or are dispersing individuals remains unclear. We reviewed some cases of unusual sightings of wild animals beyond their ranges in Uttarakhand Himalaya, indicating that temperature variation is affecting the wildlife and consequently their capabilities to respond to the changing environment. In this study, we present approaches to understand and address the ecological impacts of climate and human-induced changes on the ecosystems and wildlife in the State (Figure 1).

Case study of Tiger

In May 2019, a tiger (*Panthera tigris*) was captured in a camera trap in the Madhmaheswar area of Ukhimath forest of the Kedarnath Wildlife Sanctuary at an elevation of 3,431m, which was the highest elevation record of tiger's presence in the State, as well as in India (Pawar et al., 2020). Prior to this observation, in the year 2016, a female tiger was spotted at an elevation of 3,274 m from the Askot landscape in the State (Bhattacharya et al., 2016). Even though the Rajaji National Park has been considered as the northwestern limit of the natural distribution range of the tiger in the State (~1000 m) (Rasaily, 2012), a recent study has identified the eastern and western Himalayan zones, spread across Bhutan, India and Nepal as a potential habitat for tigers (Global Tiger Forum, India, 2019).

Case Study of Elephant

Asian elephant (*Elephas maximus*) is one of the flagship species in Indian forests, which has an important functional role in maintaining forest ecosystem and biodiversity. Rajaji National Park is one of the protected habitats of the elephants in northwestern India, which is spread across an elevation of 302-1,000 m (ENVIS) and there were no reports of elephant movement in the State beyond this elevation till the year 2019. However, a study has recorded the movements of adult male elephants at an elevation of about 1,200 m, which was first ever an indication of the elephant's movements in higher ridges in the State (Joshi, 2019). However, the study revealed that such movements of the male elephants are seasonal and occur mainly to feed upon palatable crops. During the elephant population estimation 2020, the Uttarakhand Forest Department has recorded the elephant's presence at an elevation of about 1,450 m from the Almora Forest Division (Azad, 2020). A study predicted that elephants may lose nearly 40% of their habitat by the end of this century, mainly due to human-induced disturbances and global climate change in human-dominated regions. The study also predicted that these changes may lead the elephants to shift towards higher elevations, along the river valleys (Kanagaraj et al., 2019). Changes in the movement and behaviour of elephants have been observed following severe droughts triggered by El Nino events (Sukumar, 2018).

Case Study of Asiatic Black Bear

Since a decade, the movement of Asiatic black bear (*Ursus thibetanus*) near rural areas was found increasing due to which cases of livestock depredation (cattle lifting) are escalating. However, a recent study indicated that there is some confined residential population of the species, which do not perform altitudinal migration or hibernation, especially in foothills dominant areas

Table 1: Unpredictable range of wildlife from the Uttarakhand State, India

S. No.	*Particular*	*Scientific name*	*IUCN status*	*Previous elevation range*	*New elevation range reported*
1.	Tiger	*Pantheratigris*	Endangered	1000 m	3431 m and 3274 m
2.	King cobra	*Ophiophagushannah*	Vulnerable	1000 m	2303 m and 2400 m
3.	Elephant	*Elephasmaximus*	Endangered	300 -1000 m	1200 m and 1450 m
4.	Himalayan trinket snake	*Orthriophishodgsonii*	Least Concern	1000 - 3200 m	835 m

Figure 1: Climate and human induced impacts on the ecosystem and wildlife in Uttarakhand and feasible conservation strategies to mitigate the impact.

(Singh et al., 2020). Though the species is not known to hibernate in the tropics, except females giving birth during winter (Hwang et al., 2007), there are reports which indicate that the species perform hibernation (Sathyakumar et al., 2013; Furusaka et al., 2017).

