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CHAPTER [13]

Biodiversity of entomofauna with reference to habitat degradation at Pancheshwar dam site on the River Mahakali, Central Himalaya

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ABSTRACT

Conservation of insect biodiversity is essential as insects play numerous crucial roles in ecosystem functioning and the global economy. The Pancheshwar Multipurpose Project is the largest hydropower project in South Asia envisaged to built at the confluence of the River Sarju with the River Mahakali, forming international boundary of India with the North-West of Nepal. Despite its nature to threaten the existence of biological diversity at large scale, the serious efforts to quantify regional diversity have been entirely overlooked in the current project. Keeping this in view, a study was conducted during 2017-2018 aimed to inventorize diversity and richness of entomofauna with reference to the adverse impacts of pre-dam construction activities and degradation of forests at the Pancheshwar dam site located in the district Champawat of the state Uttarakhand, Central Himalaya. A total of 5908 individuals and 140 species under seven insect orders were reported of which the Lepidoptera was the most species rich (67.85%) and abundant (47.61%) group of insects with 10 species of butterflies protected under the Indian law. The present records indicated the existence of rich insect diversity in the dam site which is expected to meet the needs of understanding the importance of biodiversity conservation in such critical areas which are continuously being affected from the large-scale developmental projects, eroding and threatening flora and fauna.

KEYWORDS Butterflies, Disturbance, Insects, Pre-dam construction, Rare species

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Introduction

Class Insecta, constituting more than 58% of the known global biodiversity is the most specious group that consists 66% (10, 20,007 species under 39 orders) of all animals on the Earth (Zhang, 2011). Besides the provisioning of vital ecosystem services, insects are of utmost importance because of their direct or indirect influence on agriculture, human health and global economy (Berenhaum, 1995; Adetundan *et al*., 2005; Premalatha *et al*., 2011). Insect diversity and abundance is critical for the functioning and stability of terrestrial and freshwater ecosystems (Godfray, 2002). They affect the nutrient and energy flow of ecosystems and are essential in diverse ecological processes such as pollination, seed dispersal, nutrient cycling and decomposition, bio-turbation, maintenance of wildlife species (Losey and Vaughan, 2006; Nichols *et al*., 2008), and they serve as predators of pests and prey for valued vertebrates (Engelmann, 1961; van Straalen, 1998). Insects act as ecosystem engineers since they are the major modifiers and controllers of the physical state of abiotic and biotic materials (Samways, 2005). Insects have been employed extensively in the landmark studies in biomechanics, climate change, developmental biology, ecology, evolution, genetics, palaeolimnology, and physiology. Moreover, insects that act as predators of economically damaging insects provide effective means for biological pest management of the crops (Dempster, 1968).

The insect distribution is mainly influenced by the ecological, climatic and edaphic factors, such as the vegetation, rainfall and temperature. Habitat structure influences insect diversity and abundance (Spitzer *et al*., 2008). The occurrence and abundance of insects may directly reflect environmental changes (Wahizatul *et al*., 2011). They have short generation times and respond quickly to minor ecological changes in the environment (Work *et al*., 2002). Because of their conspicuousness and susceptibility to environmental factors many insect taxa can be used as ecological indicators of ecosystem integrity (Pyle, 1976; Heath, 1981; Kremen, 1994; King *et al*., 1998; Tscharntke *et al*., 1998; Kati *et al*., 2004; Choi, 2006; Langor and Spence, 2006; Maleque *et al*., 2009).

The Pancheshwar Multipurpose Project is the largest hydropower project in South Asia. It is a bi-national scheme between the Governments of India and Nepal signed under the Mahakali Treaty on February 12, 1996. The construction of 315 m tall, 20 m wide and 814 m long high rock fill dam spreading over an area of 116 sq km has been envisaged across 2.5 km downstream near Pancheshwar temple of the village of Pancheshwar at the confluence of the Sarju River with the River Mahakali. A re-regulating dam is also proposed downstream of the main dam at the Rupaligad to mitigate hydrological impacts generated from the main dam powerhouses (Everard and Kataria, 2010). The region covered by the entire project structure located between 29°25′0″ to 29°47′30″ N latitude and 79°55′0″ to 80°35′0″ E longitude, lies in Champawat, Pithoragarh, Bageshwar and Almora districts of the Kumaon Division, Uttarakhand, India and in Baitadi and Dharchula districts of the Far Western Development Region in the Nepal. The affected area by the project that extends nearly from 400 m to 2100 m contains tropical to temperate type of vegetation. The lower elevational zones are dominated by sal trees which gradually merge into pine and oak mixed forests in the upper ridges (PDA, 2015). The entire area of 14,000 ha of which 9,100 ha lying in India and rest in Nepal will be acquired for construction of the both dams. In order to construct main reservoir at the Pancheshwar, 51.6% of the total land of the region (2415.1 ha), covered with forests (1456.8 ha), shrubs (584.6 ha) and grasslands (373.7 ha) will be acquired for clearance to harness power potential of both rivers (PDA, 2017).

IUCN, UNEP and WCD recommendations on dams and biodiversity highlight the avoidance of areas rich in species which needed to be given high priority in selection criteria. Accelerating rates of biodiversity loss lead to the signing of international agreements, such as the convention on biological diversity and agenda 21, have called for the world biodiversity to be inventoried and monitored (Stork and Samways, 1995). Lack of knowledge on biodiversity, ecology and geographic distributions of species due to poor surveys and expeditions from such areas may have serious impediments (McAllister *et al*., 2001). The assessment of environmental impact of large dams on lower groups of organisms such as insects remained poorly understood for the loss of wildlife in India (Mishra, 2009).

Environment Impact Assessment of the proposed project by the Pancheshwar Development Authority revealed the presence of 47 species of butterflies which is severely under reported information on insect fauna of the region (PDA, 2017). Despite the importance of common and largest insect orders *viz*. Coleoptera, Lepidoptera, Hymenoptera and Diptera as herbivores, pollinators, parasitoids and predators (Steffan-Dewenter and Tscharntke, 2002), they have been entirely neglected in the preliminary assessment of environment by the authorities. In order to mitigate massive habitat loss and decline of the ecologically important group of insects, monitoring and quantification of insect diversity and abundance is the pre-requisite in systematic conservation planning and sustainable development.

