DST-NMSHE

Project Inception Workshop Report

March 2015

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

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National Mission for Sustaining the Himalayan Ecosystem (NMSHE)

Task Force: Micro flora and fauna and wildlife & animal population

Assessment and Monitoring of Climate Change Effects on Wildlife Species and Ecosystems for Developing Adaptation and Mitigation Strategies in the Indian Himalayan Region

Project Inception Workshop Report, 23rd – 24th March, 2015

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Content

Introduction

The Himalaya has been endowed with rich and diverse life forms, recognized as a global biodiversity hotspot, and have a profound effect on the climate of the Indian subcontinent and the Tibetan Plateau. It provides life support systems and ecosystem services to several million people in the mountains and plains of northern Indian subcontinent. About 6% of India's human population lives in the IHR, but the growing population and consequent anthropogenic pressures have exerted considerable influence on the various ecosystems here. In addition to this, climate change induced impacts are predicted to affect the critical ecosystem goods and services provided by the Himalaya. Climate change effects are invariably overlooked until the threshold is reached and the negative consequences are experienced, which becomes too late to develop adaptation/mitigation strategies. It is therefore, necessary to envision an early warning system wherein available data could be used to represent the present condition and project various future scenarios in a visually explicit form. The current level of scientific knowledge is inadequate to meet the present and future challenges of climate change induced threats to biodiversity and ecosystem services of the Himalaya.

National Mission for Sustaining the Himalayan Ecosystem (NMSHE)

Realizing the need for data for developing science-based action plans to address the threats of climate change in the fragile mountain ecosystems of the Indian Himalayan Region (IHR), a dedicated mission - the National Mission for Sustaining the Himalayan Ecosystem (NMSHE) has been initiated as part of the National Action Plan on Climate Change (NAPCC) under the coordination of the Department of Science & Technology (DST). The NMSHE aims to understand the complex processes affecting the Himalayan ecosystem and evolve suitable management and policy measures for sustaining and safeguarding the Himalayan ecosystem. This is being envisaged by creating and building capacities in different domains through networking of knowledge institutions engaged in research for development of a coherent database on Himalayan ecosystem. The scientific work under NMSHE is structured under six thematic task forces, each with one coordinating institution.

Role of the Wildlife Institute of India (WII)

The Ministry of Environment and Forests and Climate Change (MoEFCC), Government of India has granted approval to the Wildlife Institute of India (WII) to implement the activities under NMSHE as the task force for micro flora and fauna and wildlife and animal population. The Wildlife Institute of India has set up a 'Mission Cell' or 'Project Management Unit' and is currently executing the programme under the joint supervision of the identified faculty, project scientists, researchers and assistants. The programme has identified four major themes, (i.e. terrestrial ecology, aquatic ecology, spatial ecology and human ecology). The research team presently includes 3 project scientists (terrestrial ecology, aquatic ecology, human ecology, spatial ecology and climate change); 3 project associates (micro flora and fauna, spatial ecology and climate change); 8 project fellows; and 5 project assistants. To initiate the work, discussions on the theme, focal sites, work components and harmonization of research design and identification of collaborators and partners was necessary. Thus, a Project Inception Workshop was conducted on 23rd – 24th of March, 2015 to discuss the process of networking for research and data sharing to enable finalising the research plan.

Workshop Venue and participants

The Project Inception Workshop was conducted in the Wildlife Institute of India, Dehradun and was attended by academicians, managers, scientists and researchers related with the conservation of Himalayan biodiversity and sustainable management. A detailed list of 39 participants along with their designation is given in Appendix I.

Inaugural session

After the registration between 9:00 to 9:30 am, the workshop programme started with the welcome introduction of Dr. P. K. Mathur, Dean Faculty of Wildlife Science. He mentioned about the importance of the NMSHE as well as the past initiatives taken by Wildlife Institute of India to sustain Himalayan biodiversity. After his welcome address, the Director, Wildlife Institute of India, Dr. V.B. Mathur delivered the opening speech by describing the wonders of the Himalayan ecosystem and their importance. He said that the genesis of this project was that no credible information had been provided for the Himalaya yet, and that biological sciences haven't yet contributed to climate change. He also mentioned that harnessing of ecosystem and water resources should be conducted judicially, keeping in mind the socio-economic references. He further added about the various aspects of livelihood on downstream communities which should be monitored. He recited a short briefing on the methodologies that can be used in the project, i.e. the construction of the landscape ecology lab and conversion of all the information collected from various components, which would be useful for the climatologists in the future. Dr. V.B. Mathur further stated that the project should involve good science based on credible, salient and legitimate information, which is unbiased. Lastly he highlighted the importance of 'Wildlife Watch' species, which would act as indicators and should be monitored by the stakeholders. Then Dr. S. Sathyakumar, Nodal Scientist of the project introduced to the audience the roles and responsibilities of WII in this project. He also mentioned the proposed study areas, tentative methodologies, project deliverables and project monitoring framework with specific outputs within specified timelines.

After completion of the project introduction, the keynote address was given by Shri Jai Raj, Additional PCCF Uttarakhand. With his captivating oratory, Shri Jai Raj emphasized the importance of Himalayan ecosystem and biodiversity and the services provided by them to sustain the people living downstream. Several issues such as man-animal conflict and possible detrimental roles of climate change were mentioned by him. He also mentioned the inception of this project was a dream-come-true for many managers and policy makers like him, and the expectation for this project to deliver was quite high. After this keynote address, Dr. K. Ramesh thanked all the delegates and participants on behalf of the Wildlife Institute of India. A group photograph of all participants was taken just before the beginning of the first technical session. The detailed descriptions of each session are mentioned below and brief of each presentation is attached as abstracts in Appendix II.

Session I: Mammals, Birds, Herpetofauna, Fishes, Invertebrates

This session was on climate change impacts on fauna and their habitats in the Himalayan region. It comprised of five substantive presentations on various fauna groups, each covering the state of knowledge on climate change impacts on fauna, and approach and methodology for investigation. The session was chaired by Shri D.V.S. Khati and co-chaired by Dr. G.S. Rawat respectively.

Mammals - presentation by Dr. S. Sathyakumar

This session was opened by Dr. S. Sathyakumar where he talked about richness of the species in the Himalayan region and their existing information. Impact of climate change on mammals of the Himalaya is particularly studied for three Himalayan taxa, (i.e. Royale's pika, snow leopard and brown bear). Approach for investigating impacts of climate change on mammals was presented and explained.

The discussion round was initiated by Dr. G.S. Rawat. He asked about the sampling of micro habitat data for mammals. In his response Dr. S. Sathyakumar explained that although in the presentation he had discussed mostly about large mammals, microclimate sampling will be done for small mammals like pika and voles. Dr. I. D. Bhatt mentioned the challenges that the study might face to decouple the anthropogenic and climate change effects, and asked how it is going to be done for this study. Clarifying Dr. Bhatt's doubts, Dr. S. Sathyakumar explained that sampling would be done in different areas with different level of anthropogenic disturbance, and compared with areas where there is no anthropogenic disturbance. Such sampling would help in decoupling climate change effects from that of anthropogenic disturbance. Dr. I. D. Bhatt then mentioned that many areas in the Himalayas are well studied and have enough databases. He also suggested that those areas should be given priority.

Adding to the conversation Dr. V. P. Uniyal suggested that the Alaknanda basin is one such well-studied area; so why not include it in this study. In response, Dr. S. Sathyakumar said that including Alaknanda will make the study area too large to be efficiently sampled, given the team size. Dr. D. V. S. Khati then advised the speaker to be careful as lots of people are working in that part of Ganga basin, and to ensure that the work is not repeated. Dr. Khati then asked whether any indicator species will be used in this study. The speaker replied by saying that the initial phase of the study was to look at the mammalian diversity, but at a later stage, focus would shift on the indicator species too.

Birds - presentation by Dr. Pratap Singh

The speaker in this presentation emphasised on the coupling effect of anthropogenic and climate change effects on the rich and unique avifaunal biodiversity in the Indian Himalayan region. Climate change has the potential to cause responses in bird communities, (i.e. range shift, change in migration routine, and breeding pattern). The approach for investigating impacts of climate change on bird species was then described by Dr. Pratap Singh.

In the questionnaire and discussion round, Dr. V. P. Uniyal suggested some of the bird species like bee-eaters that can be used as indicator species. Nonetheless, Dr. Pratap Singh mentioned the limitation of species like bee-eater to be used as indicators as they do not go beyond a certain height. But he agreed on the point that they can be good indicators in agricultural systems. Showing his keen interest on the topic, Dr. Manoj Nair suggested few ideas for the study. Firstly, he recommended study of species association for example between resource, (i.e. fruits, flowers and birds). As when these get affected by climate change, the birds would also response. Secondly, he advised study of brood parasitism in response to climate change. In his third suggestion, he suggested that citizen science and migrant watch studies should be conducted to keep a check on migration and arrival of birds. In his last suggestion, he stressed on the study of owl species, as they are indicators of forest health.

Dr. S. Sathyakumar argued that climate change response can be seen in all the taxa, so why does the speaker think there will be asynchrony caused due to climate change. The speaker defended himself saying that birds do not respond immediately as compared to plants and insects. The difference in response will cause asynchrony. Supporting his point, Dr. G. S. Rawat said that migrants will respond early as compared to other species. Dr. D. Mohan suggested that in India, research on permanent plots are undergoing like in the states of Uttarakhand, Himachal Pradesh, Kashmir and West Bengal. Getting help from those areas would be valuable for this study. Dr. K. Ramesh in the end said that data on occupancy and densities (index based) should be sampled in the study, as it will be helpful in correlating bird taxa with other studies as well as for future projection in response to climate change.

Herpetofauna - presentation by Dr. Abhijit Das

In his presentation, Dr. Abhijit Das communicated the vulnerability of Herpetofauna to climate change. Being physiologically constrained by temperature and humidity and coupled with limited vagility, herpetofauna are candidate organisms for forecasting climate change scenarios. Climate change effects are known to impact their body size, breeding, gaseous exchange, range expansion in case of venomous species and range contraction in case of endemic species. He mentioned the need of studying the identifying factors that govern species richness, community composition and endemism in an east to west gradient.

Dr. K. Ramesh initiated by putting forward a question as to what will be the strategies for identifying the indicator species. Dr. Abhijit Das replied by explaining the characters which will be chosen as the set criterions for biological indicator species identification, like the knowledge extracted from the existing studies, biological information and habitat type of the species. The next query put forward was by Dr. Gautam Talukdar who said that as informed by the speaker, researchers believe that the spread of *Batrachochytrium dendrobatidis* fungus due to climate change has caused mass mortality in frogs. His concern was that whether it was possible to have collaboration between herpetofauna and micro faunal thematic areas. To this query, Dr. Abhijit Das replied by saying that it would indeed be really helpful and is feasible by experimentally assessing such diseases and their causes in the lab with the help of the micro faunal team.

