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HYDRO POWER DEVELOPMENT AND ITS IMPACTS ON THE HABITATS AND DIVERSITY OF MONTANE BIRDS OF WESTERN HIMALAYAS

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Hydro Power Development and Its Impact on the Habitats and Diversity of Montane Birds of Western Himalayas. Jolli, V. — The montane forest ecosystems of Western Himalayas are under severe anthropogenic pressure because of hydro-electric project (HEP) development. Several studies have highlighted downstream effects of HEP, but there is no information on the effects of HEP-building activities on upstream fauna. In particular, studies on upstream Himalayan montane ecosystems and fauna around dams are lacking. I investigated effects of dam-building activities on bird communities in Indian Western Himalayas. I studied the response of bird communities along a disturbance gradient with the aim to identify key factors influencing their distribution. I surveyed primary and secondary montane forests, agricultural lands, and dam-affected (disturbed) habitats. Response variables included total avifaunal and woodland species richness and abundance, which were estimated by point-count surveys. Explanatory variables included tree and shrub density, canopy cover, disturbance intensity, and elevation. Bird species richness was higher in undisturbed and lesser disturbed sites, lower in agricultural sites, and lowest in HEP-affected sites. Canonical correspondence analysis revealed that canopy cover, shrub density, and disturbance influenced species distribution; woodland birds significantly negatively responded to dam-building activities. The study has shown that dam-building activity has negatively affected montane birds. I propose that increasing shrub and tree cover in dam-disturbed sites would minimise losses of avian habitats.
Key words: Habitat disturbance, montane birds, species richness and Hydro-electric project, Western Himalayas.

Introduction

The Himalayas are among 34 global biodiversity hot spots harbouring over 10,000 higher plant species, 300 mammals, 977 birds, 176 reptiles, 105 amphibians, and 269 fresh water fishes (Conservation…, 2014). The Western Himalaya is an identified Endemic Bird Area because 11 out of 15 endemic bird species are found here (Birdlife International 2003). Critically endangered Himalayan Quail (*Ophrysia superciliosa*) and vulnerable species such as cheer pheasant (*Catreus wallichii*) and western tragopan (*Tragopan melanocephalus*) are restricted to the Western Himalayas (Collar et al., 1994). Because of the conservational significance of this area, the Government of India has established several protected areas in the region (Gaston et al., 1983). One such site is Great Himalayan National Park (GHNP), which is a candidate for World Heritage Site (UNESCO, 2010). Despite high conservation value of the region, land use changes driving deforestation have resulted in unprecedented losses of its endemic biodiversity (Pandit et al., 2007). The large-scale hydropower development is likely to result in loss of ecosystem services, natural value, and species extinctions across the Himalayas (Pandit and Grumbine, 2012). Worryingly, the dam-building activities are concentrated around dense and protected forest areas (Grumbine and Pandit, 2013). For example, Parvati and Alaknanda Hydroelectric Projects are located near two important protected areas, such as the Greater Himalayan National Park (GHNP) and Nanda Devi Biosphere Reserve. The clearing of vegetation cover for construction of roads, installation of power lines, and expansion of human population in formerly natural areas are reported to cause habitat loss and fragmentation (Small and Hunter 1988, Sisk et al., 1994) and hydropower development will probably change the climate, and hence vegetation, and thus potentially the habitat for birds via its effect on climate.

I selected one such area for conducting studies where hydropower development is butted against well-endowed protected areas. Sainj Valley located in the Himachal Pradesh, a western Himalayan state of India, is surrounded by several protected areas, such as Great Himalayan National Park, Sainj Wildlife Sanctuary, Pin Valley National Park, and Rupi Bhaba Sanctuary, and hydropower projects such Parvati and Larji hydroelectric projects. The activities associated with dam construction include blasting, dumping, heavy machines usage, construction of roads, and labor colonies are likely to create disturbance in the valley. I define disturbance as "any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment" (White and Pickett, 1985). I investigated in detail effects of Parvati Hydroelectric Project (PHEP) being constructed by National Hydro Power Corporation Ltd. (NHPC Ltd.) on bird communities of GHNP and its environs. The area is a well-known habitat for several bird species; approximately 183 bird species have been recorded from the GHNP area (Gaston et al., 1984). The majority of the birds in these habitats are residents (66 %), followed by seasonal migrants (11 %) and altitudinal migrants (9 %). The migrants assume considerably greater significance from the habitat conservation point of view (CISMHE, 2000 a).

Sainj valley is also the habitat of five species of pheasants, of which two are endangered, i. e., western tragopan (*Tragopan melanocephalus*) and cheer pheasant (*Catreus wallichii*). To comprehend the effects of Parvati hydroelectric project, we examined the following questions: (i) are avifaunal species richness, abundance, and species diversity among different habitats affected by the HEP development? (ii) are there any distinct bird communities associated with certain habitat types and, if so, which habitat characteristics (e. g., tree and shrub density, degree of disturbance) explain such distribution? (iii) do woodland birds more negatively respond to habitat disturbance than other species inhabiting other habitats? It is expected that this study would help conservation planning and would be useful to wildlife managers, planners and policy makers to better mitigate the effects of hydro-electric projects.

Study Area and Methods

Study Area

The study area encompasses the entire Sainj Valleys that constitutes the catchment area of Sainj Khad (river), an important tributary of Beas, which is one of the main channels of Sind (Indus). The valley, situated in the north-western Himalayas in Kullu District of Himachal Pradesh (approximately 45 km southeast of Kullu), covers a geographic area of approximately 737 km^2. The field study was conducted between April and June, 2011. The latitude and longitude of the valley are 31°45′0″ to 31°55′0″ N and 77°15′0″ to 77°25′0″ E, respectively (fig. 1, *a*). Some of the prominent villages of Sainj Valley, where sampling surveys were conducted were: Deohri, Shangar, Ropa, and Neuli; the elevation these sites ranged between 1300 and 2800 m above sea level (fig.1, *a*).