In the light of the aforesaid statements, the purpose of the present study was to assess diversity and abundance of common insect orders, their seasonality and also aimed to evaluate the species of conservation concerns that may decline potentially in reaction to changes in the microclimatic conditions. Besides providing insight into the diversity and richness of insects, the present study is very critical for their future conservation and management purposes as insects are extremely important biological resource, essential in ecological functioning and sustainability of the region.

Study site

The present study was conducted at the proposed Pancheshwar dam site (29°26.84′ N Latitude and 80°13.70′ E Longitude) and within 10 km periphery of the submergence area. The glacial and snow-fed River Mahakali forming international boundary of India with west of Nepal flows in a narrow V- shaped gorge, flanked by 45 degrees slopes rising more than 1000 m above the river bed. The River Mahakali is not only rich in ichthyofauna but also harbors several threatened, game and migratory species of fish (Saund *et al*., 2012). The study area is located on a mountain with elevation ranging from 440 m to more than 1000 m above msl in the district Champawat of the state Uttarakhand, India (Figure 1). The region is well connected with 40 km long road that starts at an altitude of 1600 m from the main town of Lohaghat and goes down to the low-lying valley, reverent for its sacred deity Lord Shiva temple in the study area. The terrain is undulating with mountains and ridges intersected by deep ravines and rivulets in low-lying areas and covers grasslands on hilltops (PDA, 2017). The forest of the study area is classified as 3C/C2a Moist Siwalik Sal Forest and 5B/C2 Northern Tropical Dry Mixed Deciduous forest mainly at low-lying areas which merge with 9C1/b Upper Himalayan Chir Pine Forest at upper altitudinal zones (Champion and Seth, 1968).

Some part of the land nearby the Sarju River is cultivated for agricultural practices and some fruit bearing trees like mango, papaya, pear, banana, guava, walnut, tamarind, cinnamon, grapes, jackfruit and several citrus fruits are also grown by local villagers. The yearly precipitation is

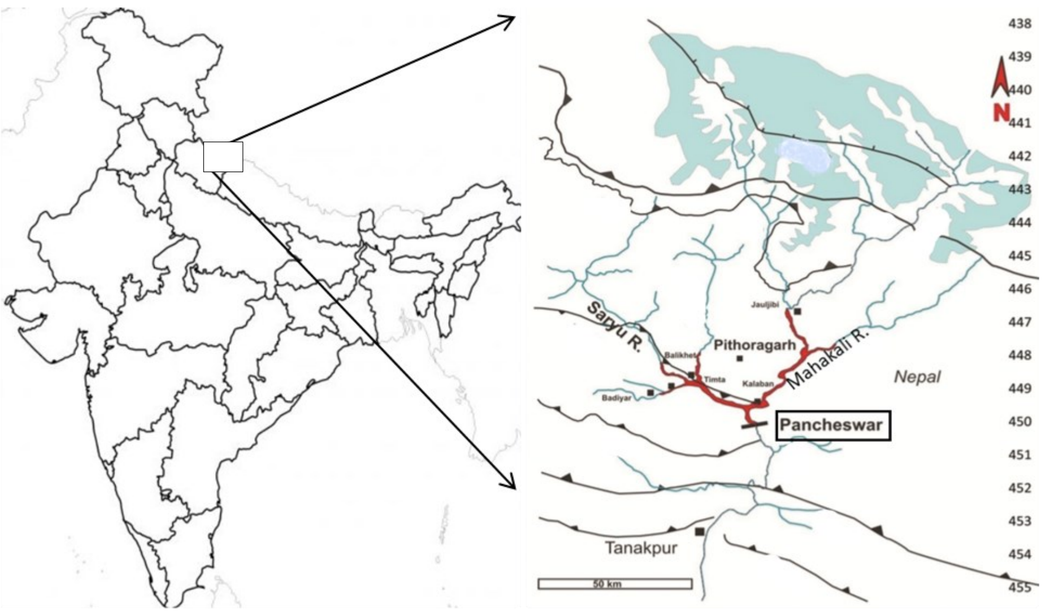

Figure 1. Map showing the location of the Pancheshwar dam site on the River Mahakali (Modified: Sati et al., 2019).

roughly less than 1000 mm with variable climate of tropical to sub-tropical type, characterized by hot summer season (March-June), moist and wet rainy season (July-October) and cold winter season (November-February). The relative humidity was high i.e., 93% during July while least during December i.e., 45.5%. During the present study monthly temperature varied with an average from 22°C to 29°C during hot summers and from 14.5°C to 20°C in dry cold winters. For the purpose of the present study, five permanent transects each of length one km were chosen to cover a range of micro-habitats with varied degree of anthropogenic pressures within 10 km periphery of the submergence area, given as under:

- Transect 1- Upstream of the confluence area i.e., right bank of Sarju River
- Transect 2- Upstream of the confluence area i.e., left bank of Sarju River
- Transect 3- Downstream of confluence area between Sarju River and River Mahakali
- Transect 4- Concrete road merging with un-metalled track towards dam construction site
- Transect 5- Uphill road along forest edges near village Khaikot Talla

The lower elevation was selected in village Pancheshwar containing transects 1 to 3 which is characterized by riparian zone with diverse array of micro-habitats. The higher elevation site comprised transects 3 and 4 that link village Khaikot Talla located 10 km uphill from the main dam site characterized by degraded forest land with high level of disturbance (Figure 2a-e). It is also that an area of 83 ha has been selected nearby village Khaikot in the proposed project for carrying out mechanized construction activities.

Sampling and identification of insects

The insect survey in the selected transects of the study area was conducted on three consecutive days in a month during a period of one year from August 2017 to July 2018. Both transect walk and quadrant methods were employed for the sampling of different insect orders. Observations took place between 08.00-16.00 h of the day mainly during suitable weather conditions i.e., on clear sunny days with low wind velocity. The record of population trends of adult Lepidoptera was made by using Pollard Walk Method counting individuals seen around an imaginary 5 m radius of the observer while walking with constant pace in each transect on the same sampling day at different timings (Pollard, 1979; Pollard and Yates, 1993). Species were identified following butterfly identification guides (Haribal, 1992; Kumar, 2008; Kehimkar, 2014; Singh, 2017; Sondhi and Kunte, 2018). In case if identification is difficult, butterflies in question were captured using the butterfly net, identified with field identification guides and were released at their point of capture to avert biodiversity loss.