Then came a series of informative suggestions put forward by Dr. Manoj Nair. He suggested that: (a) in case of herpetofauna, there are lots of options to conduct manipulative experiments like (i) breeding experiments (embryology of frogs, fast flowing stream species vs. slow flowing stream species); (ii) light/temperature manipulative studies; (b) automatic data logger should be incorporated to study the microhabitat conditions; (c) evolutionary studies can be done by using molecular clocks etc. This might be helpful in the eastern Himalaya and western Himalaya; and (d) instead of limiting our studies to

Khangchendzonga, we should go beyond Arunachal Pradesh, because we will definitely get to collect good observations.

Fishes - presentations by Dr. K. Sivakumar and Dr. J. A. Johnson

The talk was first initiated by Dr. K. Sivakumar where he talked about the diversity of fishes in the Himalayan region. In his presentation he then explained how fishes are the prima fascia for climate change effect on the aquatic fauna. Increased temperature leads to increase in the glacier melting and increased precipitation. Species richness of cold dwelling fishes tends to decrease with the increase in temperature. The presentation was then continued by Dr. J. A. Johnson explaining various sampling procedures and methodologies for fishes. Targeting on the indicator species will be the way forward. Study of the invasive alien fish species and effect of climate change of the fish migration are criteria worth focusing.

Dr. G. S. Rawat here initiated the round of suggestions and discussions by asking that what would be the seasons chosen for sampling. To this, the presenters responded by explaining that sampling would be done in pre-monsoon, post-monsoon and intermediate-monsoon seasons. This according to them would let them know the seasonal variability in the fishes. The next question put forward by Dr. Abhijit Das depicted the fact that the project can go better when we go hand in hand. His query was that is there any difference in the microhabitat sampling like day and night, depending on specific species behaviour? As herpetofauna team will also be sampling during night. The presenters agreed to it by saying that there would be a difference in microhabitat sampling for different species as some species are very different and highly adaptive to timings. For example, most Cyprinids are active early during the day and late in the evening however, catfishes can be sampled at night. Early morning and late evening will be important, but if time permits, night sampling will be done.

Invertebrates - presentation by Dr. V. P. Uniyal

Dr. V. P. Uniyal initiated the presentation by explaining various ecological roles of Invertebrates. Being ectotherms, their distribution is largely governed by temperature. Change in temperature might affect the insects by extending the ranges, extending the length of development seasons, and increased overwintering success. Some possible insect bio-indicators are dragonflies and damselflies, beetles, ants and butterflies. Various methodologies for sampling invertebrates were also discussed.

The round of discussion was here initiated with the question put forward by Dr. Manoj Nair. He said that most of the sampling techniques mentioned in the presentation were for terrestrial invertebrates. His concern was that how the sampling would be done for odonates and other invertebrates which depend on water. Dr. V. P. Uniyal responded to this query by ensuring that it will be taken care of by collaborating with other groups. Dr. Abhijit Das put forward a query to know about the elevation distribution of the dung beetles in the Himalaya. The speaker replied to it by putting forward that beetles are found in high altitude areas and that dung beetles have been reported from Trans Himalaya (Ladakh). But beetles like tiger beetles are found till 2,500 m altitude also.

Concluding speech

The session was concluded by Shri D. V. S. Khati and Dr. G. S. Rawat on a common note that studies need to be planned and converged for the success of this project. Dr. G. S. Rawat stated that such planned study can help in final stage of visualisation and climate change predictions. Sh. D. V. S. Khati expressed his gratitude to all the speakers and participants. He expressed the immense importance of this project for the Himalayan region. He also mentioned that focus on medicinal plants and microorganisms were found lacking in the presentations. He stated that loss of such diversity will be caused by climate change and needs attention. Dr. G. S. Rawat considered separating anthropogenic and climate change effect on species will be the greatest challenge for this project. Concerns were also expressed about the limited time for this project. The chair and co-chair were delighted to see studies to be planned and appreciated effort of participants who have assisted in making presentations. Also, chairperson thanked participants for their contribution in discussions

Session II: Micro flora, Landscape Ecology and Human Ecology

Chair Dr. S. S. Bist delivered a short welcoming speech regarding the impacts of climate change globally.

Micro-flora – presentation by Dr. G. S. Rawat

Soil microbes are central to ecosystem functioning especially in terrestrial environment, exhibiting great range of diversity in form and function. These organisms significantly contribute to crop fertility, recycling of nutrients, detoxifying pollutants, regulating carbon storage and controlling the production and absorption of greenhouse gases such as CO_2, methane and nitrous oxides. Soil microbial communities play key role in cycling of carbon and nutrients in ecosystems and their activities are regulated by biotic and abiotic factors, such as the quantity and quality of litter inputs, temperature and moisture. Soil microbial populations determine key soil functions, thereby directly affecting the value of land. They are, in turn; strongly influenced by regional as well as local climate leading to changes in ecosystem functioning including biogeochemical cycling, soil carbon storage and plant-soil feedbacks.

Climate change may affect microbial populations in soil with many potential consequences, including loss of soil carbon; changes in soil-borne greenhouse gas levels; and alterations to the important plant-soil feedbacks giving rise to soil fertility. Therefore, there is an urgent need for assessing the current state of knowledge on this issue, greater understanding of how soil microbial ecology contributes to land–atmosphere carbon exchange in the context of climate change, and identification of some challenges for future adaptation and mitigation.

According to Dr. J. A. Johnson, microbial communities are highly complex system, making identification of species and their functions difficult. Therefore, he suggested focusing on some essential groups like archae-bacteria, methanogenic bacteria and nitrogen-fixing bacteria where immediate functional information could be obtained. In addition to soil ecosystem, stream ecosystem and microbial communities involved in leaf litter processing should also be focused upon. Heterotrophs could be the major focus of study in order to link entire microbial community metabolism to the ecosystem. In response, Dr. Rawat agreed that microflora and associated microclimate are diverse and challenging to monitor. Therefore, certain functional groups associated with key above ground indicators will be taken into consideration first. However, overall profiling of soil nutrient and microbial diversity is important. According to Dr. Rawat, in certain types of ecotone present in pioneer environment at very high altitude, (e.g. nival ecotone, where plant succession initiates), archae bacteria, soil bacteria and fungi colonize first and is going to be the area of study. Similarly, changes taking place in the glaciated valleys and organisms playing important role in succession will also be considered. Additionally with respect to temperature and moisture gradient key indicator species will be identified.

Dr. K. Ramesh enquired about existing models on microflora for predicting distribution and the scale used by such models. Dr. Rawat stated that most of the models are at regional scale. He cited a study conducted to predict the presence of *Dactylorhiza hatagirea* species at high altitude marsh meadows and their future distribution. However, microclimatic variables and seasonality were not considered in the study and their approach was general. To address this issue, he advised all sub-teams within the group to think of the best ways to collate data on climatic variables, altitude, land use, habitat parameters and microclimatic conditions. Knowledge of microclimatic variables at different habitats will strengthen the understanding in comparison to board scale climatic parameters. For example, microbial community and their function in snow covered area can be determined with this approach. Dr. Ramesh agreed that the existing models use broad scale data and suggested that the model to be prepared must incorporate extensive microclimatic condition to understand ecosystem change with respect to climate change. To achieve adaptive cluster sampling could be one approach.

Dr. I. D. Bhatt asked about plans to access density of lichens, which apart from being good climate change indicators, have food and medicinal value, (e.g. jula). In response, Dr. Rawat stated that most ground lichens of high altitude zones like nival zone have medicinal properties and could be indicators of climate change. He said that some of the lichens are colourful and easy to detect, whereas some are microscopic and difficult to monitor. Hence, we require expertise and feasible methods for generating baseline data. He further mentioned that temperature tolerance for different species would be one way to understand species abundance and their growth patterns. For example, lichen communities near the road are different from interior regions. Similarly the community density changes rapidly with altitudinal gradients leading to different distribution at different altitudes.

Dr. Pratap Singh enquired about the number of bacterial, fungal and lichen species found in India. Dr. Rawat stated that there are almost 2, 000 species in India, out of which 50% are in the Himalayan region and 70-80% of the Himalayan species are terrestrial. Bacterial species isolated so far from the western Himalaya were not studied in terms of climate change. Different fungi have been studied in the entire range and their distribution decreases with altitude. He mentioned that sophisticated techniques and methods are required to focus our study on these species.

Human Ecology – presentation by Dr. Nishikant Gupta

Human ecology is the study of the interaction between humans and their environment. This is often crucial as humans have, and still continue to draw vital services from the ecosystems around them. Human activities play a major role in the upkeep of the ecosystems around them. For example, major services can be obtained from the ecosystem to sustain vital human services; however, anthropogenic activities have the potential to cause irreversible damage to the very source of these services, (i.e. the ecosystem). The presentation explored this fragile link between the indigenous communities dependant on the various ecosystem services in the Indian Himalayan region; and coupled this with the future effects of climate change in this region.

Dr. K. Ramesh suggested looking at the other ecosystem services as well, when discussing or investigating the dependence of local communities on surrounding ecosystems. This was highlighted as this aspect was not very clear in the methodology section presented by Dr. Gupta.

Landscape Ecology – presentation by Dr. K. Ramesh

The session for landscape ecology was opened by the presentation delivered by Dr. K. Ramesh. The presentation provided information on baseline knowledge on various climate change models used for predicting change. It also dealt with all the activities that have to be accomplished within the landscape ecology and visualization lab, (e.g. development of interoperable database, climate change analyses and scenario building, habitat suitability and species distribution models, identification of drivers of landscape change, development of Decision Support System (web-enabled) and visualization of the outputs).

Dr. Pratap Singh asked how the spatial inter operable data base would be performed. Dr. Ramesh replied that Data collection would be recorded according to hierarchical level addressing habitat suitability and species distribution, based on field data and expert knowledge. Dr. Asha Rajvanshi enquired how visualization technique would benefit human ecology. Dr. Ramesh suggested that online human footprint area and population density data would be incorporated into models to predict population changes. Dr. J. A. Johnson wanted to know about Bio-envelope model and its simulation possibilities. In reply Dr. Ramesh stated that BIOCLIM, a Bio-envelope model can be used to analyse the variables identified in the aquatic system.

Dr. Abhijit pointed out that it would almost a year to generate field data. In that case existing museum data should be digitalized and used for building a basic model which would assist us during our field survey. The Director was interested to know the three big challenges and the measures to confront them. Dr Ramesh replied that data downscaling would be the biggest challenge, followed by synergizing the information from all the components to develop a clear strategy. Finally, to deal with big data sets new technologies are required.

Dr. Rawat informed the group that Bhagirathi basin data is available. He recommended the visualization lab to look into the past and present state. Although agencies like ICIMOD has a running project on Bhagirathi basin, more collaborations and holistic approach were required to accomplish our task. In response, Dr. Ramesh cited names of few institutes like, Wadia Institute, National Institute of Hydrology (NIH), and Soil Institute of Dehradun who also have ongoing research projects in the valley. Therefore, data can be obtained from these institutes to understand shifts in agriculture and other land covers.

Dr. I. D. Bhatt questioned about the kind of data required on climatic variables, methods to distribute the data logger and data analysis. According to Dr. Johnson's view, common datasheet for all domains would be essential. Mr. Naitik Patel asked if historical data can be used in building model. Dr. Ramesh said although such data can be used but new data are required. Dr. Manish Nair asked how we can fill the gaps between different datasets.