The presence of mugger crocodile (*Crocodylus palustris*) was documented from the river Ganges and its tributaries near the Haridwar area, which was never reported from the area (Joshi et al., 2011). These observations indicate that the natural range of the mugger crocodile is expanding in the upper catchment of the river Ganges. Similarly, an individual of king cobra (*Ophiophagus hannah*) was sighted at an elevation of about 2,400 m in State (in Mukteshwar area, Nainital district), which was an unusual sighting in such a high range (Jha, 2020). Prior to this record, the presence of king cobra was reported from 2,303 m elevation (Dolia, 2018). Considering the known distribution range of the species in the State (~1000 m), it appears that there might be a little range extension in species' distribution. In contrast, in the year 2016, two individuals of Himalayan trinket snake (*Orthriophis hodgsonii*) were sighted from the SahastraDhara area near Dehradun at an elevation of 835 m, which was unusual since the species is known to be found at an altitude ranging from 1,000-3,200 m in the Himalayas (Singh et al., 2018).

Uttarakhand Action Plan on Climate Change reveals that the abrupt changes in climatic conditions in mountainous areas are affecting the regeneration of various plant species and there may be upward movement of the habitats of many species from their current locations. Similarly, the State of Environment Report highlights the upward shifting of the tree-line and decreasing trend of the quantum of rainfall. Any minor or drastic change in the local climate of an area may affect the species' distribution and thus the structure of the entire ecosystem. In the recent past, quite a few studies have put on record the evidence of species' response towards climate change, which also includes their movements beyond their ranges, in higher or lower elevations. It is also a fact that various species have learned to respond to the changes happening in their immediate climate as part of evolution. However, do we have adequate and accurate information about such ecosystem-level changes, are we ready to manage the new habitats of species and possible conflicts, which may likely arise in the near future, etc., are some questions, which need to be thought of and addressed on priority.

Conclusion

The ecological aspects of most of the species have been studied in their natural ranges, but our knowledge is still lacking for new distribution ranges of the species. Similarly, little is known about the acute causes of such upslope or downslope movement of species. Climate change along cannot be blamed for such unpredictable changes in the movement of wildlife. Anthropogenic activities are influencing such micro climatic conditions to a great extent. We have to strengthen our knowledge on climate change at the local and regional levels and its effect on biodiversity. In near future, ecosystems and communities may face the consequences of climate change, coordinated efforts are needed to be adopted to mitigate the negative effects of climate change, especially in the Himalayan States. Currently, our focus is on understanding the impacts of climate change on ecosystem level and in the collection of datasets.

Considering the predictions that novel climate change will appear in the future, it may be presumed that quite a few communities may be restructured to some extent, mainly by changes in range distributions. Long-term studies are needed to be conducted to record the changes in climate and their consequences on species and natural habitats. Unusual sighting records of various species in middle and higher Himalayas have opened the scope to revisit our existing knowledge on the distribution of species and to start working towards a landscape level conservation model. Providing wider landscape connectivity would strengthen our conservation approaches towards mitigating the negative impact of climate change on the population distribution of species in a small area. Moreover, since indigenous knowledge has always been considered as a conservation tool to manage various ecosystems and biological resources, ensuring the local community's participation would be of paramount importance in documenting such cases. Considering the behavioural responses of species towards changing climate, we need to change our priorities for the conservation of protected areas and wildlife.

Further opportunities of environment education for climate change can be explored as well as achieved through both formal and non-formal education. In order to encourage students about the environmental issues, outdoor learning modules need to be designed, like nature camping, expedition, organisation of training programmes and workshops, etc. Such related activities should be conducted on regular basis with a focus on climate change mitigation and adaptation process. Today

when climatic conditions are changing adversely and all living beings are suffering from the negative impacts of environmental pollution and climate changes, there is a need to inculcate such an education, which will play an important role in sensitising the people about environmental issues. This will facilitate the people to adopt green social responsibility for the protection of the environment.

Acknowledgements

We would like to acknowledge Dr. Anil Prakash Joshi, recipient of the Padma Bhushan Award & Chairman of the Himalayan Environmental Studies and Conservation Organisation for sharing valuable inputs on the climate change aspects in Uttarakhand Himalaya.

References

Azad, S., 2020. Jumbos moving up Himalayas for food and water. *The Times of India* (11 June 2020); https://timesofindia.indiatimes.com/india/jumbos-moving-up-himalayas-for-food-and-water/articleshow/76318468.cms (accessed on 2 January 2021).