Two quadrates each having dimensions of 10 m × 10 m in the each selected transects lines were laid at random for the sampling of insects belonging to orders other than the Lepidoptera. The methods such as baited pitfall traps, aerial net, manual collection and sweep net were employed

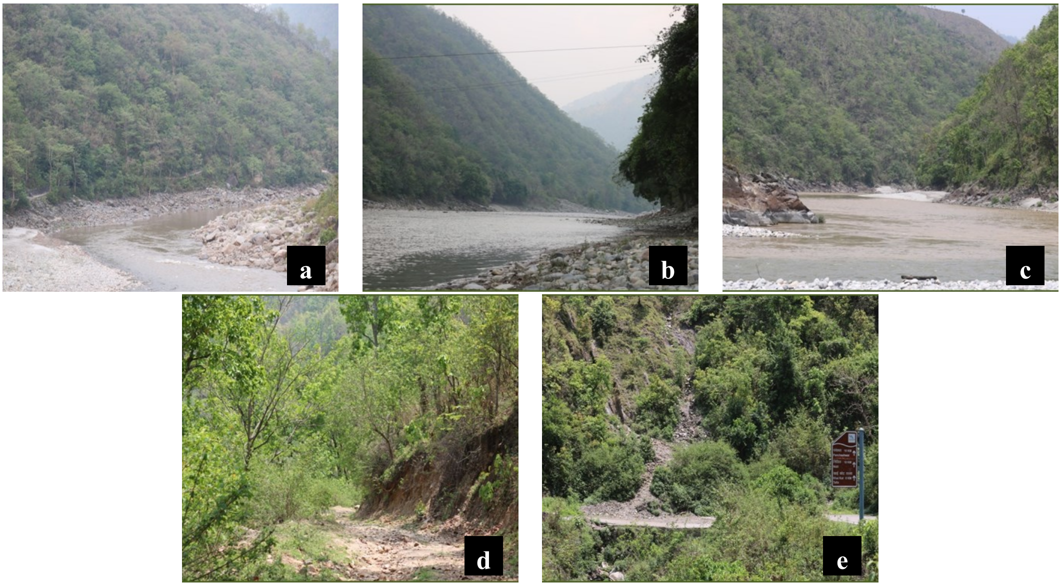

Figure 2. View of the selected transects (a) right bank of the Sarju River, (b) left bank of the Sarju River, (c) downstream of confluence area between the Sarju River and the River Mahakali, (d) Pancheshwar dam construction site and (e) uphill road along forest edges near the village Khaikot Talla.

(Gadagakar *et al*., 1990). After the collection, insect specimens were curated, preserved and got identified at the Insect Biodiversity Laboratory of Department of Zoology, DSB Campus, Kumaun University, Nainital, Uttarakhand. The specimens of plants were collected from each transect and got identified after preparing the herbarium on scientific guidelines.

Data analysis

Based on the number of sightings, the relative abundance of each species was calculated. In order to assess diversity and seasonality of different insect orders across the seasons *viz*. pre-monsoon (March-May), monsoon (June-August), post-monsoon (September-November) and winter (December-February), measures of diversity indices such as Shannon (H_s for insect diversity), Margalef (H_m for species richness) and Evenness (E for even distribution of species) were calculated using the program PAST version 3.4. Data for the number of species and individuals recorded during the study period was pooled to obtain individual based rarefaction curve at 95% confidence level to determine the sampling effort using the same program.

Floristic composition of the study site

Appendix I (Available as supplementary information in e-version of this chapter) provide the information on vegetational composition of the Pancheshwar dam site which was recorded during the study period. Floral studies of the region resulted in a total of 187 species of plants comprising 46 species of trees, 38 species of shrubs, 63 species of herbs, 29 species of grasses and 11 species of climbers (Figure 3). The common plant species in the tree layer include *Shorea robusta*, *Mallotus philippinensis*, *Adina cordifolia*, *Holoptelea integrifolia*, *Syzygium cumini*, *Terminalia tomentosa*, *Acacia catechu*, *Sapium insigne*, *Kydia calycina*, *Bombax ceiba*, *Boehmeria rugulosa*, *Ougeinia oojeinensis*, *Trema politora*, *Toona ciliata*, *Mangifera indica*, *Aegle marmelos*, *Pinus roxburghii* and several species of *Ficus*. The common shrubs and floor vegetation included *Vitex negundo*, *Callicarpa macrophylla*, *Justicia adhatoda*, *Woodfordia fruticosa*, *Ricinus communis*, *Persea odoratissima*, *Eupatorium odoratum*, *Lantana camara*, *Murraya koenigii*, *Cassia mimosoides*, *Indigofera heterantha*, *Rubus ellipticus*, *Calotropis procera*, *Zizyphus mauritiana*, *Bidens pilosa*, *Cannabis sativa*, *Circium walichii*, *Conyza japonica* and *Sida acuta*.

Taxonomic composition and diversity of entomofauna

During the one year of study period, a total of 5,908 individuals under 140 species that belonged to 29 different families and seven orders of the class Insecta were reported from the Pancheshwar

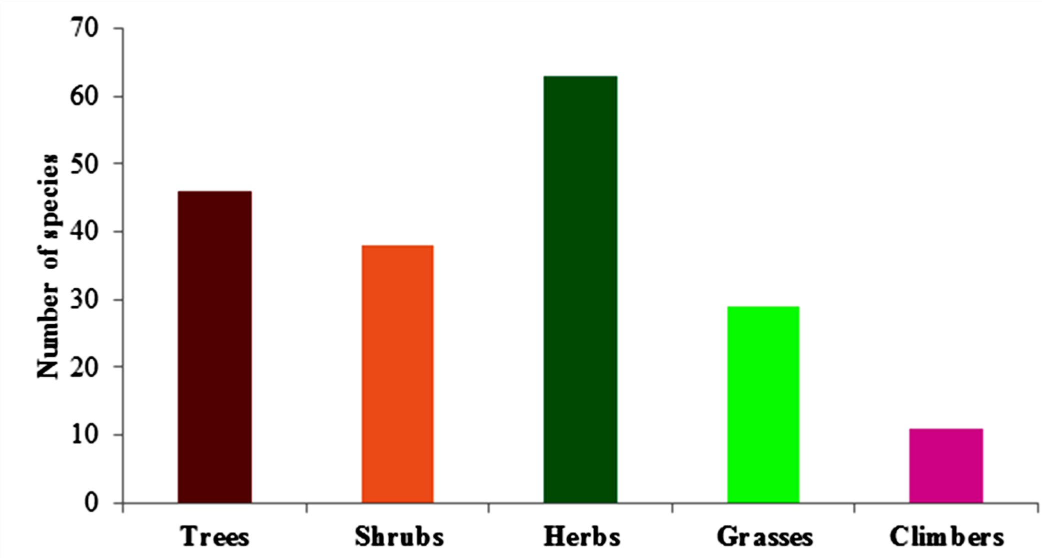

Figure 3. Diversity of the plants recorded from the Pancheshwar dam site.