Bird Sampling

The counting of birds in the study area was performed using "point count" method. The birds were identified using published sources (Grimmett et al., 2009). Likewise, foraging guilds were identified with the help of published literature (Ali and Ripley, 1983).

Point-count surveys

To quantify the species richness and abundance of birds across habitat types, a variable radius point count method along transects was used (Bibby et al., 2000). This method is preferable in steep mountain slopes where visibility is usually low. The point count in general is the preferred method for the study of bird communities in temperate and tropical regions (Bibby et al., 2000; Sorace et al., 2000; Raman, 2003; Acharya et al., 2011). Depending upon the habitat accessibility, 51 transects (500–1000 m length) of variable width were laid within the Sainj valley at different elevations between 1300 m and 2800 m. In each transect, 2–4 sampling points were established by maintaining a minimum of distance 200 m between the points to avoid double counting. I surveyed a total of 33, 30, 49, 61, and 46 point counts in the primary forest, disturbed forest, secondary forest, agricultural land, and disturbed agricultural land, respectively. In total, 207 points were sampled during the study. The points sampled in each habitat type were treated as statistical replicates. Each point was surveyed twice. The counts were conducted from 0700 to 1100 hours on fair weather days (i. e. absence of heavy rain, fog, or strong wind). The point counts were made from April 2011 to June 2011. All birds seen or heard during sampling at each point were recorded for 5 min (Raman, 2003). Bird location was noted to avoid counting the same individual twice. All birds flying over the canopy were excluded as it can yield false estimation of bird count (double counting). It is likely that visibility difference among the habitats can bias our data, but attempts were made to minimize such bias by extensively scanning habitats with dense vegetation and sampling each point twice.

Habitat type

The habitats were classified into five types based on the predominant land use pattern. These include primary forest, disturbed forest, secondary forest, agricultural land, and disturbed agricultural land (fig 1, *b*). These habitat types are defined as follows:

Primary forest refers to pristine forests with little human interference and nearly natural condition. Such forests had > 40 % canopy cover with regard to land cover (Pandit et al., 2007; Pandit, Grumbine, 2012). The Valley had 27 % of it area under primary forest.

Disturbed forest or degraded forest refers to a previously pristine forest, which is affected by human intervention such as removal of trees, forest produce, such as fodder, fuelwood, or disturbance in the form of HEP development activities. Around 2.07 % of study area was under this category

Secondary forest or open forest refers to a forest or woodland area which has re-grown after a natural or human disturbance. With regard to land cover, this forest has a canopy cover between 10 % and 40 %. A total of 13.82 % of study area was under this category.

Agricultural land refers to the area subjected to cultivation as primary activity.