Bhattacharya, A. and Habib, B., 2016. Highest elevation record of tiger presence from India. *CATnews,* **64:** 24-25.

Bickford, D., Howard, S.D., Ng, D.J.J. and Sheridan, J.A., 2010. Impacts of climate change on the amphibians and reptiles of Southeast Asia. *Biodivers. Conserv.,* **19**: 1043-1062.

Cavanaugh, K.C. et al., 2014. Poleward expansion of mangroves is a threshold response to decreased frequency of extreme cold events. *Proc. Natl. Acad. Sci.,* **111**:723-727.

Christensen, J. H. et al., 2013. Climate phenomena and their relevance for future regional climate change. *In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (eds Stocker T. F. et al.) 1217-1308 (Cambridge Univ. Press, 2013).

Diaz, S. et al., (eds). 2019. *The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services summary for policymakers of the global assessment report on biodiversity and ecosystem services* (IPBES, 2019).

Dirnbock, T., Essl, F. and Rabitsch, W., 2011. Disproportional risk for habitat loss of high-altitude endemic species under climate change. *Glob. Chang. Biol.,* **17**: 990-996.

Distribution shifts of plant and animal species (European Environment Agency; https://www.eea.europa.eu/data-and-maps/indicators/distribution-of-plant-species-2/assessment#:~:text=Observed%20climate%20change%20is%20having,projected%20over%20the%2021st%20century (accessed on 31 December 2020).

Dolia, J., 2018. Notes on the distribution and natural history of the king cobra (*Ophiophagushannah* Cantor, 1836) from the Kumaon hills of Uttarakhand, India. *Herpetol. Notes,* **11**: 217-222.

Elephant at Crossroads "ENVIS (Wildlife & Protected Areas)" (Wildlife Institute of India, 1998).

Fei, S. et al., 2017. Divergence of species responses to climate change. *Sci. Adv.,* **3:** e1603055.

Furusaka, S. et al., 2017. The selection by Asiatic black bear (*Ursusthibetanus*) of spring plant food items according to their nutritional values. *ZooKeys,* **672**:121-133.

Hughes, L., 2000. Biological consequences of global warming: is the signal already apparent?. *Trends Ecol. Evol.,* **15:** 56-61.

Hwang, M.H. and Garshelis, D.L., 2007. Activity patterns of Asiatic black bears (*Ursusthibetanus*) in the central mountains of Taiwan. *J. Zool.,* **271**: 203-209.

India's National Wildlife Action Plan 2017-31 (Ministry of Environment, Forest and Climate Change, Government of India, 2017).

IPCC Climate Change 2007: Impacts, Adaptation and Vulnerability (eds Parry, M.L. et al.) (Cambridge Univ. Press, 2007).

IUCN-CMP Unified Classification of Direct Threats: Version 3.2 (IUCN, 2012).

Jha, P., 2020. Uttarakhand: King cobra at 2,400 m altitude sets new record. *The Times of India* (2 September 2020); https://timesofindia.indiatimes.com/city/dehradun/king-cobra-sighting-at-2400-mts-in-nainital-sets-new-altitude-record-for-species/articleshow/77876768.cms. (accessed on 31 January 2021)

Joshi, R, Singh, R. and Negi, M.S., 2011. First record of mugger crocodile *Crocodyluspalustris* (Lesson, 1831) from the Rajaji National Park, North India. *Int. J. Biodivers. Conserv.,* **3**: 444-450.

Joshi, R., 2019. The Secret life of Elephants (Natraj Publishers, 2019).

Kaeslin, E., Redmond, I. and Dudley, N., 2012. Wildlife in a changing climate. Forestry paper 167 of the Food and Agriculture Organization of the United Nations (FAO, 2012).

Kanagaraj, R., et al., 2019. Predicting range shifts of Asian elephants under global change. *Divers. Distrib.,* **25**: 822-838.

Kosanic, A., Anderson, K., Harrison, S., Turkington, T. and Bennie, J., 2018. Changes in the geographical distribution of plant species and climatic variables on the West Cornwall peninsula (South West UK). *PLoS One,* **13**: e0191021.