dam site located in the Kumaon Mountains of the Central Himalaya (Appendix II; Available as supplementary information in e-version of this chapter). Figure 4 depicts that among the recorded entomofauna, Lepidoptera outnumbered the other insect orders in terms of species richness (N = 95; 67.85% of the total species) and abundance (2,813 individuals; 47.61% of the total individuals). Odonata was the second most specious (N = 11; 7.85% of the total species) and abundant order (15.53% of the total individuals). Coleoptera and Orthoptera were similar in terms of species richness (N = 9 each; 6.42% of the total species), wherein the former group consisted 13.32% of the total individuals while the latter comprised 8.12% of the total individuals. Hymenoptera was represented by 5.71% of the total recorded species (N = 8) and 8.56% of the total individuals (506 individuals). Diptera and Hemiptera were found to be least diverse in terms of species richness (N = 4 each; 2.85% of the total species) and abundance (4.23% and 2.60% of the total individuals, respectively). Sample based individual rarefaction was asymptotic and the steeper curve was observed for the insect communities, signifying sufficient sampling efforts (Figure 5). This also point towards the potential of the region in sustaining more insect diversity and further samplings might result in addition of more species from the study area.

The values for various measures of diversity indices varied significantly among the recorded insect orders (Table 1). Order Lepidoptera exhibited maximum value for species diversity (H_s = 4.20) and species richness (H_m = 11.84), followed by Odonata (H_s = 2.22 and H_m = 1.46). Hymenoptera showed higher species diversity (H_s = 1.99) as compared to the Orthoptera (H_s = 1.88) and the Coleoptera (H_s = 1.80), however it showed slightly lower species richness (H_m = 1.12) than Orthoptera (H_m = 1.29) and Coleoptera (H_m = 1.20). Minimum diversity and species richness was calculated for the orders Diptera (H_s = 1.35 and H_m = 0.54) and Hemiptera (H_s = 1.24 and H_m = 0.59). The maximum value of evenness as recorded for the order Diptera (E = 0.972) revealed that members of this order are more evenly distributed than the others while the members of Coleoptera (E = 0.677) and Lepidoptera (E = 0.706) were less evenly distributed during the study period.

Table 1. Diversity indices calculated for the different insect orders during the study period.

Order	Shannon (H_s)	Margalef (H_m)	Evenness (E)
Lepidoptera	4.20	11.84	0.706
Hymenoptera	1.99	1.12	0.916
Coleoptera	1.80	1.20	0.677
Diptera	1.35	0.54	0.972
Hemiptera	1.24	0.59	0.867
Orthoptera	1.88	1.29	0.727
Odonata	2.22	1.46	0.836
Total	4.55	16.01	0.680

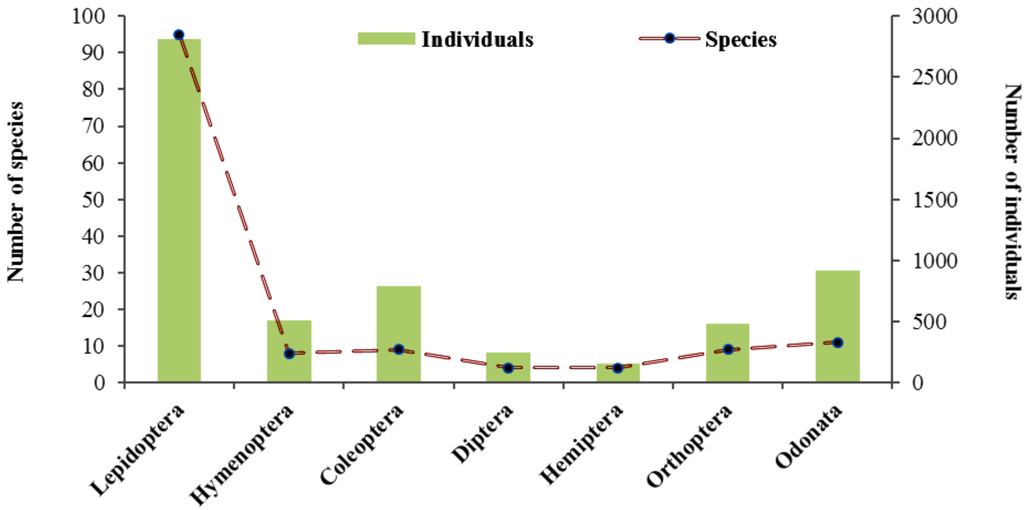

Figure 4. Species richness and abundance of different insect orders as recorded during the study period.

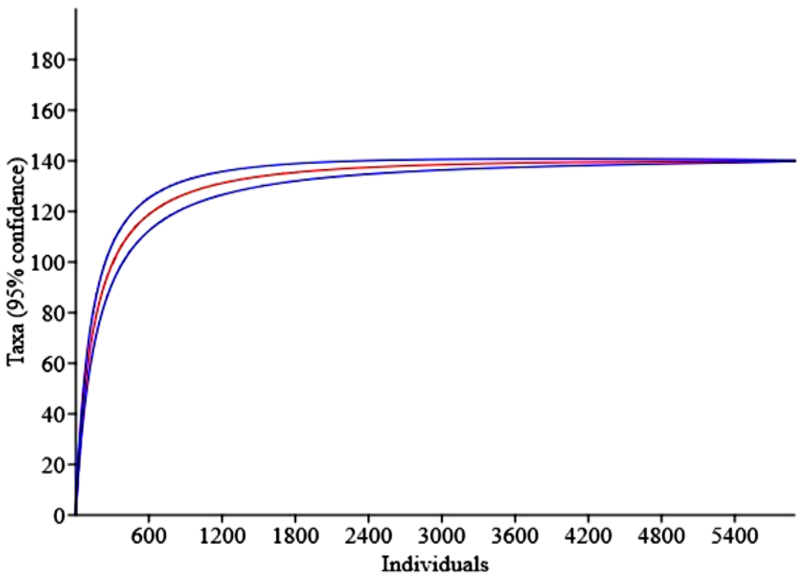

Figure 5. Sample based individual rarefaction curve with 95% confidence interval (blue lines) in the Pancheshwar dam site (August 2017 to July 2018).