In case we do not identify the species on field then how to go about it. Dr. Ramesh mentioned that we only need presence/absence and richness data of the species. If species identification is not possible then we can refer to the species as morpho-species and data on the species can be collected in the future.

The co-chair Dr. Asha Rajvanshi in her closing remark said that we should continue to clear the haze in our mind and enhance our knowledge by reading and sharing. Any negligence can be harmful for the study and continuous interaction and openness between the groups would be beneficial.

Session III: group exercise

All the participants were divided into four different groups according to the themes such as: (a) mammals, birds and insects; (b) microflora and fauna; (c) aquatic ecosystem and herpetofauna; and (d) landscape ecology and human ecology. Each group was involved in a three-hour long discussion regarding the methodologies that can be adopted during the field work. One representative for each thematic group was selected who collated the information that emerged out from the discussion, and made presentations for the entire workshop audience to be presented in Session IV of Day 2.

Session IV: the way forward

This session was chaired by Dr. L. M. S. Palni and co-chaired by Dr. V. B. Mathur. Dr. Mathur introduced the distinguished guest and chair of the session to the participants, followed by a round of introduction of all participants to Dr. Palni. Then, the technical procedure of the session was initiated. The brief description of the presentations and the detailed discussions are presented here. The abstract of each thematic group with the proposed methodologies are presented in appendices.

Objective of the session

Presentation by working groups of various thematic areas; and discussion for improving the methodological approach. The detailed methodologies of each thematic group are given below.

Key points of the presentations

a) Key research questions

b) Methodology of project proceedings

c) Required equipment

d) Work plan for the period 2015-2017

Research Questions and Methodologies

Thematic area: mammals and birds (Dr. Tapajit Bhattacharya)

The presentation focused on selected parameters of the study, field methodology of both mammals and birds, and a detailed work plan for the year 2015 – 2017.

Post presentation deliberation

Dr. K. Ramesh pointed out that the methodology should incorporate the study techniques for riverine birds. He suggested avoiding extensive sampling near the camera traps to evade disturbance. He also pointed out the demographic methodology to be too ambitious. He also suggested escaping very extensive survey keeping in mind the time frame of the study. He also questioned how the data logger would display the data. Dr. Gautam Talukdar suggested harmonization of the vegetation data for habitats.

Dr. Abhijit Das enquired whether the study followed different approaches of relating climate change effects between completely modified habitats and natural habitats. Dr. Tapajit replied stating that the study would hold natural habitat as control site and disturbed habitat as sample site. This response was counteracted as "not a valid method of keeping control and sample site" by Dr. Ramesh. Dr. G. S. Rawat suggested incorporation of phenological component in the permanent plots.

Thematic area: Herpetofauna (Mr. Naitik Patel)

The presentation focused on the methodological approach of the study in both eastern and western Himalaya.

Post presentation deliberation

Dr. S. Sathyakumar commented that the studies will first be conducted in the western and then in the eastern Himalaya, while also pointing out that the methodology adapted in western Himalaya will be applicable to the eastern Himalaya. Dr. Ramesh enquired about nesting the data from herpetofauna and other thematic areas. Dr. Abhijit Das clarified that there will be two approaches of data collection; firstly, along the stream and secondly, in the zones along the terrestrial habitat. Dr. Das further added that herpetofauna are more concentrated in the lower elevation zones. Dr. Das also enquired about digitization of the existing museum collection data to which Dr. Ramesh replied affirmatively suggesting immediate action.

Dr. Ramesh suggested synchronization of the data even if the same region is sampled in varying seasons. Dr. Manoj Nair recommended inclusion of laboratory based experiments to record climate change effects at molecular level, and that use of call recording of frogs as visual sighting is near impossible. Dr. Sathyakumar suggested finding good collaborators in the IHR to give them the responsibility of laboratory based work or do it at WII. Dr. V. B. Mathur enquired the specification of indicator species for 'Wildlife Watch' and recommended enlistment of indicator species for wildlife watch. Dr. Abhijit Das responded mentioning the low species (herpetofauna) density in the Himalaya further adding that only two or three species have been identified as biological indicators.

Thematic area: micro-flora and fauna (Dr. Devendra Kumar)

The presentation focused on the field methodology, sampling techniques and work plan for the year 2015 – 2017.

Post presentation deliberation

Dr. J. A. Johnson recommended inclusion of microbes of the aquatic ecosystem to have a pattern of microbes to correlate with fishes. Dr. G. S. Rawat pointed out that there is no need of separate studies on aquatic fauna and micro fauna and suggested that they should be studied together. Dr. Ramesh enquired on additional strategies of study other than elaborate survey. Dr. Rawat replied that there will be involvement of efficient mobile field workers selection for special microhabitat in every ecosystem as an additional study technique. Dr. Manoj Nair recommended sampling of fire affected areas through *ad libitum* sampling for obtaining additional data of anthropogenic stressors on the ecosystem. Dr. Rawat applauded the suggestion specifying it to be challenging as it will require much more focused study area and even more focused sampling design.

Thematic area: invertebrate and micro fauna (Dr. Manish Bharadwaj)

The presentation focused on the field methodology, sampling techniques of selected group of insects and work plan for the years 2015 – 2017.

Post presentation deliberation

Dr. Ramesh enquired whether the different aspects of the study area were to be analyzed, or was it constricted. Dr. Manish gave an affirmative reply explaining that both the northeast and south east aspects of the mountains will be included in the study, as there is a difference of species diversity in the aspects. Dr. Ramesh suggested keeping of photograph records of the species, even if spotted by non-domain team members for identification later on by experts and inclusion in the spatial database. Dr. Ramesh also suggested correlation study of insects and host plant abundance to study their inter-dependency and effect of climate change and anthropogenic factors.

Dr. V.P. Uniyal recommended marking of the plots or study site as done in previous studies in the Greater Himalaya. Dr. Abhijit Das enquired about the taxonomic issues for identification of species and who the collaborating bodies to be consulted were. Dr. Manoj Nair enquired about the preservation process to be adopted for sample preservation. Dr. Manish Bharadwaj responded by asserting the use of both wet and dry preservation techniques.

Thematic area: Fishes (Dr. Nishikant Gupta)

The presentation focused on the field methodology of the study.

Post presentation deliberation

Dr. Ramesh stated the sampling of the streams of all orders to be challenging. Dr. Nishikant Gupta agreed but also pointed out that its equally important to survey streams of all order as fishes has been found to breed in streams of all orders. Dr. Abhijit Das enquired whether invasive species will be recorded as a part of the study. To this Dr. Gupta responded affirmatively referring to the altitudinal shift in fish habitat as per past literature. Dr. Pratap Singh aptly enquired the surveying techniques at high elevations. Dr. Gupta responded that the study sites would be adjusted as per accessibility factor; while Dr. Johnson detailed on the fish habitat distribution criteria in brief as less distributed at higher elevation than lower elevation.

Thematic area: landscape ecology and visualization (Mrs. Sujata Upgupta)

The presentation detailed the research questions, design and frame work of generating a geodatabase, climate models and data collection format for all the thematic groups.

Post presentation deliberation

Dr. V. B. Mathur recommended resolving the interoperable part of spatial database so that each collected data can be fed along with the GPS data and data from secondary data sources. Dr. Rawat recommended reviewing of already tested good climate models, and to share the same among team members. Dr. Sathyakumar and Dr. Uniyal opined inclusion of other species record collected by non-domain groups along with photographs and for the data collected to be passed on to the specialist group. Dr. Uniyal suggested insertion of a blank column into the data sheet for feeding data other than those specified in the column. Dr. Ramesh stressed on arranging a precipitation counter for each group.

Thematic area: human ecology (Dr. Nishikant Gupta)

The presentation detailed chiefly on the methodological approach of the pilot survey to be conducted before finalization of the study site.

Post presentation deliberation

It was recommended by a majority of the faculties to get a detailed note on the Task Force V of Jawaharlal Nehru University, New Delhi dealing with traditional knowledge of the Himalayan communities, so that their study didn't overlap with this thematic area of

NMSHE. Dr. Rawat and Dr. Ramesh recommended study of post developmental effects on the communities as a part of the study. Dr. Ramesh suggested recording of the distance of the villages from the water sources and other landmarks as and where available, to estimate the anthropogenic stressors on the ecosystem by the villages. Dr. Ruchi Badola recommended study of disease emergence in the Himalayan communities.

Proposed methodologies as presented in Session IV

Thematic group: mammals and birds (*Presenter: Tapajit Bhattacharya*)

Mammals

The diversity and endemism of mammals in the Himalaya is exceptional, however, scientific knowledge on many of these mammals is still lacking in the Indian context. There are only three Himalayan species for which impact of climate change has been studied. The proposed field methods and analytical approaches for the present study are presented here.

Proposed methodology

The Ganges river basin particularly the Bhagirathi basin in Uttarakhand is selected as the intensive study area for the initial two years, then the field work can be extended in Teesta basin in Sikkim and Sutlej basin in Himachal Pradesh during the later phase of the study. The entire Bhagirathi basin (from Rishikesh to Gomukh and upwards to trans-Himalayan zones of Uttarakhand) will be subdivided according to different watershed along the elevation gradient. Fieldwork according to order specific methodologies will be carried out within each sub-basin with spatial as well as temporal replicates. Different mammal group specific field methods are as follows:

a) Local interviews: During the initial one to two months, reconnaissance surveys will be carried out in the sub-basins identified for fieldwork. During this period, semi-structured interviews will be conducted involving villagers, especially aged and experienced people who possess knowledge about locality-specific animal distribution, and may indicate about the changes in their status in comparison with the past. During this interview, colour photographs of mammals will be shown to the participant to ensure proper identification of a species. This particular exercise will help to design the other order/species-specific field methods.

b) Sign survey: Sign survey will be carried out on the forest trails (one to two km long) along the ridges or small streams covering the elevation gradients of the study area. During the sign survey, tracks and signs of ungulates, carnivores and small mammals will be recorded and also searching for den sites of carnivores will be carried out. Pugmarks of felids, canids and ursids and hoof marks of ungulates will be observed and the location will be recorded. Similarly, scratch marks on trees and scrapes on the trails will be recorded with geo-referencing. Location of carnivore scats will be recorded and fresh scats will be collected and preserved for further genetic analysis and identification of species. Direct sightings of mammals during sign survey will also be recorded with geo-referenced locations, habitat types and special observations if any. Similar sign surveys will be carried out for carnivores of aquatic habitat (such as otters) along the rivers/streams along with the fish species; and riverine birds will also be monitored.

c) Trail sampling: After the sign survey, several (at least three in each 500 m elevation difference covering each aspect) trails will be selected for repeated survey. Direct sightings of mammals (particularly primates, ungulates and small mammals) will be recorded. Number of individuals, sighting distance and angle and the adjacent habitat features will be recorded along with the geo-referenced location of the sighting. Encounter of pellets or scats or any other signs of mammals will also be recorded. Pellet or dung count for ungulates will also be carried out in a 20m x 2m belt transect at every 200 m interval along the trail. Once the pellet count is over, the pellet groups will be removed from the plot to avoid repetition during the next count.