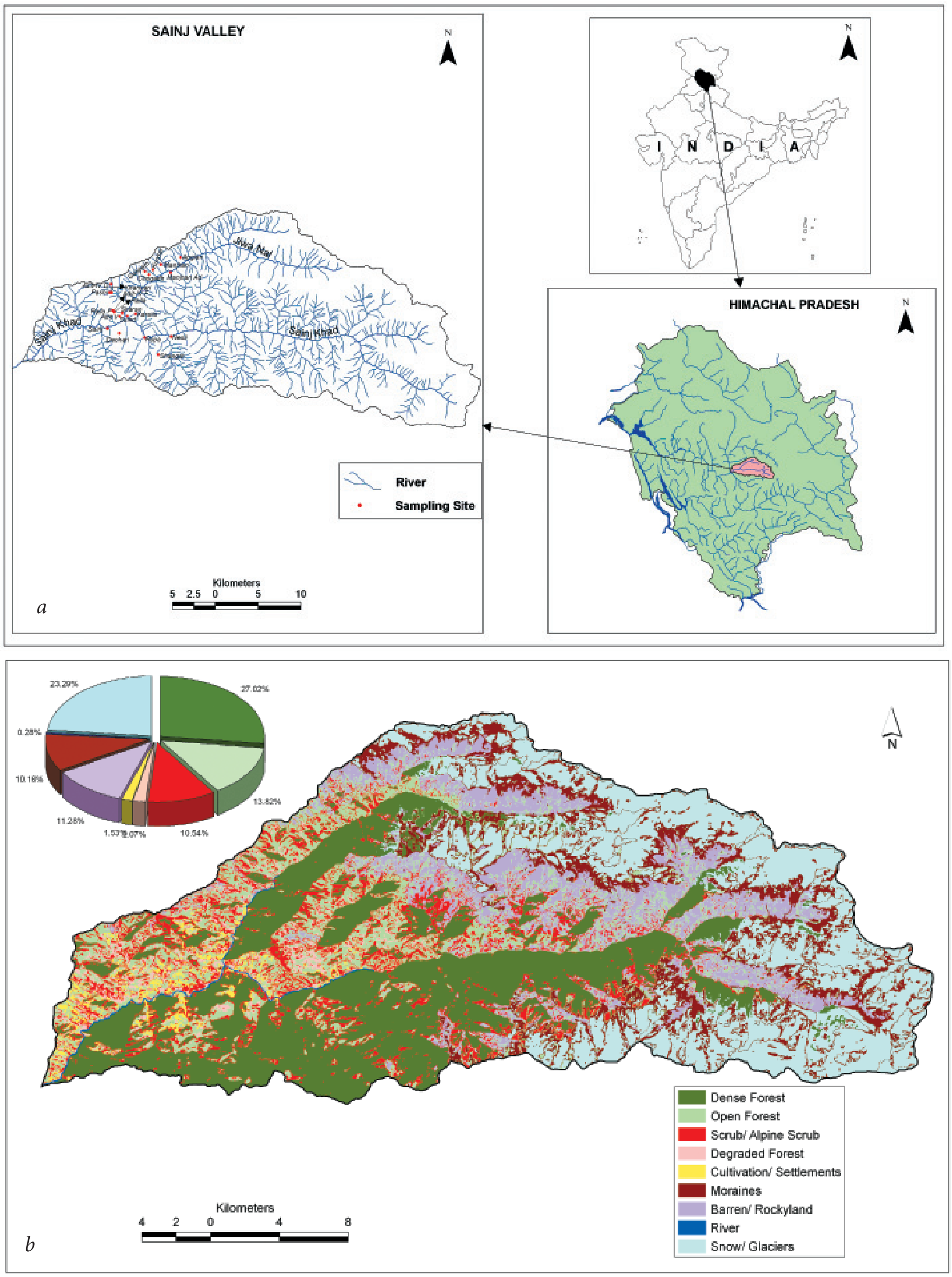

Fig. 1. Location map: *a* — location map of sampling sites in Sainj Valley of Western Himalayas; *b* — land use and land cover map of Sainj Valley-2010 (Jolli, 2014).

Disturbed agricultural habitat refers to the land cover type, which was previously cultivated land, but is now affected by developmental activity such as HEP. The cultivated and disturbed agricultural land comprised of 1.53 %.

Vegetation and Land cover survey

The surveys were conducted to determine if the bird distributions correlated with canopy cover, tree density, and shrub density etc. The variables were measured for each habitat type within a 11.3 m radius circular plots. These plots were located on suitable point counts, which were easily accessible for laying circular plots. For vegetation variables, a modified James and Shugart's (1970) method for habitat description was used. The variables for the vegetation structure included diameter of trees at breast height (DBH), tree and shrub density, and canopy cover using a densitometer. The tree and shrub density at breast height is estimated along two transects running in the cardinal directions and centered within a 0.04 ha circle.

Measurement of habitat disturbance index

Five parameters of disturbance were included in the construction of habitat disturbance. These parameters were associated with construction activity of Parvati hydroelectric project in the valley. Disturbance parameters included in this study were; volume of dumping waste, noise level, number of vehicles/hour, human population around place, and number of house settlements.

The capacity of allotted dumping sites, which was mentioned on the notice board at disturbed sites, was used in the index. Noise levels were recorded in each habitat type using a sound level meter (Cygnet D 2023) during bird census. The maximum sound recorded during the bird census was included in constructing the index. Total number of vehicles moving across the habitat was recorded during the peak hour of human traffic i. e., 1000–1100 hours and included it in the index. Data related to human population and number of households was collected from Raila Panchayat office in Sainj (except for Manjhan, Kundar, and Manjhan adit where direct counting was conducted because of seasonal migration of people in these villages). The data related to number of workers employed in the study sites was collected from Gammon India Private Ltd., Sainj for total estimation of population pressure across the habitat types.

The disturbance variables measured at each site were first converted into relative percentages (measured value of variable at site "x"/total measured value of variable in all sites × 100). However, noise level being non additive was not transformed. All the component parameters were added and log transformed. The final values gave the disturbance intensity at each studied site.

In addition, other environmental variables were log transformed before inclusion in the multivariate analysis to normalize error-term distributions (Zar, 1996; Gutzwiller, Borrow, 2002).

Data Analyses

To understand the influence of habitat disturbance on birds, 56 bird species were selected that have elevational distribution range of 1200–3000 m. The bird species that are observed at either higher or lower elevations were excluded. The elevational ranges of each species were determined using BirdLife International online database and published source from Kazmierczak and Perlo (2009). Sample-based rarefaction curves were generated to determine how adequately habitats were surveyed (Gotelli and Colwell, 2001). Observed species richness, as determined by a survey, may not necessarily reflect the natural total species richness of the community (Colwell and Coddington, 1994; Gotelli and Graves, 1996). Even in thorough surveys, one can never be certain that all species are accounted for (Pomeroy and Dranzoa, 1997), which renders direct comparison of species richness impossible (Lande, 1996). To estimate the bird species richness for each of the studied habitat, nonparametric species estimator was used from EstimateS 7.5 (Colwell, 1994): Jackknife1 species estimator was selected based on previous literature (Hortal et al., 2006; Walther and Moore, 2005).

The sampling adequacy is determined by studying the rarefaction curve. In vegetational studies, this curve is known as species-area curve. Rarefaction curves for all the habitat types are shown in fig. 2. The rarefaction curves are asymptotic for each habitat type. An increase in the occurrence of species is observed up to 25 point counts. After this, the rise in the curve slopes down, which indicate chances of encountering new species appearing in the observation are extremely few; this shows that the Sainj Valley was adequately sampled during 2011. Curves for all the habitat types showed the identical trend. The proportion of observed species richness to all the true species richness estimate range from 70 % to 100 % for all habitat types, except disturbed forest, where it range from 65 % to 70 % (table 1). Thus, apart from disturbed forest habitat, the inventories were relatively complete for all habitat types.

Differences between vegetation (tree and shrub density), habitat disturbance, and altitude attributes recorded in four different habitat types were tested using non parametric Kruskal–Wallis tests. Rarefaction curves were plotted using MS Excel.

Further, for statistical corroboration, I tested differences in species diversity, species richness, and abundance (per sample) among the habitats, using non parametric Kruskal–Wallis one way ANOVA. Mann–Whitney test was used to test the difference between two habitat types. Margalef species diversity was selected because it has good discriminant ability and high sensitivity to sample size (Magurran, 1988). Species diversity, richness, and statistical analyses were performed using PAST version 2.05 (Hammer et al., 2001).