The family-wise collection of number of species and individuals of the different insect orders has been presented graphically in the Figure 6. Order Lepidoptera comprised six families of butterflies namely, Nymphalidae (45 species and 1,241 individuals), Lycaenidae (16 species and 335 individuals), Pieridae (12 species and 689 individuals), Hesperiidae (11 species and 159 individuals), Papilionidae (7 species and 263 individuals) and Riodinidae (3 species and 72 individuals). The moths were represented by single species with 54 individuals under the family Sphingidae. Species such as *Eurema laeta*, *Eurema hecabe*, *Pieris brassicae*, *Euploea core*, *Junonia iphita* and *Papilio polytes* were the most abundant butterflies which altogether constituted 10.32% of the total insect individuals. On the other hand, *Horaga onyx*, *Moduza procris*, *Belenois aurota*, *Curetis bulis*, *Castalius rosimon*, *Hestina nama*, *Udaspes folus* and *Pseudocoladenia fatih* were the least abundant species of butterflies. Order Hymenoptera was represented by five families, of which Apidae was the most specious and dominant family consisting three species and 3.63% of the total insect individuals. *Apis dorsata* was the most abundant bee species of this family. The species of wasp namely, *Vespa basalis* of the family Vespidae was the most dominant species of the order Hymenoptera.

Order Coleoptera was comprised of four families namely, Scarabaeidae (4 species and 333 individuals), Chrysomelidae (3 species and 155 individuals), Coccinelidae (single species with 266 individuals) and Meloidae (single species with 33 individuals). *Coccinella septumpunctata L. var. divaridata* was the most dominant species of this order followed by *Anomala dimidiata* and *Altica*

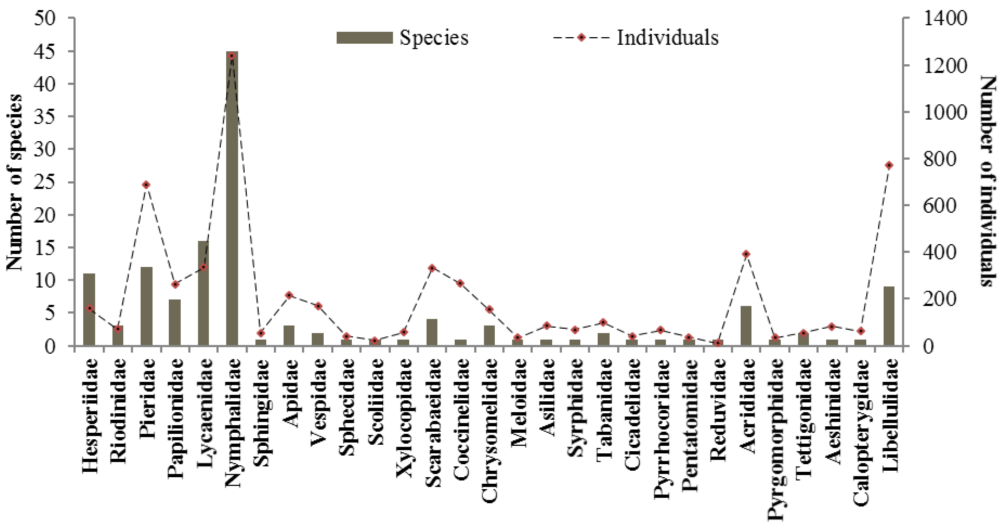

Figure 6. Family-wise collection of species richness and abundance of different insect orders.

himensis while *Protaetia neglecta* was the least abundant species of the beetles. Order Hemiptera was represented by four families with single species in each family, Pyrrhocoridae was the most dominant among them and *Physopelta gulta* as the dominant species of this family. Among the order Orthoptera which consists of three families, Acrididae was the most dominant family consisting six species and the species such as *Acrida exaltata* and *Trilophidia annulata* were the dominant. Diptera was represented by three families namely, Tabanidae (2 species and 98 individuals), Asilidae (single species with 84 individuals) and Syrphidae (single species with 68 individuals). Among three families under the order Odonata, Libellulidae was the most dominant represented by nine species and 13.08% of the total insect individuals. Dragonflies such as *Orthetrum taeniolatum*, *Orthetrum triangulare*, *Orthetrum pruinosum* and *Orthetrum glaucum* were the most abundant species of this order.

Seasonal diversity of insects

Figures 7 and 8 represent the relative number of species and individuals recorded among the different orders of insects across the four major seasons *viz*. pre-monsoon, monsoon, post-monsoon and winter, respectively. It is evident that different seasons exerted marked impact on the species richness of the Lepidoptera, wherein the species richness peaked twice i.e., during the pre-monsoon (N = 90; 64.28% of the total species) and post-monsoon seasons (N = 86; 61.42% of the total species). No such major difference in the trend of species richness across the different seasons was observed for the other orders. The individual abundance for most of the orders was reported to be maximum during the monsoon season while the species richness and individual abundance was least during the cold winters. The calculated values of diversity (H_s), species richness (H_m) and evenness (E) across the major seasons for the different insect orders has been presented in the Figure 9. The species diversity and the species richness of the order Lepidoptera was maximum during the pre-monsoon season ($H_s = 4.21$ and $H_m = 13.22$) and the post-monsoon season ($H_s = 4.20$ and $H_m = 12.65$). The species diversity of the orders Hymenoptera ($H_s = 2.03$), Coleoptera ($H_s = 1.89$), Diptera ($H_s = 1.37$), Hemiptera ($H_s = 1.29$) and Odonata ($H_s = 2.24$) was maximum during the post-monsoon season while the Orthoptera showed high species diversity during the monsoons ($H_s = 1.93$). The species richness was fairly high during the post-monsoon season among the orders Hymenoptera ($H_m = 1.42$), Coleoptera ($H_m = 1.48$), Hemiptera ($H_m = 0.78$) and Orthoptera ($H_m = 1.60$) while the orders Diptera ($H_m = 0.78$) and Odonata ($H_m = 1.90$) showed maximum species richness during the pre-monsoon season. Similarly, trends in the evenness of species under different orders varied significantly across the different seasons.