d) Scanning: Scanning from vantage points will be carried out for open slope dwelling mountain ungulates such as Himalayan tahr, blue sheep and for goral in mid-elevation zones. Scanning an open meadow/ cliff will be carried out using spotting scopes or binoculars and sighting of ungulates will be recorded. Number of individuals, age, sex and other demographic parameters of a group will be recorded. The habitat features will also be recorded as observed from the distance and/or if possible by visiting the areas when the group is not there.

e) Camera trapping: Camera trapping for carnivores and elusive forest ungulates such as musk deer and serow will be carried out following a 1 km x 1 km grid structure. The results of sign survey and trail sampling will be used to select the camera location in each grid, and information on the habitat and climatic variables around the camera location will be collected. Cameras will be placed using double flanking design with two units at a particular location facing each other and standard monitoring protocols (Sathyakumar et al. 2011) for mammals using camera traps in mountains will be followed.

f) Physical trapping: Small mammals particularly rodents, pika and shrews will be trapped physically using Sherman traps and pitfall traps. Baited traps will be placed in a systematic manner, following a concentric circular design. Pitfall traps will be placed along the trails or near the camera locations or can be synchronized with the pitfall trapping exercise for arthropods. The captured individuals will be released after species identification/ photographic documentation and morphometric measurements. Individual may also be marked to carry out capture-recapture analysis for abundance estimation.

g) Playback calls: Calls of flying squirrels will be played during the dusk and evening at the places where indirect evidences would be found. This exercise will result to detect at least the presence of flying squirrels, and if possible to estimate relative abundance of them.

In addition to these specific methods, data will also be collected on vegetation structure, composition and anthropogenic disturbances following 10 m x 10 m quadrates or 10 m radius circular plots. Camera traps and Sherman traps will be placed near the trails/plots designated for bird sampling and sampling for arthropods, microflora and fauna may also be carried out along these trails or inside the plots. Data loggers will be used to record the climatic variables such as temperature and humidity of a particular area covering a number of trails, plots and trap locations. The design of data logger installation in the field will depend on the number of data loggers and study design of other themes. Information generated through these field methods will be used directly to prepare species distribution models and also for abundance modelling. Behavioural aspects of selected mammals will be monitored after the completion of the initial phase of the study and would be designed separately keeping the results of primary field observations in mind.

Birds

As there is a dearth of literature on climate change impacts on birds of the Indian Himalayan region, several field methods are proposed for the current study which aims to document impact of climate change on Himalayan avifauna.

Proposed methodology: The Ganges river basin particularly the Bhagirathi basin in Uttarakhand is selected as the intensive study area for the initial two years, then the field work can be extended in Teesta basin in Sikkim and Sutlej basin in Himachal Pradesh during the later phase of the study. The entire Bhagirathi basin (from Rishikesh to Gomukh and upwards to trans-Himalayan zones of Uttarakhand) will be subdivided according to different watershed along the elevation gradient. Field work according to species/order specific methodologies will be carried out within each sub-basin with spatial as well as temporal replicates. Different bird group specific field methods are as follows:

a) Spot-mapping: Spot-mapping (Ralph et al. 1993) will be carried out in a 5 ha/ 200 m x 200 m plot at every 500 m interval on a trail selected for sampling in a particular sub basin. Spot-mapping will be targeted for the breeding birds in forest and open habitats as this is based on the territorial behaviour of the birds (Ralph et al. 1993).

b) Variable radius point count: Along the elevation gradient, variable radius point count (Bibby et al. 1992) will be carried out to detect species distribution and community composition at every 200 m interval on the selected trail for sampling in a particular sub-basin. Birds will be counted for 10 minutes duration and the sighting distance (at which the individual will be first observed) will be recorded using range finder. For birds near the 50 m border, the category may be confirmed by measuring paces to the border when the counting is over (Ralph et al. 1993). If a bird flees when the observer arrives at the point, the bird will be included according to its take-off place. Birds that will be detected flying over the point, rather than detected from within the vegetation, would be recorded separately.

c) Call count: Call count (Gaston, 1980) will be used for galliformes, particularly pheasants which call distinctively (only male) during the breeding season (March – May) as part of display and territory defence. Similar call count technique will also be used during dusk and at night for owls. Call count for pheasants will be carried out only in March – May, both morning and evening sessions, following the similar framework of variable radius point count. For aquatic birds and riparian species, variable radius point count will be carried out at every 100 m along the same 500 m river/stream segment where sampling for fish and invertebrate diversity will be carried out.

d) Scanning: Scanning from vantage points will be used to detect and quantify the raptors. Scanning will be done using a spotting scope/binocular, and if nest of any raptor species can be identified then nest monitoring can also be tried.

e) Trail sampling: Trails of 1 to 1.5 km length will be selected to conduct trail sampling to detect the presence of galliformes, and to also detect species composition of mixed flocks during winter. Camera trapping will also be carried out to detect the presence of galliformes in the sub-basin. However, to convert the encounter data into density consideration of division of the trail according to the curvature points into several smaller transects may be necessary.

f) Opportunistic records: Records of bird species presence and abundance before and after sampling period will also be documented and daily logs will be maintained where information on species, number, timing, habitat and observations on behaviour will be noted. In addition to these specific methods, data will also be collected on vegetation structure and composition and anthropogenic disturbances following 10 m x 10 m quadrates or 10 m radius circular plots. Different phenophases of flowering and fruiting trees and dependency of birds on them will also be recorded. The sampling for arthropods, microflora and fauna may also be carried out along these trails or inside the 5 ha / 200 m x 200 m plots designated for spot mapping. Data loggers will be used to record the climatic variables such as temperature and humidity of a particular area covering a number of trails, plots and point count locations. The design of data logger installation in the field will depend on the number of data loggers and study design of other themes.

Behaviour/demography of selected species: A few species (three to four) will be selected for long term monitoring based on their distributional range (timberline species), niche breadth, and dispersal ability and present population status. These species will be monitored on several behavioural aspects such as feeding ecology, breeding behaviour, egg-laying behaviour, emergence, survival and altitudinal distribution during breeding and non-breeding seasons. Basic nest monitoring techniques will be followed as described by Ralph et al. 1993. Data will also be collected on date and time of arrival and departure of long ranging as well as altitudinal migratory birds. This information can be collected from citizen science and bird-watcher networks and also from daily logs maintained during field observations.

Thematic group: Herpetofauna (*Presenter: Naitik Patel*)

So far, 119 reptile and 108 amphibian species have been recorded from the Himalaya. Among them 21% of reptiles and 40% of amphibians are endemic to the region. About 18% of reptiles and 44% of amphibians that are endemic were categorised as Data Deficient and their status remains unknown. This largely covert diversity demonstrates the need for baseline information gathering on these faunal groups in this region.

Objectives and Methodology

Describe the pattern in herpetofaunal species richness along the latitudinal gradient

This data will be used to analyse patterns in species richness along the latitudinal gradient. Geographic ranges will be inferred in the intervening areas where suitable habitats are available and discontinuous records are available. Geographical coordinates will be recorded using a high sensitivity GPS. Tropical herpetofaunal communities, like many other biological communities, have a preponderance of rare species. It is difficult and often impossible to sample such biological communities exhaustively, therefore estimation of asymptotic species richness is mandatory. Estimation of species richness in the sites will be made based on museum records. Similarly, data from museum collections, species geographic distributions can be compared using rarefaction method. A measure of productivity and heterogeneity will be obtained using global datasets on precipitation, land use and land-cover data and Potential Evapo-transpiration rates (PET). Worldclim is a set of global climate layers with 1 km^2 spatial resolution (http://www.worldclim.org/). This data set is based on extrapolation and interpolation of climatic data from regional climatic station. As climate stations are relatively few in the Himalayan region, this is the only dataset available for the entire region.

Identify factors that govern herpetofaunal communities in the eastern and western Himalaya

Within representative sites (15' x 15' grid) in each biotic province standard methods will be used to detect species and record abundance. Nocturnal stream Visual Encounter

Surveys (NVES) – it involves three, one hour Visual Encounter Surveys (VES), formalized by Crump and Scott (1994), at each of the sites. Each site is a 100 m marked segment along stream courses. Previous studies have shown that frogs aggregate along watercourses and this method yields substantial detections of amphibians. Hence, all the sampling effort for amphibians will be concentrated along the stream courses. The sampling will involve two people walking abreast with torches along the stream course looking for amphibians. Such surveys will be carried out post sunset between 18:30 – 21:00 hrs. The search does not involve active searching for amphibians and only those amphibians spotted by the torchlight will be recorded.

Similarly, in the high elevation Himalayan lakes, the same methods as mentioned above will be followed to detect amphibians and reptiles. Diurnal VES (DVES) In each elevation zone (ca. 200 m bins), two persons will search four to six belt transects (50 m x 2 m) for amphibians and reptiles by raking the leaf litter, turning logs and rocks, peeling bark and by opening fallen logs. This technique targets litter dwelling herpetofauna. The starting point of each belt will be positioned randomly between the edge of the water and 50 m up-slope in the riparian zone. In each belt, altitude, microhabitat features including soil pH, moisture and temperature will be measured using a soil pH and moisture tester and a soil thermometer, respectively. Litter depth will be measured with a metal ruler from the top of the soil to the top of the leaf litter. A canopy densiometer will be used for measuring canopy cover. These microhabitat features will be recorded at every 10 m interval along the belt. The mean obtained from all the points in an elevation zone will be used for analysis. Distance of the belt from the stream, canopy height and slope will be quantified using a clinometer. All belts will be searched for herpetofauna from 09:00 hrs to 14:00 hrs.

A robust estimate of abundance and species richness would be derived by utilizing count and presence data from transects and information on habitat co-variates to model site and species specific detection probabilities in an occupancy framework. In order to detect changes in the structure and composition of herpetofaunal communities, the empirical species richness and abundance estimate will be compared with a null model. Once a deviation is observed from the null model, then identifying the factors that contributed to it becomes important. Geographic distances between sites and the distances in the herpetofaunal communities in the sites will be analysed. Historical factors will be addressed using phylogeny and examining patterns in diversification of species. If historical factors have played a role, geographic ranges of species will be restricted to certain biotic provinces. There are several methods to test for niche conservatism. The most recent and widely accepted test will be used for the purpose. With the predicted rise in temperature by 0.04ºC–0.09ºC per year in the Himalaya, its herpetofauna is likely to provide a measurable negative response. Thus, identifying factors that govern species richness, community composition and endemism in an east to west gradient and create an open-access database on Himalayan herpetofauna following metadata standards will go a long way in future prediction of climate change scenarios in the Himalayan region.

Thematic group: Micro flora (*Presenter: Devendra Kumar*)

This article deals with an initial review of work done on three groups of soil micro-flora viz., lichen, soil bacteria and fungi. The study proposes to carry out the assessment of climate change on micro-flora.