Multivariate statistical analysis was conducted using CANOCO 4.5 software (ter Braak, 1988). Canonical correspondence analysis (CCA), which is a direct gradient analysis, was used to understand the distributed of

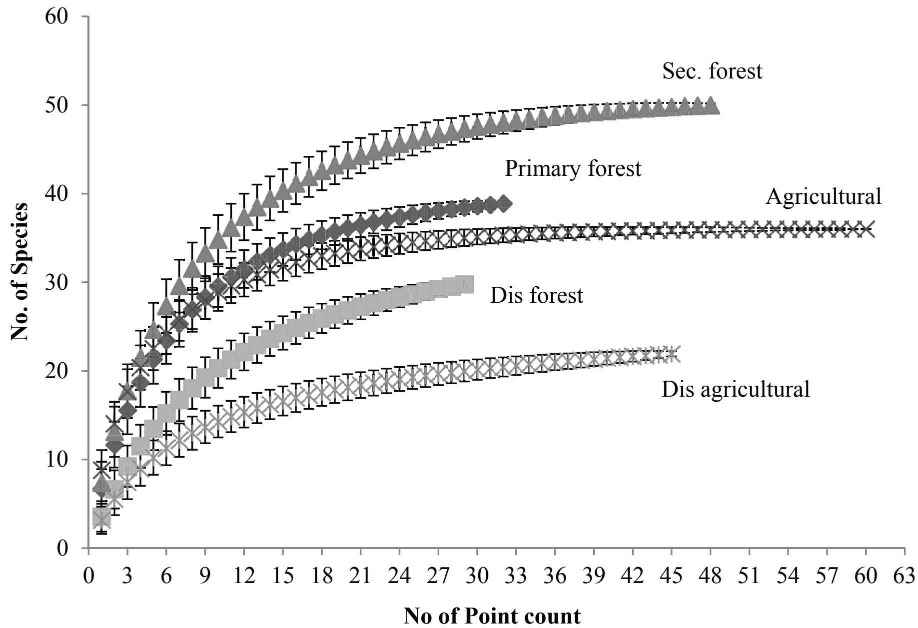

Fig. 2. Sample based rarefaction curves of each habitat types from point count surveys for montane species only found within the range of 1300–2800 m.

species along a specific gradient (Austin et al., 1984; Oksanen et al., 1988; Oksanen, 1997). I selected CCA because I was interested only in bird community structure that was related to the measured environmental variables.

Results

The estimated mean true species richness (Jack 1) of montane birds for secondary forests was highest among all other habitat types. While, disturbed agricultural land had the lowest estimated mean true species richness of birds (fig. 3 and table 1). The species richness for primary forest was higher than that of disturbed forest. Similarly, agricultural species richness was considerably higher compared with that of disturbed agricultural land.

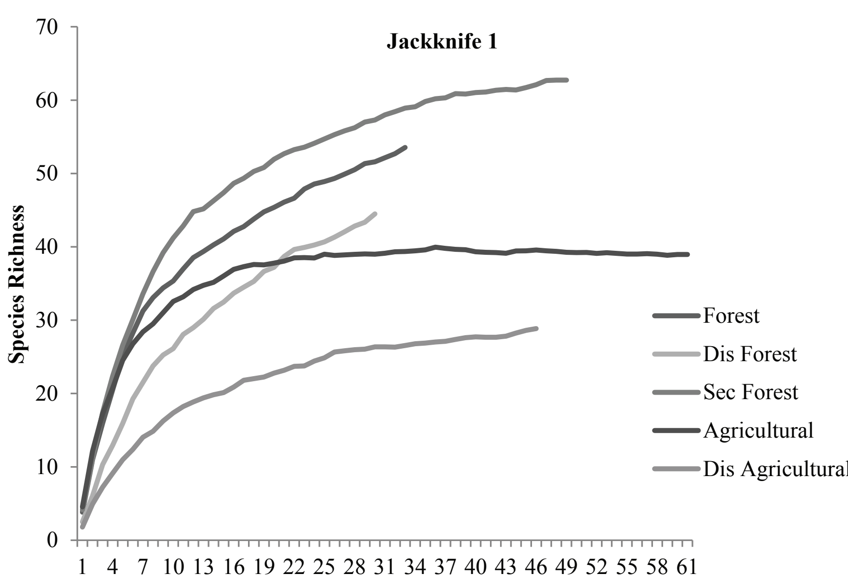

Fig. 3. Species accumulation patterns of birds in five different habitat types of Sainj Valley, Himachal Pradesh. Estimated species richness Jackknife 1 is shown.

Table 1. Nonparametric species richness (Jackknife 1) estimate for each habitat type (ordered in increasing habitat disturbance) from point-count surveys

Parameters	Primary Forest	Disturbed Forest	Secondary Forest	Agricultural	Disturbed Agricultural
N	33	30	49	61	46
Sp_{obs}	39	30	50	36	22
Ind_{obs}	261	116	414	726	165
Jack 1	53.55 (0.73)	44.5 (0.67)	62.73 (0.80)	38.95 (0.92)	28.85 (0.76)

Note. N represents the number of sampling points. Sp_{obs} and Ind_{obs} represent the number of species and individuals observed each site, respectively. Jack 1 represent different species estimators (Colwell and Coddington, 1994).

Proportion of observed species richness to each of the "true" species richness estimates are shown in parentheses.

Table 2. Mean values ± SE and result of Kruskal–Wallis tests of five habitats variables across five different habitat types in the Sainj Valley, India

Habitat variables/ (0.04 ha circular plot)	Primary Forest (N = 22)	Disturbed Forest (N = 16)	Secondary Forest (N = 21)	Agricultural (N = 24)	Disturbed Agricultural (N = 23)	Across site difference
Tree density	14.64 ± 0.86	8.25 ± 1.75	6.33 ± 1.02	6.75 ± 0.7	3.65 ± 0.78	H = 42.49, P = 1.323E-08
Shrub density	14.36 ± 1.58	5.72 ± 1.35	19.44 ± 2.96	12.29 ± 1.84	1.53 ± 0.6	H = 11.5, P = 0.009
Canopy cover	77.86 ± 4.97	47.74 ± 6.85	57.33 ± 9.42	18.93 ± 7.7	4.06 ± 2.2	H = 36.52, P = 2.257E-07
Disturbance index	1.56 ± 0.02	1.89 ± 0.15	1.71 ± 0.06	1.90 ± 0.06	2.14 ± 0.09	H = 11.5, P = 0.02
Altitude	2229.09 ± 85.8	2237 ± 67.2	2221.22 ± 116	1725.26 ± 49.8	1494.89 ± 66.9	H = 36.97, P = 1.83E-07

* N = Number of circular plots sampled.