Species of conservation priority and economic importance

During the present study a total of ten species of butterflies are legally protected under the different schedules of Indian Wildlife (Protection) Act, 1972 indicating high host plant richness in

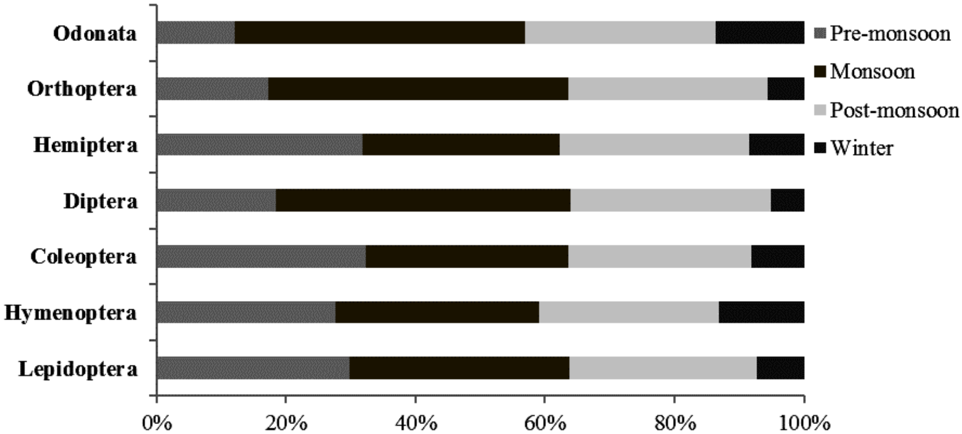

Figure 7. Relative composition of species richness of different insect orders across the seasons.

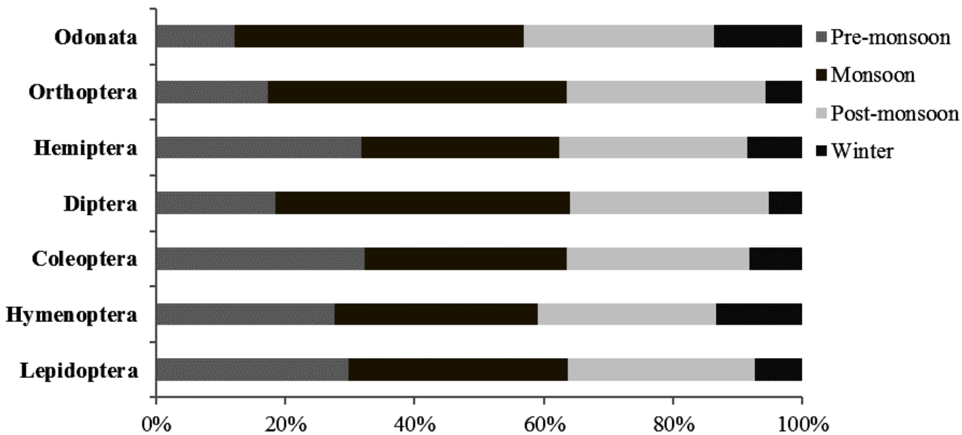

Figure 8. Relative composition of individual abundance of different insect orders across the seasons.

Table 2. List of species of butterflies under different schedules of the Indian Wildlife Protection Act (WPA), 1972 recorded from the Pancheshwar dam site (Anonymous, 2006).

Family	Species	Schedules of WPA	Local status
Papilionidae	*Papilio clytia* Linnaeus	I	Rare
Lycaenidae	*Castalius rosimon* (Fabricius)	I	Rare
	Deudorix epijarbas (Moore)	II	Rare
	Euchrysops cnejus (Fabricius)	II	Uncommon
	Everes argiades (Pallas)	II	Uncommon
	Horaga onyx (Moore)	II	Very Rare
	Lampides boeticus (Linnaeus)	II	Common
	Megisba malaya (Horsfield)	II	Rare
Nymphalidae	*Euploea core* (Cramer)	IV	Very Common
	Euploea mulciber (Cramer)	IV	Uncommon

the Pancheshwar dam site and are thus, these species are important from the standpoint of their conservation in ecological studies (Table 2). Of these, *Horaga onyx* was very rare and *Papilio clytia*, *Castalius rosimon*, *Deudorix epijarbas*, *Megisba malaya* were rare in their distribution range throughout the study period. Thus, there is an urgent need to adapt conservation policies for these species as they are of more conservation priority over rest of the other taxa available in the study area. Five species namely, *Eurema brigitta*, *Euploea core*, *Junonia almana* and *Junonia hierta* present in the study area are listed as least concerned species in the IUCN Red list of threatened species. Besides, butterfly known as 'Common Peacock' (*Papilio bianor*), common in its distribution range in the present study area was declared as the 'State Butterfly' of the Uttarakhand by the State Wildlife Board in November 2016.

Species namely, *Coccinella septumpunctata L. var. divaridata* (Coccinelidae, Coleoptera) and *Altica himensis* (Chrysomelidae, Coleoptera) have strong implications as bio-control agents while the oil extracts of *Mylabris cichorii* (Meloidae, Coleoptera) possess anti-carcinogenic properties. Five species namely, *Anomala dimidiata*, *Anomala lineatopennis* of the family Scarabaeidae under the order Coleoptera, *Pieris brassicae*, *Pieris canidia* of the family Pieridae and *Papilio demoleus* of the family Papilionidae under the order Lepidoptera have been reported earlier as the pestiferous insects. Each insect provide an ecosystem service and contributes to the stability of the ecosystem. Therefore, the direct and indirect benefits of the other insects can never be overlooked. The state of Uttarakhand nestled in the Central Himalaya is endowed with magnificently diverse land-scapes and is bestowed with marvelous range of biodiversity supporting many endemic animal and plant species. The state forms a potential zoo-geographical zone and is home to an