Objectives: Specific objectives of this sub-component are as follows:

1. Generate baseline information on diversity of soil micro-flora, (i.e. lichens, bacteria and fungi) across elevation gradients and changing land use.
2. Develop better understanding of microbial ecology vis-a-vis C-flux across major ecosystems and establish linkages between microbial community structure with ecosystem functioning.
3. Standardization of protocols for long term monitoring and identification of microbial indicators for ecosystem functioning

Framework of research and proposed methodology

The soil micro-flora of the Himalaya region will be sampled following stratified random sampling in different eco-climatic regions (viz., alpine, sub-alpine, temperate, sub-tropical and tropical) of the proposed river basin and sub-basin. As per Champion and Seth (1968) classification, the representative vegetation types in each eco-climatic region, especially in transitional zone (viz., tree line and snow line) and high altitude peat-land shall be sampled for soil micro-flora diversity and richness (bacteria and fungi). Lichen sampling will be done at random at the substrate and soil level.

In each sampling point, the representative vegetation patches shall be sampled by setting transect of suitable width and length. All individual (stems) ≥10 cm girth shall be enumerated. The specimens of plant species shall be collected, packed in polythene bags, dried in herbarium press and processed to put up on the herbarium sheets. Every individual plant shall be identified with the help of regional floras and herbaria. Each enumerated individual stem shall be measured for the girth (cm), height (m) and phenophase, (i.e. flowering, fruiting, and leaf flush.). The herbs shall be enumerated by placing up to three quadrates of 1 m x 1 m at three different locations nested within each transect. Habitat characterization at different intervals including vegetation type, abundance of species would be done.

The soil sample for microbial richness, (i.e. bacteria and fungi) shall be collected at different depth (10 – 15 cm) within the representative vegetation classes at different elevation gradient. Sub-sample of soil should be preserved in liquid nitrogen for microbial stock. Soil microbial richness/diversity (for bacteria and fungi) shall be analysed using molecular techniques based on 16S and 18S rDNA sequence, and fungi: bacteria biomass ratio shall be calculated using slandered methods. Litter trap decomposition rate shall be analysed for determining soil microbial health and nutrient status. For ground lichen, Lichenometry and Open Top Chamber (OTC) experiments will be performed.

Thematic group: Invertebrates (insects and nematodes) (*Presenter: Manish Bhardwaj*)

Insects are the most dominant groups of organisms on the earth in terms of species richness, abundance and biomass. The crucial roles that insects play in ecosystems are well understood and are critical for ecological function and food web structure. Effect of climate change has been studied on various insect taxa but most of the studies show bias towards using butterflies as indicator of climate change. In India, there are very few studies that reports impacts of climate change on insects. Similarly, Nematode assemblage structure, diversity, distribution and environmental predictors have not yet been studied in detail in the Himalaya. Therefore extensive research is required to understand the role of insects and nematodes in relation to climate change in the IHR.

Proposed methodology

The Bhagirathi river basin is selected for the first year study. Sampling is proposed to be conducted in different elevation zones and vegetation types to have representation of varied insect and nematode diversity. Trails and plots are proposed to be laid in each 500 m elevation band. Currently we are planning to sample Nematodes and insect indicators of various environment and disturbance variables, (i.e. Odonates, Sacarabaedeae, Carabidae, Rhopalocera and Formicidae) during current study. A reconnaissance study will be conducted during June – July, 2015. A final sampling design will be developed after the initial data analysis. Two sampling approaches *viz.* quantitative and presence/absence will be employed to collect data on insects. Opportunistic sampling will also be conducted to increase the inventory of the species.

Field methods

Well established sampling protocols for insect collection will be adopted in different selected sampling plots. Odonates and butterflies will be sampled by visual encounter on transects. Beetles and ants will be sampled through pit fall traps, vegetation beating and visual encounter. Nematodes will be sampled through litter sampling. The detailed descriptions of the collection techniques are as follows.

a) Pitfall trapping: Pitfalls will be used to trap the ground dwelling insects like beetles and ants (Magagula, 2003). The pitfall traps consists of small deep plastic jar, one-third filled with 30% ethyl acetate and a few drops of liquid soap/detergent. The pitfall traps will be left open for a period of three days to a week, as this allows increasing the catch and maintaining the specimens in good condition before processing in the laboratory for their identification. Five pitfall traps will be laid on each of the plots selected for sampling.

b) Sweep netting: This involves collection through herb and shrub layer swinging net for a standard number of times (Coddington et al. 1991, 1996). This sampling method will be applied to collect the foliage and flying insects like pollinators and ants, from low level vegetation of shrubs (up to 2 m in height). The sweep net consists of a handle and ring and the collection will be made on white canvas. The net will be emptied at regular intervals to avoid loss and destruction of the specimen. During sampling time sweep net will be moved back and forth to cover all ground layer herbs and shrubs till all vegetation in the sampling plots will be swept thoroughly.

c) Ground hand collection: Ground hand collection involves the collection of insect samples from ground to knee level (Coddington et al. 1991, 1996). This method of sampling is used to collect the ants and beetles, which are found to be visible in the ground, litter, in broken logs, and rocks.

d) Aerial hand collection: Aerial hand collection involves the collection of insect samples from knee level to arm length level (Coddington et al. 1991, 1996). This method accesses web-building and free-living insects on the foliage and stems of living or dead shrubs, high herbs, and tree trunks.

e) Vegetation beating: The method is employed to access insects living in the shrub, high herb vegetation, bushes, and small trees and branches (Coddington et al. 1991, 1996). The insects will be collected by beating the vegetation with a stick and collecting the samples on a cloth.

f) Light traps: This sampling involves collection of insects, which are active at night. This method will be employed for recording beetles.

g) Litter sampling: Soil samples will be collected from different depth classes and will be places in labelled ploy bags. This method will be employed to sample nematodes from different soil layers.

Preservation and identification of specimens

Dry specimens will be starched, dried and preserves in insect boxes, while wet collections will be transferred to 70% alcohol. All adult specimens will be identified to at family, genus and species level or morphospecies level. Identification will be done on the basis of morphometric characters of various body parts. For this collaboration will be made with expert institutions. A detailed taxonomic study is to be carried out based on the various keys and catalogues and other relevant literatures. Collected data will be analysed to see sampling efficiency and patterns of diversity. Further, species distribution models will be generated and sampling design will be finalized.

Thematic group: Aquatic ecosystems (fishes) (*Presenter: Nishikant Gupta*)

Freshwater ecosystem in the Himalaya is one of the most vulnerable habitats to be affected due to climate change. Freshwater fish species are the best indicators of climate change, because they are expected to be influenced by climate change due to their ectothermic characteristics. There is a need to evaluate the ecology and conservation of fishes of the Indian Himalaya in connection with climate change.

Specific objectives

The study has the following specific objectives:

a) The presence/absence data of fish species across latitude, longitude and altitude will be recorded;

b) Baseline data on the status, structure and composition of fishes and their habitats in the Himalaya especially in the Indus, Ganges and Teesta/Brahmaputra basins will be estimated;

c) The species-habitat relationship focusing on indicator species, (e.g. generalists and specialists) and climate variables will be studied;

d) The effects of climate variability on the species diversity, distribution and abundance both in the present and futuristic contexts will be determined;

e) Critical fish habitats will be identified by covering 3-4 basins;

f) A suggestion will be made to set up Fish Safe Zones (FSZs), and criteria for identifying important fish habitats;

g) Indicator species for climate change would be identified for 'Wildlife Watch'; and

h) An adaptive climate change management plan will be set up.

Proposed methodology

A review document will be prepared to obtain baseline information on Himalayan freshwater fish species, (i.e. food habit, size of adult). Approximately 40 – 45 days will be required to sample a basin with 20 – 30 sites per sampling season. Sampling will be carried out over a 500 m stretch at every 5 km (except for 1st and 2nd order streams as they could vary in length). Sampling will be done in all orders of streams.

Seasonal sampling will be conducted, (i.e. over 3 seasons - winter, summer and monsoon (with limitation)). Sampling for fish species will be conducted at each 500 m reach; and fish diversity and abundance will be assessed based on catch per unit effort (CPUE) and by underwater observation (if the conditions permit). Various fishing gears will be used, (i.e. monofilamentous gill nets, cast nets, drag nets and scoop nets). Fish species recorded will be photographed and confirmed using standard protocols. Standard body length (mm) and weight (g) of the fishes will be measured for analysing growth and condition factor. Current conservation status of the fish species will be adopted from the IUCN Red List (2014).

Habitat characteristics will also be recorded at each site. These will be conducted using watershed survey to determine the:

a) Stream order classification;

b) Riparian cover;

c) Man-made activities, (i.e. water diversion, irrigation, cultivation, bathing, washing);

d) Stream bank stability; and

e) Gradient.

Physio-chemical properties of water will also be recorded at each site, (i.e. water temperature, conductivity, pH, total dissolved solids (TDS), dissolved oxygen (DO), alkalinity, hardness, nitrogen, and phosphorus). Microhabitat variables will also be measured at different transects within each sampling reach. Field surveys for otters will be carried out. This is to explore the potential of otters as flagship species for the region. In addition, sampling for phytoplankton will be done to estimate productivity.

Thematic group: Landscape ecology and visualization (*Presenter: Sujata Upgupta*)

Landscape ecology principles underscore the inter-linkages between spatial pattern and ecological processes at varying spatial and temporal scales. In the context of management inputs and garnering support for decision making at local level, the modelling inputs require spatial reference and appropriate visualization effect. Such interface approach has largely being used for policy advocacy and in marketing sector, but it is still at early stage in the ecological and climate change studies, especially in the Indian Himalayan region. There is a need to understand the species-landscape relationship which include both climate and anthropogenic drivers and create spatial database to undertake spatially explicit analyses of these relationships.

Specific objectives

The following are the specific objectives under the component landscape ecology and visualization:

a) To identify and quantify the drivers of landscape change in the context of climate and anthropogenic variables;
b) To undertake climate change analyses and develop models and scenarios towards vulnerability assessment and spatial prioritization of adaptation and mitigation; and
c) Development of interoperable database and decision support system involving 2D and 3D visualizations of the outputs.

Methodological and analytical framework

The over-arching strategy would be hierarchical approach taking into consideration appropriate ecological, (e.g. watershed/climatic zone) and spatial units, (e.g. grid cells) for various eco-region and taxa. The optimal resolution of spatial scale would be 1 km grid cell, but finer scale would also be considered depending on data availability and visualization requirement. Or it can be done along the river basins based on elevation ranges following either a top-down approach or bottom-up approach for 1^{st}, 2^{nd} and 3^{rd} order streams.

a) Development of an inter-operable database

The development of GIS database will be including nine broad classes with 36 layers in them, including remote sensing sources and field collection. The broad classes include administrative and ecological boundary, climate, geology, topography, hydrology, ecology, socio-economic and location data along with relevant attributes. The database will be dynamic and will be updated/expanded based on the need, if found to be any gap in addressing the above mentioned objectives.

b) Climate change analyses and scenario building

Global climate models (GCM) and Regional Climate Models (RCM) are complex, three-dimensional coupled models that are continually evolving to incorporate the latest scientific understanding of the atmosphere, oceans, and earth's surface The GCMs/RCMs used in this study would be chosen based on their evaluation, range of uncertainty in climate sensitivity, and availability of continuous time series of temperature and precipitation archive for the scenarios and also their suitability to the Himalayan region. The latest Coupled model Inter-comparison Project 5 (CMIP5) GCM outputs based on the new set of Representative Concentration pathways (RCPs) scenarios by IPCC would be used for the study. The projections from General Circulation Models (GCM) and Regional Climate Models (RCM) cannot be directly applied to climate change impact studies as they are at a coarse grid, and further downscaling is needed. Downscaling is a term used to describe the process of relating information or data at relatively coarse spatial and temporal scales to desired products at finer spatial and temporal scales. The RCM resolution is usually around 12 – 50 km and it accounts for the sub-GCM grid scale forcing by complex topographical features and land cover heterogeneities in a physically-based way. RCMs do not accurately represent extreme events so there is a need for further downscaling of RCMs.