Habitat characteristics

There were significant across-site differences in all montane vegetation characteristics (table 2). Canopy cover and tree density significantly declined across the habitat types; primary forest recorded the highest while disturbed agricultural habitats had minimal canopy cover and tree density. Secondary forest had the maximum shrub density followed by forest and agricultural habitats, while disturbed habitats recorded the minimum shrub density (disturbed forest and disturbed agricultural). Disturbance was recorded highest at the disturbed agricultural habitats followed by disturbed forest; in the primary forest least disturbance was observed.

Avifaunal species richness, diversity and abundance

A total of 56 bird species and 1711 individuals were included in data analysis. Appendix 1 summarizes species detected and their mean abundances within each habitat category. Table 3 demonstrates that mean species richness and diversity per point count significantly decreases between primary forest and disturbed forest habitats, (Mann–Whitney $U_{Richness} = 283$; $P < 0.001$ and $U_{Diversity} = 355$; $P < 0.05$). The species richness and diversity in secondary forest habitats were significantly higher than disturbed forest ($U_{Richness} = 360$; $P < 0.001$ and $U_{Diversity} = 482.5$; $P < 0.01$), the species richness marginally increased in agricultural habitat with 4.7 ± 0.37 and recorded no significant increase ($P = 0.51$). As habitat disturbance levels increased further, species richness and diversity decreased to minimal level in disturbed agricultural habitat. This was significantly lower than that of agricultural habitats ($U_{Richness} = 422.5$; $P < 0.001$ and $U_{Diversity} = 451$; $P < 0.001$).

Table 3. Mean species richness, diversity of total avifauna, and woodland birds per point count in five different habitat types in Sainj Valley (2011)

Avifaunal Parameter	Primary Forest	Disturbed Forest	Secondary Forest	Agricultural	Disturbed Agricultural	Across site difference
Mean Avifaunal Species Richness	3.97 ± 0.39	2.3 ± 0.38	4.1 ± 0.25	4.7 ± 0.37	1.6 ± 0.24	H = 45.23; P < 0.001
Mean Avifaunal Species Diversity	1.3 ± 0.15	0.86 ± 0.16	1.43 ± 0.09	1.58 ± 0.1	0.49 ± 0.1	H = 56.06; P < 0.001
Mean Avifaunal Abundance	8.23 ± 0.92	3.93 ± 0.77	8.45 ± 0.69	11.8 ± 1.39	3.25 ± 0.54	H = 55.51; P < 0.001
Woodland Avifaunal Species Richness	1.79 ± 0.25	0.73 ± 0.14	0.55 ± 0.1	0.69 ± 0.1	0.19 ± 0.07	H = 32.27; P < 0.001
Mean Woodland Avifaunal Species Diversity	0.5 ± 0.1	0.18 ± 0.06	0.08 ± 0.03	0.09 ± 0.04	0.03 ± 0.02	H = 12.42; P < 0.01
Mean Woodland Avifaunal Abundance	4 ± 0.58	1.37 ± 0.36	1.26 ± 0.27	1.08 ± 0.32	0.46 ± 0.19	H = 33.61; P < 0.001

The mean avifaunal abundance of forest habitats were recorded as 8.23 ± 0.92 which significantly decreased to 3.93 ± 0.77 in disturbed forest ($U = 246$; $P < 0.001$). The abundance in secondary forest significantly increased to a mean value of 8.45 ± 0.69 ($U = 324.5$; $P < 0.001$), which rose again in agricultural habitat as 11.8 ± 1.39 ($P = 0.19$). The mean abundance decreased to 3.25 ± 0.54 which was significantly different from agricultural habitats ($U = 467.5$; $P < 0.001$).

Woodland species richness and abundance

The mean species richness and abundance in forest habitat was significantly higher from disturbed forest habitats ($U_{Richness} = 283.5$; $P < 0.001$ and $U_{Abundance} = 259.5$; $P < 0.001$). Along habitat disturbance, mean species richness and abundance per point marginally dropped in secondary forest habitat with no significant difference with disturbed forest ($P_{Richness} = 0.4$ and $P_{Abundance} = 0.69$). Similarly no significant difference was recorded in between secondary forest and agricultural habitats ($P = 0.47$). However, the mean species richness and abundance in agricultural habitats were significantly higher than disturbed agricultural habitat ($U_{Richness} = 974$; $P < 0.01$ and $U_{Abundance} = 1085$; $P < 0.01$).

Habitat variables and bird community ordination

The vectors of habitat variables in fig. 4 accounted for 59.7 % of the variation of the 56 bird species with respect to 5 variables, the sum of all eigenvalues being 2.28. Most bird species centroids were projected in the middle of the bird community ordination plot (fig. 4). The middle of ordination plot attributed to moderate level of canopy cover, high shrub density, and moderate level of disturbance. Thus, habitat heterogeneity favoured congregation of bird species in the middle of the ordination plot. Bird centroid in the middle of the ordination plot indicated that secondary vegetation in around secondary forest and agricultural habitats support maximum number of species. The bird centroids on the right-hand side were associated with forest habitats. The species associated with these habitats were mostly forest bird species and sensitive to human disturbance. The bird centroids on the left side were mostly open forest and agriculture birds, which can utilize human modified habitats. The ordination showed that montane birds avoided highly disturbed habitats and very few bird centroids were observed at extreme right hand side. The high level of disturbance on the extreme right probably has shifted the number of bird species in the middle of the ordination plot. Thus, from the plot one can infer that HEP disturbance has influences the community structure of montane birds.