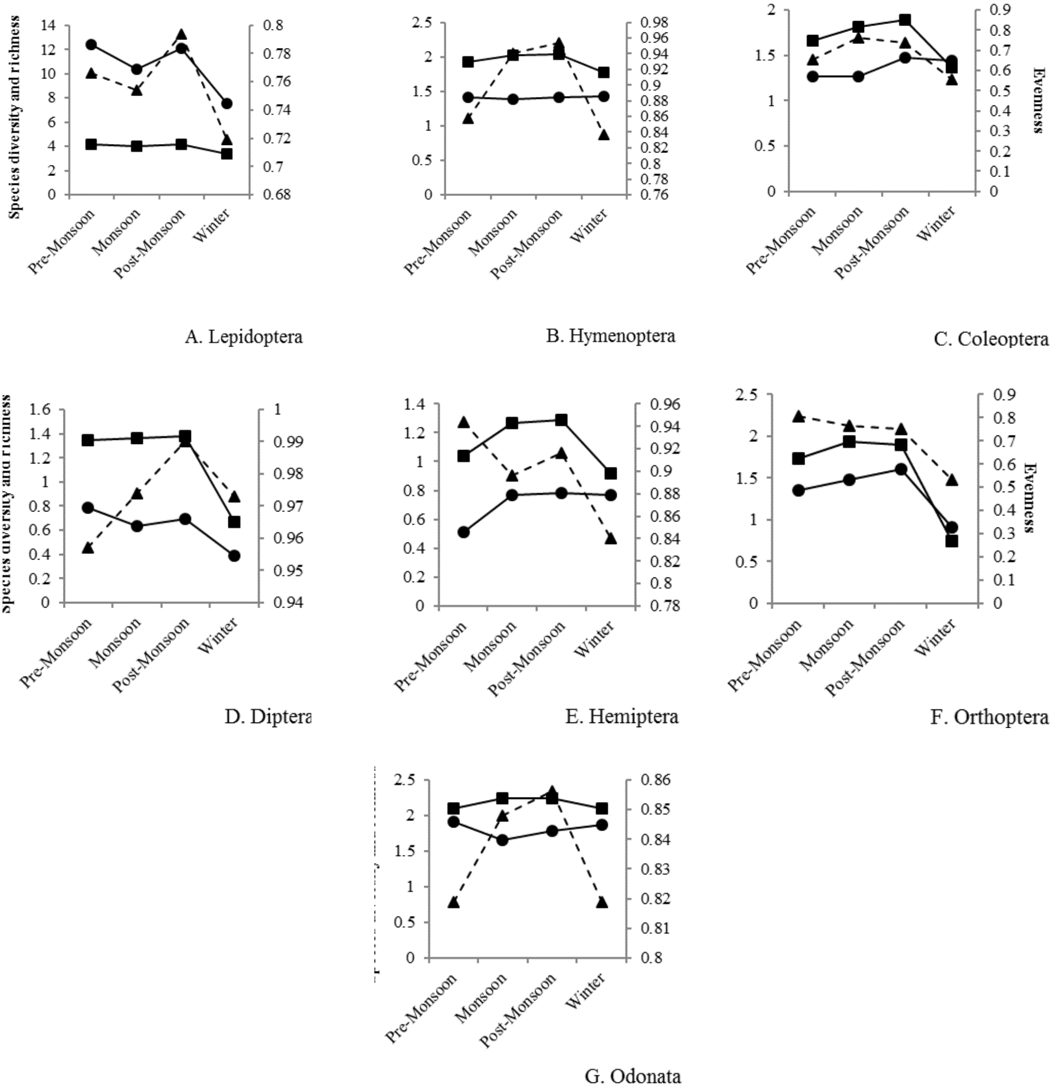

Figure 9. Measures of diversity indices of the recorded insect orders across the different seasons (unbroken lines, ■ Shannon, Hs and ● Margalef, Hm; dashed lines, ▲ Evenness, E).

average of 4,160 species of insect fauna including Lepidoptera (1,523 species), Coleoptera (1,074 species), Diptera (541 species), Hymenoptera (181 species), Orthoptera (144 species), Odonata (122 species) and others (Chandra, 2011). Scientists and academicians have published numerous reports in regard to the distribution and diversity of different insect orders from the Indian Himalayan Region (Mani, 1956; Singh, 1963; Biswas, 1995; Tandon *et al*., 1995; Uniyal *et al*., 2000; Uniyal and Mathur 2000; Kumar *et al*., 2007; Uniyal, 2007; Joshi *et al*., 2008; Chandra *et al*., 2012; Arya and Dayakrishna, 2013; Arya *et al*., 2013; Sanyal *et al*., 2013; Sondhi and Kunte, 2016; Singh and Sondhi, 2016). The attempts made in the present study revealed a rich diversity and richness of insects, especially of butterflies with 94 species from the Pancheshwar dam site, providing better life supporting natural resources for the existence of many rare and economically important insect species. The high diversity and richness of butterflies and dragon flies might be attributed to the diverse vegetational composition and the pre-dominance of riparian habitat in the region.

Seasonality is a conspicuous feature in the life history of many insects (Wolda and Wong, 1988) and occurs for a variety of reasons including macroclimatic and microclimatic changes, and seasonal availability of food resources (Wolda, 1988). Since diversity and its structure are intricately linked to climatic seasonality in tropical forests and for those parts of the tropics where wet and dry seasons alternate (Davis, 1945), any assessment of global biodiversity by extrapolation from local and regional measurements requires that seasonal patterns to be recognized (Plant *et al*., 2017). Insect diversity and abundance tend to vary over time in association with multiple factors that are associated with each season. It include changes in ambient temperature, light intensity, precipitation, host plant quality, vegetation cover, and a differential set of predators and predation risk (Sajjad *et al*., 2012; Shobana *et al*., 2012). Each insect taxa in each season could exhibit different responses, so that the effects of the wet or the dry season could be reflected in numeric responses and herbivorous insects peak in abundance depending upon the time that the resource they exploit is most abundant (Pinheiro, 2002). Moreover, underlying factors such as life span, number of generations per year and fecundity of each insect could be the determinants for the diversity of different insect orders (Sajjad *et al*., 2012), besides the plant diversity (Koricheva *et al*., 2000). In the present study, the measures of diversity indices *viz*. Shannon, Margalef and Evenness calculated across the different seasons followed different patterns among the different insect orders. The peak abundance for most of the orders was reported during the monsoons coincident with leaf flush and flowering (Wolda, 1978).