Therefore, it is proposed to statistically downscale the RCM produced climate projections by using the best statistical downscaling techniques like regression or Bias-Correction methods. These downscaled outputs from the GCM-RCM in the form of geographic grid-based projections of temperature, precipitation, humidity, evaporation, solar radiation, and other climate variables on daily and monthly scales would then be used to conduct species and eco-region level impact study for three different time slices: short-term (2030s), mid-term (2050s) and long-term (2080s).

Species Distribution Modeling (SDM)

SDM's are numerical tools that are used to gain ecological and evolutionary insights and to predict distributions across landscapes. It is proposed to use the Boolean or predictive models which will be based on data like species presence or absence and abundance data. The outputs of climatic variables from downscaled RCMs will be given as an input to the SDMs.

Identification of the drivers of landscape change

The first step in executing this study would be to identify the possible drivers of landscape change whether anthropogenic or climatic and decouple changes which are exclusively due to the impact of climate change. For this, detection of change in land cover, spatially and temporally, would be carried out along-with a time-series analysis of land cover change and then correlate with growth pattern of human density, development projects and climate parameters.

Spatial Decision Support System

Decision Support System (DSS) is a computer-based system composed of a language system, presentation system, knowledge system, and problem-processing system whose collective purpose is the support of decision-making activities. It incorporates modelling along with database management systems and user interfaces for aiding the user. The framework of SDSS would involve analytical and spatial modelling capabilities, spatial and non-spatial data management, domain knowledge, spatial display capabilities, and reporting capabilities. The spatial decision-making process would involve the following steps:

a) Identifying the issue;

b) Collecting the necessary data;

c) Defining the problem, including objectives, assumptions, and constraints;

d) Finding appropriate solution procedures; and

e) Solving the problem by finding an optimal solution.

The proposed SDSS will integrate GIS technology, 2-D mapping, and numerical/graphical-analysis capabilities with robust 3-D visualization technology.

Visualization tool

The visualization tool aids in visual cognition and visual communication. Visualization techniques help in understanding of spatial problems and make ideas, questions, and concerns easily understandable for the general public. Considering the cartographic complexity of Himalayan terrain, this can be an arduous task. The proposed SDSS will integrate GIS technology, 2-D mapping, and numerical/graphical-analysis capabilities with robust 3-D visualization technology. It is underscored that the entire process of integration and successful outcome of the component have significant interdependence amongst and across the thematic groups and the task forces in NMSHE project.

Thematic group: Human ecology (*Presenter: Nishikant Gupta*)

The fragility, diversity and uniqueness in terms of its geology, geography and sociology characterize the Himalayan ecosystem.The Indian Himalaya is also home to great cultural diversity. Being a water tower of India, the region constitutes a lifeline for millions. Over the centuries, people of different ethnic origins, have migrated into the region and inhabit the mountain ecosystems.

Scope of the study

The broad scope of the study will focus on exploring the tenuous linkages between nature and humans, and look at the additional threats that climate change would pose.

Research questions

The key questions that this research aims to answer are:

a) What are the critical biodiversity resource and ecosystem services that sustain indigenous communities and the existing levels of dependence on these in the Indian Himalaya?

b) How ecosystem changes are going to impact upon human communities in terms of reduction of resources, and degradation of ecosystem services in the future?

c) What are the socio-cultural dimensions linked to natural resource and ecosystem?

d) What are the likely forms of vulnerabilities to climate change and how do these vary across communities and spatially along altitudinal gradients?

e) Are there significant variations in vulnerability and preparedness for climate change between the communities in the eastern and western Himalaya?

Proposed methodology

One of the approaches of this project is to conduct a review of literature, and compile secondary data from unpublished sources on the economic status, census, and health records of local communities. This will assist in obtaining preliminary information on the ecosystem services, economic activities, lifestyle, culture, and production systems, (i.e. agricultural, handloom, etc.) of the Himalayan communities.

Select key indicator and parameters will be used for quantifying existing dependencies that will serve as a baseline against which projections of vulnerability will be made for the future. Structured questionnaire will be used for identifying dependencies of local communities on key resources and ecosystem services. All the indigenous communities needed to be studied will also be mapped, and factors such as their population size, economic status, and resource use patterns will assist in identifying more or less vulnerable communities in the region. This component of the larger study under the project would draw upon the information from other thematic areas for strengthening complementarities and would also provide relevant support to other disciplines for projecting the "big picture".

Concluding comments by the chair and co-chair

Co-chairperson: Dr. V. B. Mathur

In this last session of the conference, Dr. V.B. Mathur expressed his regards for the successful completion of all the session and he mentioned that with every meeting NMSHE team is progressing higher. As a final outcome of the workshop certainly project had a better idea, and the new challenges they would face. Dr. Mathur focused on how individual persons can work as a team. As this project had diverse group of people with different capability and weaknesses, so he requested lots of understanding. Every person had to work as a team and had to cover for each other. Dr. Mathur suggested that everyone will have the opportunity to learn from the different disciplines, and from such efforts the project will only benefit. Dr. Mathur highlighted that Dr. Ramesh has given us a format and we have to implement it in the field, and it is the responsibility of the researchers to collect the data.

As 'Wildlife Watch' program was one of the initiatives of this project, NMSHE team had to come up with what were the indicator monitoring species for microclimatic changes in the Himalayan region from every taxon. Dr. Mathur recommended making an initial list of all the potential indicator species and attempt to come with 20-25 species' name as indicator species to watch for the 'Wildlife Watch' program. Indicator species for microclimatic changes could include information like threats to species, status of the species, image of the Species, habitat of the species, and geographical distribution of the species.

Dr. Mathur suggested that by next month the indicator species list should be prepared, and ideas should be opened up by interactions, and non-scientific community should also be made aware of this issue, so that lots of people can contribute to the 'Wildlife Watch' program. In his last remark, Dr. V. B. Mathur advised the entire NMSHE team to learn to lead with tolerance, and as young scientists try to develop skills in every aspect of wildlife and animal behavior.

Chairperson: Dr. L. M. S. Palni

Dr. Palni began with the historic background of government policies on climate change and NMSHE. Dr. Palni mentioned about the announcement on action plan on climate change by the former Indian prime minister Shri Atal Bihari Vajpayee. He further went on to inform the audience that presently there were 8 national missions under the "Action Plan for Climate Change", and out of these 8 missions, (i.e. National Solar Mission, National Mission for Enhanced Energy Efficiency, National Mission on Sustainable Habitat, National Water Mission, National Mission for Sustaining the Himalayan Ecosystem, National Mission for a "Green India", National Mission for Sustainable Agriculture, and National Mission on Strategic Knowledge for Climate Change) 7 were thematic mission, and only National Mission for Sustaining the Himalayan Ecosystem (NMSHE) was the location specific mission.

Dr. Palni suggested referring to the G-SHE (Governance for Sustaining Himalayan Ecosystem) document to understand the perspectives of various stakeholders of the State Governments of the Indian Himalayan region. Dr. Palni very correctly pointed out that all other missions were going to affect NMSHE. Dr. Palni made very constructive comments about working strategies as follows: NMSHE has relevance to all the missions, and is going to deal with the biological perspective. Further, it is a demanding and ambitious mission that all scientists and researchers of the project have to be involved in through discussing plans, strategies and also changes and alteration if needed, to come up with a very robust methodology. As this is going to be 5-year project, the entire NMSHE team would require lots of brain storming sessions to come up with mitigation plan and strategies. NMSHE team appeared to be an excellent team of youngsters, and all members had to be physically strong and should prepare themselves for the difficult field tasks ahead. All team members had to put in very special effort to collect data from the previous available records and literatures.

Dr. Palni suggested thinking about recruiting a professional person for team management purpose as NMSHE team was so diverse and vast. NMSHE team should also consider taking help from the experts outside the WII campus, and from non-biology person who have travelled extensively in the Himalaya. Further, there is a need to think of involving many interns from local communities (even school children can be involved), and from different scientific institution, (e.g. Forest Research Institute, Dehradun). Further, the extension of the present core group could also be looked into. All the efforts of NMSHE team could contribute to programs like 'Earth Watch' and strengthen data depositary.

As these microclimatic changes were so dramatic in the Himalaya, for developing the manual for climate change, all researchers would have to give emphasis on making charts and tables and may be required to take the assistance of statistical analysis tools. There are opportunities to discover plenty of new things but systematic work is required on such a large scale mission. Dr. Palni gave the example of Dr. Rawat's project with DST in relation to climate change. According to Dr. Palni, tributaries and river have very different diversity, and tributaries play very important roles in understanding the ecosystem. Diatoms too are very important, and people working on microflora should collect data on diatoms also.

He further mentioned that GBPHIED and other institutes have collected good information on GIS data of Bhagirathi basin which could be helpful for the NMSHE project. The National Chemical Laboratory (NCL), Pune too have a group on biodiversity, and they have collected good data on common species found between western and eastern Himalayan ranges which might be of our interest. There are also many projects which have generated lots of data sets in relevance to climate change, (e.g. Myanmar project, Kailash Landscape Project, Kanchenzonga project which have excess to Bhutan and Nepal). He further explained that human ecology is going to be difficult to understand in terms of how climate change is affecting local communities, and the likely lifestyle changes due to climate change effects. After giving his valuable remarks, Dr. Palni completed his concluding comments by congratulating all NMSHE team members for being an important part of the NMSHE project.