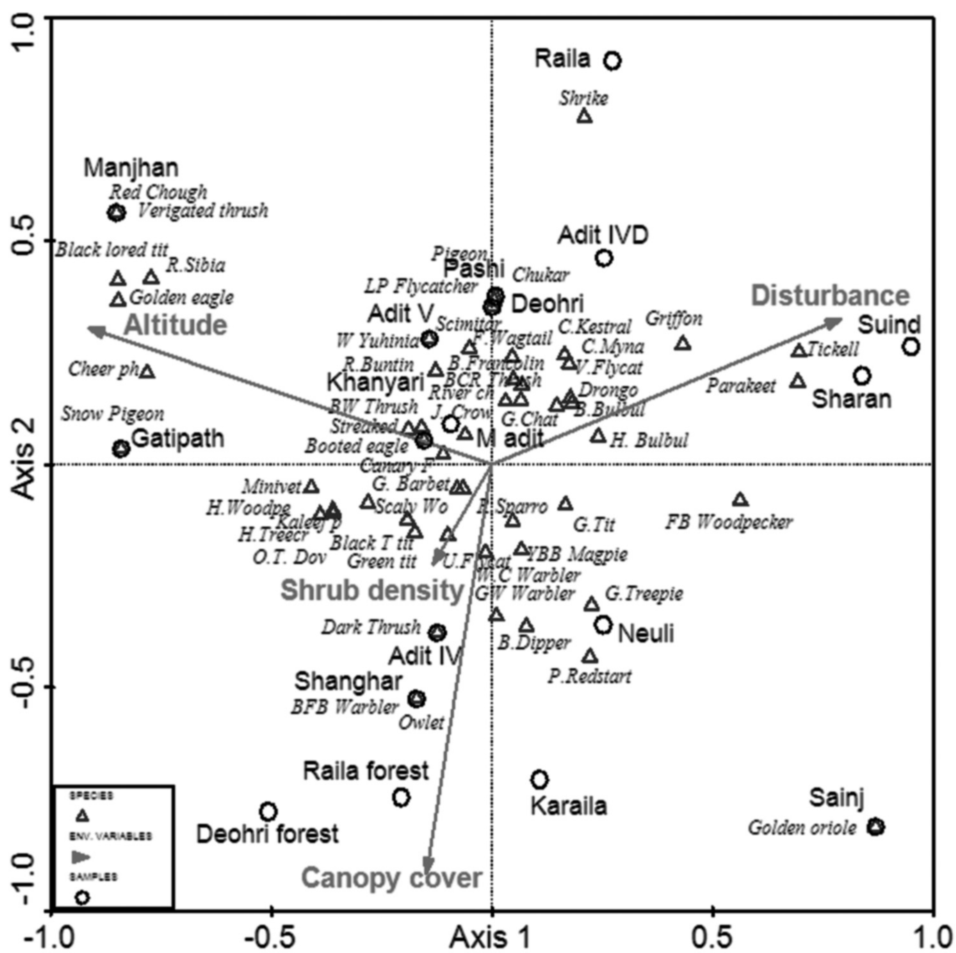

Fig. 4. Ordination of 56 bird species on the first two canonical axes with biplot for key environmental variables derived from Euclidean distance. The ordination showed altitude, tree density, shrub density, canopy cover, and disturbance to be the environmental variables influencing distribution of bird in the study area.

In bird species like Himalayan woodpecker (*Dendrocpos himalayensis)*, Bar-tailed treecreeper (*Certhia himalayana)*, Ultramarine flycatcher (*Ficedula superciliaris*), Cheer pheasant (*Catreus wallichii)*, Booted eagle (*Hieraaetus pennatus*), Oriental turtle dove (*Streptopelia orientalis*), Great barbet (*Megalaima virens*), Dark-throated thrush (*Turdus ruficollis)*, and Grey-headed canary flycatcher (*Culicicapa ceylonensis*), mean abundance decreased with increase in level of disturbance. While in birds species like Long tailed Shrike (*Lanius schach*) and Grey wagtail (*Motacilla cinerea*), mean abundance increased with increase in level of disturbance.

Further, from ordination analysis, Sharan, Suind, Sainj, Adit IV, Raila and Manjhan adit sites came under disturbed habitats; Deohri, Neuli, and Karaila, Khanyari, Pashi, Raila forest and Karaila were moderately disturbed habitats. While Manjhan, Chogadh, Gatipath, Deohri, Shangar and Adit IV forest were forest habitats with no anthropogenic disturbance.

Discussion

Impact on Wildlife and birds

The Western Himalayan region provides a superior habitat for birds, small and large mammals. Development of a hydro-electric project generally has an adverse impact on the nesting, forage and cover provided for birds and animals alike (Wood and Langford, 2013; Forest and Bird, 2013). The loss of their habitat compels the birds and animals to move their grounds which are less suitable for them. However at the same time, if water levels stabilize, zones reappear and species re-populate the same area. This results in decline of some species while others tend to become more abundant. This could be the reason for lower species diversity and abundance of montane birds in disturbed habitats.

Studies proved that insectivore montane birds were sensitive to human disturbance (Canaday, 1997). A decrease in insectivore abundance was recorded amongst the sample between agricultural and disturbed agricultural land. However, in other sites, this trend was not recorded. It is possible that the river (Sainj khad and Jiwa nal) may have provided abundant supply of insects for insectivorous bird e. g. plumbeous water redstart, and grey wagtail foraging around streams (Kazmierczak and Perlo, 2009). The foraging guilds affected by HEP development were frugivore and carnivore. The absence of frugivore indicates that diversion of previously agricultural land (orchards) to HEP development has made unfavourable environment for frugivore. The relatively high abundance of frugivore in agricultural and secondary forest is contributed by remaining orchards. The extirpation of carnivore and frugivore avian guilds in disturbed habitats indicates that they avoid highly disturbed habitat.