Knowledge of the host plants is crucial in the development of long term conservation strategies; primarily for the areas facing declining populations of butterflies and other herbivorous insects. The present study area is generally covered with sub-montane broadleaf summer-deciduous forest (Singh and Singh, 1987) and exhibit a diversity of plant species congenial for butterflies. Botanical families such as Rutaceae, Annonaceae, Lauraceae, Aristolochiaceae, Dioscoreaceae constitute larval food plants for the butterflies of Papilionidae, whereas Cruciferae, Fabaceae, Moraceae, Poaceae, Tiliaceae, Rubiaceae, Asteraceae, Euphorbiaceae, Malvaceae, Acanthaceae, Fagaceae, Myrataceae, Lauraceae, Rosaceae, Oxalidaceae and other are most preferred host plants of the butterflies of Pieridae, Nymphalidae, Lycaenidae and Hesperiidae (Robinson *et al*., 2001). The members of these botanical families are of common occurrence in the dam site and have been listed in the present study.

The loss in biodiversity due to habitat degradation and fragmentation is of global concern irrespective of regional and local importance (Baur and Erhardt, 1995). During the years 1970-2000 a net deforestation rate of 0.54% has been recorded in the Indian Himalayan Region due to the ongoing anthropogenic forest conversion aggravated by global climate change. Nevertheless, considerable progress has been made in the protection of forests, gross deforestation rate continues as a focal hindrance (Reddy *et al*., 2013). It is also estimated that if deforestation in the Himalaya continues at the current rate, the dense forest cover (>40% canopy cover) will be restricted to 10% of land area in the Indian Himalayan Region by 2100 (Kumari *et al*., 2019). This may lead to a significant loss of 366 endemic plants and 35 endemic vertebrates (Pandit *et al*., 2007). Insect pollinators are strongly affected by the habitat loss and pollinator limitation due to decreased diversity or abundance lead to reductions in pollination efficiency, fruit and seed set, and gene flow among plant communities (Kunin, 1993; Matthies *et al*., 1995). Forest disturbance affects bee and butterfly species diversity thus impacting key stone ecological process of pollination (Steffan-Dewenter and Tscharntke, 1999). Habitat fragmentation affects particularly the specialist species of higher trophic levels such as monophagous and oligophagous butterflies and insect species with limited dispersal abilities (Steffan-Dewenter and Tscharntke, 2002).

The main dam site and the surrounding area affected both upstream and downstream in the Pancheshwar are of significant ecological, cultural and spiritual as well as of tourism importance (Everard and Kataria, 2010). The construction of the proposed dam would threaten and disturb not only the local wildlife populations but also the ecological balances over a wide geographical scale. On the other hand, it is anticipated as a milestone in the water and energy sector of India as well as Nepal (Everard and Kataria, 2010). The execution of the proposed dam in its current format raises concern regarding the feasibility and geo-environmental implications of the proposed Pancheshwar high dam in the ecologically sensitive and tectonically active terrain of the Himalaya (Sati *et al*., 2019). The Himalayan ecosystem within which the dam is planned for construction is a transitional zone between the western Nepal and the eastern Uttarakhand, thus owing stocks of mostly Palaearctic regions; however, some of the faunal elements below tree line are common between Oriental and Palaearctic regions so it supports a diversity of wildlife, much of which is threatened due to ongoing pre-dam construction activities. Moreover, Askot Wildlife Sanctuary lying in the district Pithoragarh nearly 3 km upstream of the tail end of the submergence is located 50 km away from the project area where main construction activities are likely to take place (PDA, 2017). The surrounding area at the confluence of rivers in the village

Pancheshwar was observed frequent for the activities like camping, rafting and angling, as this specified area is renowned worldwide to abode for 'Golden Mahseer' fish (*Tor putitora*) listed as endangered species in the Red list of IUCN. During this study, pre-dam construction activities such as tunneling, road constructions, soil erosion from constructions and quarrying, river impoundment, un-managed excessive felling of trees and collection of minor and major forest products by locals and labors were easily recognizable constant interferences while natural and human induced landslides are highly prevalent in the study area (Figure 10a-b). These imminent threats are causing a drastic change in the vegetational composition of the area disrupting key plant-pollinator and predator-prey interactions, which in turn affecting primarily to the floristic diversity and ultimately to all sorts of faunistic wildlife through a number of eco-biological interactions of the complex food web.

Conclusion

The present study reported rich diversity of entomofauna with total species diversity of 4.55 (Shannon) and species richness of 16.01 (Margalef) from the Pancheshwar, however the future sustenance of these insects looks uncertain in regard to the current ongoing developmental project executed on macro scale. The composition of the resident butterflies and other insect communities in degraded forests of the present study area will fluctuate with time according to the species that are better adapted for the current level of disturbances. Decline in forest quality is expected to lead to shifts in relative abundance and diversity of insect communities, which can be monitored with regular surveys to study any immediate effect of the type and degree of disturbances in the study area. It is suggested that concerted research efforts are needed for the scientific documentation of other biological resources both on temporal and spatial scales due to unique geography of the area. Successful nature conservation could only be met with adequate foresight and planning. In the current scenario, Compensatory Afforestation Fund Management and Planning Authority (CAMPA) established to promote afforestation and regeneration activities as a way of compensating for forest land diverted to non-forest uses is needed to come on the fore front and should take necessary steps for the plantations of those species important as the host plants for butterflies and other herbivorous insects. Large-scale compensatory afforestation by such authorities would help to mitigate the local extinction of fauna over a wide range. Species that are of common occurrence might require detailed conservation plans and employment of appropriate management practices. Moreover, emphasis should be on stringent legislation to reinforce the regulations regarding the use and access to resources in the present study area. There is an immediate need of understanding and conserving biodiversity at spatio-temporal scales and conservation authorities in collaboration with ecologists should reach

Figure 10. Human induced threat factors for the biodiversity, (a) tunneling and (b) frequent landslides due to current pre-dam construction activities at the Pancheshwar dam site, Central Himalaya.

these goals in order to preserve ecological integrity and sustainability of the region.

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Supplementary information

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