Appendix I: Detailed list of participants

Sr. no.	Name	Designation
1	Dr. V. B. Mathur	Director, Wildlife Institute of India
2	Dr. P. K. Mathur	Dean, Wildlife Institute of India
3	Shri Jai Raj	Additional PCCF, Uttarakhand
4	Shri D.V.S. Khati	Chairman, SPMU/CCF (HRD) Uttarakhand Forest Department
5	Shri S. S. Bist	Emeritus Scientist
6	Dr. L.M.S. Palni	Ex-Director, GBPIHED and Dean, Department of Biotechnology, Graphic Era Institute, Dehradun
7	Dr. I. D. Bhatt	Scientist, GBPHIED
8	Shri S. S. Rasaily	Ex-Director, Rajaji National Park
9	Dr. S. Sathyakumar	Faculty, Wildlife Institute of India
10	Dr. G.S. Rawat	Faculty, Wildlife Institute of India
11	Dr. Asha Rajvanshi	Faculty, Wildlife Institute of India
12	Dr. Abhijit Das	Faculty, Wildlife Institute of India
13	Dr. Gautam Talukdar	Faculty, Wildlife Institute of India
14	Dr. K. Sivakumar	Faculty, Wildlife Institute of India
15	Dr. J.A. Johnson	Faculty, Wildlife Institute of India
16	Dr. Ruchi Badola	Faculty, Wildlife Institute of India
17	Dr. V.P. Uniyal	Faculty, Wildlife Institute of India
18	Dr. Pratap Singh	Faculty, Wildlife Institute of India
19	Dr. D. Mohan	Faculty, Wildlife Institute of India
20	Dr. Manoj Nair	Faculty, Wildlife Institute of India
21	Dr. Tapajit Bhattacharya	Project Scientist, NMSHE

22	Dr. Nishikant Gupta	Project Scientist, NMSHE
23	Mrs. Sujata Upgupta	Project Scientist, NMSHE
24	Dr. Manish Bhardwaj	Project Associate, NMSHE
25	Dr. Devendra Kumar	Project Associate, NMSHE
26	Mr. Arun Kumar	Project Associate, NMSHE
27	Ms. Ranjana Pal	Project Fellow, NMSHE
28	Mr. Shashank Arya	Project Fellow, NMSHE
29	Ms. Sohini Choudhary	Project Fellow, NMSHE
30	Ms. Kamalika Bhattacharya	Project Fellow, NMSHE
31	Mr. Naitik Patel	Project Fellow, NMSHE
32	Ms. Aashna Sharma	Project Fellow, NMSHE
33	Ms. Pamela Bhattacharya	Project Fellow, NMSHE
34	Ms. Tanvi Gaur	Project Fellow, NMSHE
35	Ms. Priyanka Kashyap	Project Assistant, NMSHE
36	Ms. Anshu Shukla	Project Assistant, NMSHE
37	Mr. Shailendra Raut	Project Assistant, NMSHE
38	Ms. Sonam Priyadarsini	Project Assistant, NMSHE
39	Ms. Neha Aswal	Project Assistant, NMSHE

Appendix II: Abstracts of the presentations for each thematic groups (Sessions I and II)

State of the knowledge on impacts of climate change on mammals of the Indian Himalaya - ***S. Sathyakumar***

The richness of the species in the Himalayan region is generally attributed to variation in climate and habitat types. Of the 372 mammalian species in India as many as 241 species (65%) are recorded in the Himalaya and as many as 29 (37%) of mammalian species listed under Schedule I of Indian Wildlife (Protection) Act (1972) occur in the Himalaya. The diversity and endemism of mammals in Himalaya is exceptional, however, scientific knowledge on many of these mammals is still lacking in Indian context. Most of the information on mammals of the western Himalaya in India are based on status surveys of different Protected Areas, short and long term studies on carnivores such as snow leopard (*Panthera uncia*), common leopard (*Panthera pardus*), Asiatic black bear and Himalayan Brown bear, Himalayan and Tibetan wolf (*Canis lupus chanco* and *Canis Himalayansis*) and their prey such as mountain ungulates, small herbivores including lagomorphs and rodents. Comparatively, in India, very few status surveys and short term studies has been done in eastern Himalaya especially on mammals. Till date, a few long term studies on mammals had been carried out especially on red panda and Malayan sun bear in eastern Himalaya, and a long term study has been carried out in Pakke Tiger Reserve on wild dog *Cuon alpinus*. Status and distribution of mammals have been assessed through sign surveys and interviews in West Kameng of Arunachal Pradesh. In Sikkim, the mammal distribution and abundance in Khangchendzonga Biosphere Reserve have been assessed by using field methods and remote cameras.

From time immemorial, human have depended on subalpine forests and alpine pastures for their basic needs such as fuel wood, montane bamboo, fodder and grazing of livestock. There have been studies to evaluate livestock grazing impacts on wild ungulates of the Indian Himalaya but most of them have been confined to the Trans-Himalaya. Pastoralists lead large herds of sheep, goat, and small herds of cattle and buffaloes to graze in alpine meadows during summer and bring them back to lower altitudes during mid-autumn.

Pack animals such as horses and mules that transport human or goods also graze in alpine meadows during summer. In western Himalaya, a few investigations have been carried out on the livestock-wild ungulate interactions in the Greater Himalaya particularly in Kedarnath Wildlife Sanctuary, Great Himalayan National Park and in buffer zones of the Nanda Devi Biosphere Reserve. All of these studies and studies dealing with livestock and wild ungulate interactions in the Trans-Himalayas have confirmed that livestock grazing and collateral human activities can interfere in resource acquisition by wild ungulates.

Impact of climate change on mammals of Himalaya is particularly studied for two Himalayan taxa, Royale's pika (*Ochotona royalei*) and snow leopard. A hybrid approach to climate-adaptive conservation landscape planning for snow leopards in the Himalaya indicated that about 30% of snow leopard habitat may be lost due to a shifting treeline and consequent shrinking of the alpine zone, mostly along the southern edge of the range and in river valleys. But, a considerable amount of snow leopard habitat and linkages are likely to remain resilient to climate change, and these should be secured as the alpine habitat fragments and shrinks, threats such as livestock grazing, retaliatory killing, and medicinal plant collection can intensify. Study on influence of habitat microclimatic conditions on the activity patterns of Royle's pika revealed that changes in habitat microclimatic conditions (specifically, increases in temperature) might significantly restrict their daytime activity. Another study on the same species confirmed the influence of snow as thermal insulator on population dynamics of small mammals but also highlighted that adult and juvenile populations might be governed by different factors, invoking further studies on age-stratified assessment of population responses to climate change. Recent analysis indicates substantial brown bear habitat loss due to climate change. The approach for investigating impacts of climate change on mammals would be presented and discussed.

State of the knowledge on impacts of climate change on birds of the Indian Himalaya

- Pratap Singh

The Himalaya is recognized as a major biodiversity centre in the world. It is gifted with extremely rich and diverse avian assemblage primarily due to its unique location, climate and topography. A twofold decline in bird species richness along the Himalayas from the southeast to the northwest can be observed which is entirely due to a sharp decline in the number of forest dwelling species while open habitat dwelling species show a reverse trend. Species richness of forest dwelling species are exceptionally high at mid elevations (1,000–2,000 m) in the southeast, which experience a warm, wet climate in comparison with the cold and dry northwest, and this climatic variation caused failure of a high proportion of these species to expand their range to the northwest.

The numbers of endemic birds are 11 in the western Himalaya, including the cheer pheasant (*Catreus wallichii*) and the western tragopan (*Tragopan melanocephalus*). The western Himalaya is an important area of regional endemism, and has been designated by Birdlife International as Endemic Bird Area (EBA 128). It also contains 27 Important Bird Areas (IBAs). On the other hand the eastern Himalayan habitat supports a high diversity of birds and is one of the most diverse regions in the Orient. The eastern Himalayan mountain range is identified as an endemic bird area which supports 22 restricted-range bird species of which 19 are endemic to the eastern Himalaya. The region also represents one of the largest concentrations of globally threatened birds in Asia. Among the 19 endemic species, four bird species are fully endemic to the Himalaya. Quite similar to the variation in climate and accessibility, ornithological coverage within the eastern Himalaya varies considerably.

In terms of pheasants, eastern Himalaya is richer with 11 species as compared to eight in the western Himalaya. The eastern Himalaya also has more species exclusive to it whereas; four species, *viz*., satyr tragopan, Himalayan monal, kalij, and red jungle fowl are common across the two regions. As far as partridges, quails and francolins are concerned, five are exclusive to the western Himalaya, four are common across the entire Himalaya and only two species are exclusive to the eastern Himalaya. However, many species of pheasants are being driven rapidly towards extinction due to habitat destruction and other anthropogenic pressures. Many of the Galliformes are endangered or threatened due to poaching for meat/feathers, habitat degradation and habitat loss due to changing land use practices.

Pheasants in general being quite sensitive to habitat disturbance are good indicators of habitat health.

Climate change will cause range shifts of many species in the future. Galliformes might be particularly vulnerable to climate change, as they have low dispersal ability. Little is known about their possible responses to the future climate. However, no scientific study has been carried out in Indian Himalayan region on this aspect till date, but studies carried out on this aspect in China depicted that Galliformes at higher elevation will face greater range shifts mainly towards the north. Climate- and competition-mediated resource distributions are important in setting northerly range limits for avian species distribution in the Himalaya. Climate changes have threatened several bird species with high risk of extinction. Detailed description of impact of climate change in birds of Sikkim is available and altitudinal range shifts in the lower as well as upper limits of some bird species along with delay in breeding and reduced clutch sizes are reported. Climate change has severely affected the breeding activity of birds especially in the higher elevation areas of Sikkim leading to reproductive failure in some species. The approach for investigating impacts of climate change on birds would be presented and discussed.

In the heat of change: Herpetofauna of the Himalaya

-Abhijit Das

The Himalaya provides barriers and corridors that influence dispersal of biota and their endemism. It also dictates a monsoon regime in the Indian subcontinent. Being at the confluence of three biogeographic realms, *viz.*, Palaearctic, Africo-tropical and Indo-Malayan, the Himalaya provide diversity of habitats that are occupied by relic as well as recently evolved species. Thus, the geological history, species composition and diversity at latitudinal and longitudinal gradient provide us excellent opportunity to investigate climate change phenomenon in Himalayan biota.

Being physiologically constrained by temperature and humidity coupled with limited vagility, herpetofauna are candidate organisms for forecasting climate change scenarios. Climate change is known to impact their body size, breeding, gaseous exchange, range expansion in case of invasive and venomous species and range contraction in case of endemic species. Shift in temperature increases fungal disease in amphibians and skewed sex ratio in TSD reptiles.

An empirical evidence of climate change impact on the Himalayan herpetofauna is hitherto not known. There are however general observation of a mid-domain effect and range shift in *Ophiophagus hannah* (king cobra) and *Amphiesma platyceps* (Himalayan keel back). Obligate stream species, (e.g. *Amolops* spp. and *Nanorana* spp.) and direct developing species, (i.e. *Raorchestis* spp.) are likely to face widespread population decline.

So far, 119 reptile and 108 amphibian species recorded from the Himalaya. Among them 21% of reptiles and 40% of amphibians are endemic to the region. About 18% of reptiles and 44% of amphibians that are endemic were categorised as Data Deficient and their status remains unknown. This largely covert diversity demonstrates the need for baseline information gathering on these faunal groups in this region.

The Himalaya provides home to nearly 124 million people making it is the most populated mountain chain in the world. With the predicted rise in temperature by 0.04°C–0.09°C per year in the Himalaya its herpetofauna is likely to provide a measurable negative response. Thus, identifying factors that govern species richness, community composition and endemism in an east to west gradient, and creating an open-access database on Himalayan herpetofauna following metadata standards will go a long way in future prediction of climate change scenarios in the Himalayan region. The approach for investigating impacts of climate change on herpetofauna would be presented and discussed.