Krishnan, R. et al. (eds). 2020. Assessment of climate change over the Indian region. Ministry of Earth Sciences, Government of India (Springer Open, 2020).

Kulkarni, A., Patwardhan, S., Kumar, K.K., Ashok, K. and Krishnan, R., 2013. Projected climate change in the Hindu Kush-Himalayan region by using the high-resolution Regional Climate Model PRECIS. *Mt. Res. Dev.,* **33**: 142-151.

McCarty, J.P., 2001. Ecological consequences of recent climate change. *Conserv. Biol.,* **15**: 320-331.

Otto, S. and Pensini, P., 2017. Nature-based environmental education of children: Environmental knowledge and connectedness to nature, together, are related to ecological behavior. *Global Environmental Change*, **47**: 88-94. Doi:10.1016/j.gloenvcha.2017.09.009

Parmesan, C. and Yohe, G., 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature,* **421**: 37-42.

Parmesan, C. et al., 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature,* **399**: 579-583.

Parmesan, C., 2006. Ecological and evolutionary responses to recent climate change. *Annu. Rev. Ecol. Evol. Syst.,* **37**: 637-669.

Pawar, D. et al., 2020. Photographic evidence of tiger from Kedarnath Musk Deer Sanctuary, India. *CATnews, ,***71:** 18-19.

Rasaily, S.S., 2012. *Management Plan of Rajaji National Park (for 2012−2013 to 2021−2022).* (Uttarakhand Forest Department, India, 2012).

Root, T.L. et al., 2003. Fingerprints of global warming on wild animals and plants. *Nature,* **421**: 57-60.

Rosa, C.D. and Collado, S., 2019. Experiences in nature and environmental attitudes and behaviors: Setting the ground for future research. *Frontiers in Psychology*, **10**:763. Doi: doi.org/10.3389/fpsyg.2019.00763

Sabin, et al., 2020. Climate change over the Himalayas. *In:* Assessment of climate change over the Indian region (eds Krishnan et al.) 207-222 (Ministry of Earth Sciences, Government of India, Springer Open, 2020).

Sathyakumar, S., Sharma, L.K. and Charoo, S.A., 2013. Ecology of Asiatic black bear in Dachigam National Park, Kashmir, India. Final Project Report of the Wildlife Institute of India (Wildlife Institute of India, 2013).

Singh, A. and Joshi, R., 2018. Sighting of Himalayan trinket snake, *Orthriophishodgsoni* Gunther, 1860 (Reptilia: Colubridae) in SahastraDhara, Uttarakhand: A new elevational record. *Amphib. Reptile Conserv.,* **12**: 15-17.

Singh, V.K., Puri, K., Singh, A.K. and Joshi, R., 2020. Livestock predation by Asiatic black bear (*Ursusthibetanus*) in a sub-tropical forest of Uttarakhand: A case study from Garhwal Himalaya. *J. Wildl. Res.,* **8**: 35-38.

State of Environment Report Uttarakhand (Uttarakhand Environment Protection and Pollution Control Board, Government of Uttarakhand, India, 2018).

Status of tiger habitats in high altitude ecosystems of Bhutan, India and Nepal (Situation Analysis) (Global Tiger Forum, India, 2019).

Sukumar, R., 2018. How can climate change influence wildlife-human conflicts. *In:* Biodiversity and Climate Change: An Indian perspective (eds Bhatt, J.R., Das, A. & Shanker, K.) 230-240 (Ministry of Environment, Forest & Climate Change, Government of India, 2018).

Tandon, A., 2018. Can environment education save our planet, 2018. https://india.mongabay.com/2018/09/can-environment-education-save-our-planet/ Accessed: 1 May, 2021.

Uttarakhand Action Plan on Climate Change (Government of Uttarakhand, India, 2014).

VanDerWal, J. et al., 2012. Focus on poleward shifts in species' distribution underestimates the fingerprint of climate change. *Nat. Clim. Change,* **3**: 239-243.

Walther, G.R. et al., 2002. Ecological responses to recent climate change. *Nature,* **416**: 389-395.

Wuethrich, B., 2000. How climate change alters rhythms of the wild. *Science,* **287**: 793-795.