The analysis pointed out that habitat disturbance had significantly affected the diversity, richness, abundance and species composition of avifauna in disturbed habitats (disturbed forest and agriculture). Such habitats were severely affected due to dumping, blasting and road construction. The tree and shrub density was recorded lowest among all habitats considered in this study. The disturbed habitats bird assemblage constituted by common myna, house sparrow, large-billed crow and Himalayan bulbul. The dumping sites were located in Sainj, Suind, Sharan, Raila and Manjhan Adit. The hydro power project developers' dumps waste along the slopes of mountains, these dumping sites induced clearing of the shrub and ground cover vegetation which is crucial for passerines and pheasants like black partridge, chukar which depend on understory vegetation. These species will encounter scarcity of trophic resources within the undergrowth vegetation (i. e. arthropods and fruits), a basic substrate for feeding (Snow and Perrins, 1998). This was the probable cause for negative response of montane bird species to habitat disturbance due to HEP development. The change in land use can affect the bird community by reducing the nesting and feeding locations (Clergeau et al., 2006) as predation rates are high in habitats where the ground layer and understory are less dense and less able to conceal the birds and their nests (Chapman and Reich, 2007).

Noise levels are particularly important because certain bird species are more sensitive to noise exposure e. g. Ryal et al. (1999) showed the effect of acoustic overexposure on quail, canaries, zebra finches and budgerigars. Higher noise levels were recorded in disturbed habitats because of blasting, use of heavy machines, and heavy motor vehicles. The high noise level can reduce fitness of singing birds during breeding season (Slabbekoorn and Ripmeester, 2008), and it should be considered more seriously. Moreover, the increased influx of vehicles in eco-development zone can cause higher mortality of birds (Richard et al., 1998). The rise in human settlement especially in Suind, Sainj, Sharan, Raila and Manjhan adit as a result of hydro project may cause habitat loss. It is well known that increase in human population could lead to habitat loss (Sisk et al., 1994).

Impact on Woodland Bird

It has been seen that the Himalayan forest habitat is markedly different from other habitats. It consists mainly of woodland birds like bar tailed treecreepers, Himalayan woodpecker, long tailed minivet, Himalayan Monal, Koklass Pheasant, Western Tragopan, Kaleej Pheasant, Black and yellow Grosbeak, and Canary flycatcher, Oriental turtle dove etc.

During the development of a Hydroelectric project construction of a road is a crucial step which permits access to the area. This is possible only after trees are cut and lopped. Studies have proved that this results in major environmental degradation. Further the creation of the road results in continuous disturbance for the adjoining regions. Studies have also proved that this may have resulted in reduction of diversity, richness and abundance of breeding woodland birds.

Conservation implication and management

PHEP has been under construction since 2001, it was proposed to be finished in 2008, but because of technical delays and contract related issues, the commissioning of this project will now take place in March 2013 (NHPC, 2010). This implies that the surrounding area of project will be under extended period of stress. It will depend on the resilience of Sainj valley ecosystem to tolerate such disturbances. The afforestation efforts by Forest department and GHNP still raises hopes to avert the negative consequence of PHEP, e. g., in the Gatipath nursery they are growing *Taxus* spp., which is a threatened plant, and thus, provide a good stock of Taxus sapling. The success of afforestation plan is bleak because the regeneration of coniferous trees is extremely slow e. g., firs can take up 50 years to reach heights of 9 m (Jefferies and Clarbrough, 1986). In the Environment Management Plan (CISMHE, 2000 b), plantation of walnut, yew (*Taxus baccata*), Kail (*Pinus wallichiana*), and bras (*Rhododendron arboreum*) were proposed but these are not yet used. The birds like western tragopan, koklass pheasant, and himalayan monal forage in understory vegetation and roost on tree branches. They nest on the ground; therefore, presence of abundant understory vegetation along with mixed broad leaf and coniferous forest is vital for their sustenance. The cheer pheasant which comes under threatened category has been spotted in Karaila, Manjhan, and Manjhan Adit. The presence of these rare birds in Sainj valley represents the few remaining population of these birds in India. Therefore, secondary forest habitats can be considered as an ideal habitat where both man and animals can live in a sustainable manner, and in the eco-development zone, such sites will be of considerable significance in maintaining avian biodiversity.

The tree and shrub density is considerably low in disturbed habitat thus landscaping of the disturbed sites is proposed for the recovery of lost avian habitats.

Conclusions

Hydropower is regarded to be a superior technique to generate electricity because it is a clean energy resource. However, it has environmental impacts linked to development of hydropower. Some habitat conditions, particularly those of birds and animals, are significantly impacted on such projects irrespective of the techniques adopted by the agencies involved to reduce or mitigate such affects. However, such measures may prove beneficial for one species while proving harmful to others. To mitigate such impacts, it is crucial to implement varied protection, mitigation, and improvement policies.

The study has made it clear that development of hydroelectric projects has adversely affected the habitat of avian species, their richness, and abundance.