Effects of climate change on Himalayan aquatic ecosystem with special reference to fishes ***- K. Sivakumar & J. A. Johnson***

Globally, the effect of climate change on various ecosystems is a hotly contested topic. Freshwater ecosystem in the Himalayas is one of the most vulnerable habitats to be affected due to climate change. In freshwater ecosystem temperature is an important determinant factor for spatial distribution of several aquatic species including fishes. The western Indian Himalaya has witnessed a 0.9°C temperature rise over 102 years. While over the northwest Indian Himalayan region, there has been an increase of 1.6°C in the last century. Such fluctuations in the temperature level can strongly affect fish growth and population. Further, reduction in mass of the Indian Himalayan glaciers has been recorded. The increasing glacier melt and subsequent runoff in the Indian Himalaya is possibly due to the effects of climate change. In India, the cold water resources are said to harbour over 250 fish species that belong to 21 families and 76 genera. Climate change can affect the fish population by affecting the abiotic filters that prevent the establishment of invasive species. Cold water can be seen to act as a filter for the warm water fishes to enter this habitat. The current changing climate could potentially diminish this barrier leading to better breeding environment for the invasive species. For example, species such as *Mastacembalus armatus* (available between Tehri and Rishikesh), and *Glossogobius giuris* (available in the Haridwar stretch) were earlier never reported in the upper stretch of the river Ganga, (i.e. from Deoprayag to Kannuj) and were predominantly only available in the lower and middle Ganga in the 1950s, are now recorded from the upper cold-water stretch up to Tehri due to gradual rise in temperature. Climate change has been favourable for some species while adverse for the others. For example, the Indian major carps, (i.e. *Cirrhinus mrigala*, *Labeo rohita*, and *Catla catla*) have seen a distinct decline in numbers in the river Ganga (41% to 8%)), while the catfish species, (i.e. *Wallago attu*, *Mystus seenghala*, and *Bagarius bagarius*) are at an advantage. Summing up, climate change has the ability to put tremendous pressure on the available ecological services and socio-economic opportunities associated with freshwater ecosystems in the region. As such, there is an urgent need to study the impact of climate change and provide guidelines for a 'Conservation and Preparedness Plan' to safeguard the aquatic ecosystem and its biodiversity from the potentially harmful climatic change effects.

State of the art knowledge on invertebrates (nematodes and insects) in Indian Himalayan region *- V.P. Uniyal*

Soil micro fauna

Micro fauna are the smallest of the soil fauna and are less than 0.1 mm in size. Understanding, the wealth of soil biota and their roles in ecosystem processes is essential to address how global change alters soil communities and to determine the effect of ecosystem services provided by soil organisms. Mites and nematodes species number could substantially increase estimates of global biodiversity. The densities of microorganisms are enormous such as 10^{3-5} protozoa, $^{101-2}$ nematodes and 10^{3-5} other invertebrates may be found in a gram of soil. Despite their small size and relatively limited contribution to the total soil biomass, they play essential role in ecosystem processes, such as nutrient cycling and primary production. Nematode species richness and biomass increase at higher latitudes. Around 26,646 species are recorded from the world and in India around 200 species from the state of Uttarakhand itself. From IHR region most of the species are reported from agricultural fields than forested areas.

Insects

Insects are the most dominant groups of organisms on the earth in terms of species richness, abundance and biomass. Being ectotherms the distribution range of most of insects is determined by temperature and usually low temperature is more significant in determining their distributions than high temperature. Many species are potentially highly vulnerable to the impacts of climate change and extinction. Global climatic change might affect insects directly, through changes in physiology, behaviour and life history parameters, as well as indirectly, through changes experienced by host plants in their morphology, biochemistry, physiology, and patterns of richness, diversity and abundance. Because of insects' immense species richness and less taxonomic knowledge, exhaustive inventories are not usually feasible, and most studies focus on selected taxonomic groups. Effect of climate change has been studied on various insect taxa but most of the studies show bias towards using butterflies as indicator of climate change. Most published research (64%) is generated from Europe and North America and being dedicated to core data analysis, with 29% of the studies analysed dedicated to Lepidoptera and 22% to Diptera.

In India, there are very few studies that reports impacts of climate change on insects. Only two studies on Drosphilidae and butterflies in western and eastern Himalaya were found, which report shifts in species distribution ranges. The overall information on distribution ranges of insects is scanty for Indian Himalayan region (IHR). Information on range distribution is available for few groups like Odonates, butterflies, moths and ants in IHR. A total of 17,500 species of butterflies have so far been reported from the world, out of which around 1,500 are reported from India, and around 850 from the IHR. Around 415 species of butterflies are reported from Uttarakhand. Information is available from protected areas of the states on few insect taxa, (e.g. Gangotri, Govind, Rajaji, Corbett, Nanda Devi National Park, Govind, Askot and Chila Wildlife Sanctuary). More than 250 species of Odonata have been reported from IHR, 162 species from the western Himalaya and 90 Odonata species from the Dehra Dun valley. Around 367 species of ants have been reported from the IHR, 144 species from Jammu & Kashmir Himalaya and 40 species from the Shivalik region of Punjab. The approach for investigating impacts of climate change on invertebrates would be presented and discussed.

Assessing the impacts of climate change on Himalayan micro flora: current state of knowledge and study approach

- G.S. Rawat

Climate has long been identified as a primary driver of ecosystem structure, functioning and species distribution. Predicted changes in atmospheric CO_2 and climate are likely to affect the distribution and abundance of most species in future. Documenting the current distribution of climate sensitive species, and projecting future trends is one of the priority areas of research globally. In this context, the Himalayan region, one of the most diverse regions of the world, offers an excellent opportunity to address the questions dealing with ecosystem and species response to climate change. This region is considered more sensitive to climate change as compared to other parts of Indian sub-continent. The high resolution regional climate models reveal that temperature and precipitation in the Himalayan region will continue to increase in future, and these changes are further likely to impact the distribution of various life forms including microbes.

Microbes are central to all life on earth, exhibiting great range of diversity in form and function. These organisms significantly contribute to crop fertility, recycling of nutrients, detoxifying pollutants, regulating carbon storage and controlling the production and absorption of greenhouse gases such as CO_2, methane and nitrous oxides. Soil microbial communities play key role in cycling of carbon and nutrients in ecosystems and their activities are regulated by biotic and abiotic factors, such as the quantity and quality of litter inputs, temperature and moisture. Soil microbial populations determine key soil functions, thereby directly affecting the value of land. They are in turn strongly influenced by regional as well as local climate leading to changes in ecosystem functioning including biogeochemical cycling, soil carbon storage and plant-soil feedbacks.

We reviewed published work worldwide on the impacts of climate change on micro flora, including soil microbes, fungi, algae, lichens and bryophytes. In comparison to numerous studies conducted on micro flora in the United States, Europe and China, there are very few studies available on the Himalayan micro flora. Few studies are available on lichens and fungi of the western Himalaya. However, not much research has been conducted on micro flora of both eastern and western Himalaya. In this presentation we discuss the current status of knowledge on possible impacts of climate change on Himalayan micro flora and proposed methodology for assessing microbial diversity (on elevation gradient), in pilot areas located in the western and eastern Himalaya. Additionally, we propose key research questions on micro flora and their relevance to ecosystem functioning and climate change adaptation of the region.

Human ecology and climate change in the Indian Himalayan region

- Asha Rajvanshi & Ruchi Badola

Based on the growing body of knowledge, it is now universally acknowledged that climate change is a reality. Climate change, understood "as a change in global or regional climate patterns", has many fold implications for conservation of biodiversity and well-being of the human communities dependent on varied resources and range of ecosystem services provided by the Himalayan ecosystem.

The fragility, diversity and uniqueness in terms of its geology, geography and sociology characterize the Himalayan ecosystem. The link between nature and human communities in this part of the world is both vital and tenuous. The components of this ecosystem are already targets of climate change induced and anthropogenic impacts. It is in all likelihood that ecological, environmental and social components of this ecosystem would be further impacted by increasing vulnerability, (i.e. who gets affected and by how much). The broad scope of the project will focus on first exploring the tenuous linkages between nature and humans, and then look at the additional threats that climate change would pose.

This area is also not untouched by rapid and unplanned development in many key economic sectors, (i.e. transport, mining, construction). All put together, the complexities of climate change, population rise, urbanization, modernization, degrading resource base and migration become the major challenges for the sustainability of their sustenance, livelihood, cultural and religious traditions, and other well-being factors.

This research aims to answer key questions such as: (a) what are the critical biodiversity resource and ecosystem services that sustain indigenous communities and the existing levels of dependence on these in the Indian Himalayas; (b) how ecosystem changes are going to impact upon human communities in terms of reduction of resources, and degradation of ecosystem services in the future; and (c) what are the socio-cultural dimensions linked to natural resource and ecosystem.

The methodological approach involve using select key indicator and parameters for quantifying existing dependencies that will serve as a baseline against which projections of vulnerability will be made for the future; developing a scenario to project climate-related impacts on human ecosystem and ensuring preparedness in terms of both developing adaptations, (i.e. a process of change leading to better suitability to the environment), and resilience, (i.e. the capacity to recover quickly from difficulties).

This component of the larger study under the project would draw upon the information from other thematic areas for strengthening complementarities and would also provide relevant support to other disciplines for projecting the "big picture".

Landscape ecology and visualization: framework for spatial decision support system for understanding and responding to climate change effects on fauna and microflora in the Indian Himalayan region

- K. Ramesh & G. Talukdar

Landscape ecology principles underscore the inter-linkages between spatial pattern and ecological processes at varying spatial and temporal scales. In the context of management inputs and garnering support for decision making at local level, the modeling inputs require spatial reference and appropriate visualization effect. Such interface approach has largely being used for policy advocacy and in marketing sector, but it is still at early stage in the ecological and climate change studies, especially in the Indian Himalayan region. Climate models are usually the Global Climate Models developed based on various scenarios prescribed in the IPCC synthesis. In this project, the specific component will look into (a) drivers of landscape change in the context of climate and anthropogenic variables, (b) development of spatial database and spatial decision support system (SDSS) including 2D and 3D visualizations of the output layers, and (c) climate change analyses models and scenario development, useful for local as well as regional level decision making. The framework would involve hierarchical approach involving various spatial scales in the form of grids such that the grid cells are amenable to various bioclimatic parameters. In order to facilitate or to provide an indication of field data collection that would be suitable for data integration, it is proposed that the field design by various taxonomic or thematic teams will have to follow watershed/basin approach incorporating at least three hierarchical orders. Alternately, the data collection may be followed based on systematic design but this would be constrained by logistics in the complex terrain such as the Himalaya.

We have already prepared a list of potential database that would be used in the project, along with the sources and spatial resolution. Additional, we have also synthesized the major players who are involved in climate change modeling and decision support system across the world. The core activity would involve development of species/richness distribution model and spatial prioritization analysis leading to identification and mapping of vulnerable species and sites in the context of current and future climate variability and change.

भारतीय वन्यजीव संस्थान
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