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Appendix 1. List of Birds recorded from the Sainj Valley with their respective mean abundances recorded in different habitat types (2010–2011)

S. No.	Common Name	Scientific name	Foraging guild	PF	DF	SF	A	DA
1	Black Partridge	*Francolinus francolinus*	O	0	0	0.2	0.21	0
2	Chukar	*Alectoris chukar*	O	0	0	0.12	0.04	0
3	Cheer Pheasant	*Catreus wallichii*	O	0.45	0	0.02	0	0
4	Kalij Pheasant	*Lophura leucomelanos hamiltonii*	O, W	0.18	0.03	0.07	0.02	0
5	Scaly-bellied Woodpecker	*Picus squamatus*	O, W	0	0	0	0.05	0
6	Himalayan Woodpecker	*Dendrocopos himalayensis*	O, W	0.55	0.03	0.07	0	0
7	Brown fronted Woodpecker	*Dendrocopos auriceps*	O, W	0	0	0	0.11	0.04
8	Booted Eagle	*Hieraaetus pennatus*	C	0	0	0.02	0	0
9	Golden Eagle	*Aquila chrysaetos*	C	0.05	0	0.02	0	0
10	Himalayan Griffon	*Gyps himalayensis*	C	0	0.1	0.1	0.09	0.04
11	Great Barbet	*Megalaima virens*	O, W	0.32	0.07	0.46	0.26	0.23
12	Long tailed Shrike	*Lanius schach*	C	0	0	0	0.05	0
13	Slaty Headed Parakeet	*Psittacula himalayana*	F	0	0.07	0.05	2.09	0.02
14	Asian Barred Owl	*Glaucidium cuculoides*	C	0.02	0	0	0	0
15	Blue Rock Pigeon	*Columba livia*	O	0	0	0	0.07	0.09
16	Snow Pigeon	*Columba leuconota*	O	0.14	0	0	0	0
17	Oriental Turtle Dove	*Streptopelia orientalis*	O, W	0.64	0.03	0.34	0.32	0.06
18	Common Kesteral	*Falco tinnunculus*	C	0	0.1	0.1	0.12	0
19	Eurasian Gloden Oriole	*Oriolus oriolus*		0	0	0	0	0.04
20	Large-billed Crow	*Corvus macrorhynchos*	O	0.55	0.33	0.68	0.44	0.36
21	Yellow-billed Blue Magpie	*Urocissa flavirostris*	O	0.14	0.03	0.1	0.28	0.04
22	Little pied Flycatcher	*Ficedula westermanii*	I	0	0	0.07	0	0
23	Ultramarine Flycatcher	*Ficedula superciliaris*	I	0.18	0.03	0.02	0.07	0
24	Ashy Drongo	*Dicrurus leucophaeus*	I	0.18	0.13	0.05	0.49	0.17
25	Long tailed Minivet	*Pericrocotus ethologus*	I, W	0.59	0.03	0.15	0.04	0
26	Grey Treepie	*Dendrocitta formosae*	O	0	0.03	0	0.16	0.02
27	Red billed Chough	*Pyrrhocorax pyrrhocorax*	O	0.14	0	0.1	0	0
28	Brown Dipper	*Cinclus pallasii*	I	0	0.07	0	0.09	0
29	Verditer Flycatcher	*Eumyias thalassina*	I	0.05	0	0.29	0.21	0
30	Blue whistling Thrush	*Myophonus caeruleus*	O	0.5	0.17	0.34	0.49	0.06
31	Blue Caped Rock Thrush	*Monticola cinclorhynchus*	O	0	0	0.12	0.02	0
32	Dark Throated Thrush	*Turdus ruficollis*	O	0.23	0	0	0	0
33	Streaked Laughing Thrush	*Garrulax lineatus*	O	0.14	0.1	0.56	0.46	0.06
34	Grey Bush Chat	*Saxicola ferrea*	O	0	0.2	0.63	0.72	0.09
35	Plumbeous Water Redstart	*Rhyacornis fulginosus*	I	0.14	0	0	0.26	0
36	Grey-headed Canary Flycatcher	*Culicicapa ceylonensis*	I	0	0	0.12	0	0
37	River Chat	*Phoenicurus erythrogaster*	I	0	0.2	0	0	0.02

38	Common Myna	*Acridotheres tristis*	O	0	0	0.05	0.81	0.43
39	Bar tailed Treecreeper	*Certhia himalayana*	I, W	0.23	0	0.02	0	0
40	Great Tit	*Parus major*	O	0	0	0.17	0.25	0.02
41	Green Backed Tit	*Parus monticolus*	O, W	0.59	0.27	0	0.07	0
42	Black lored Tit	*Parus xanthogenys*	O, W	0.27	0	0.1	0	0
43	Black throated Tit	*Aegithalos concinnus*	O	1.27	0.37	0.49	0.32	0.11
44	Black Bulbul	*Hypsipetes leucocephalus*	O	0	0.23	0.41	0.49	0.26
45	Himalayan Bulbul	*Pycnonotus leucogenys*	O	0	0.13	1.02	0.93	0.57
46	Western Crowned Warbler	*Phylloscopus occipitalis*	I	0.23	0.1	0	0.18	0.13
47	Rufous Sibia	*Heterophasia capistrata*	O	0.5	0	0.1	0	0
48	Rusty- cheeked Scimitar Babbler	*Pomatorhinus erythrogenys*	O	0	0	0.07	0	0
49	Tickell's Leaf Warbler	*Phylloscopus affinis*	I	0	0.03	0.02	0.11	0.09
50	Grey hooded Warbler	*Seicercus xanthoschistos*	I	0.41	0.53	0.15	0.7	0.13
51	Brownish-flanked Bush Warbler	*Cettia fortipes*	I	0.04	0	0	0	0
52	Whiskered Yuhina	*Yuhina flavicollis*	O, W	0	0.07	0	0	0
53	Varigated Laughing Thrush	*Garrulax variegatus*	O	0.09	0	0.05	0.04	0
54	Russet Sparrow	*Passer rutilans*	O	0	0.13	0.68	1.56	0.49
55	Grey Wagtail	*Motacilla cinerea*	I	0	0.07	0	0	0
56	Rock Bunting	*Emberiza cia*	O	0	0.17	0.15	0	0

Abbreviations: PF — Primary Forest; DF — Disturbed Forest; SF — Secondary Forest; A — Agricultural Land; DA — Disturbed Agricultural Land; O — Omnivorous;I — Insectivorous; F — Frugivorous; C — Carnivorous; W — Woodland Species.

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