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Bird community structure in natural and urbanized habitats along an altitudinal gradient in Pauri district (Garhwal Himalaya) of Uttarakhand state, India

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Abstract: In the Indian subcontinent there is hardly any study that compares the bird community structure of urban/suburban areas with those of forest habitat. The present survey identified diverse assemblages of birds in the Pauri district at different elevations. A total of 125 bird species belonging to 40 families including two least count species (*Lophura leucomelanos* and *Pucrasia marcolopha*) were recorded during this survey in the forest and urbanized habitats of Pauri District (Garhwal Hiamalaya) of Uttarakhand state, India. The high elevation (Pauri 1600–2100 m a.s.l.), mid elevation (Srikot-Khanda 900–1300 m a.s.l.) and low elevation (Srinagar 500–900 m a.s.l.) contributed 88.8%, 63.2% and 58.4% of the total species respectively. Rarefaction analysis and Shannon diversity index showed that the high elevation forest habitat had highest bird species richness (BSR) and bird species diversity (BSD) followed by the mid and then the low elevation forests. BSR and BSD fluctuated across seasons at all elevations but not across habitat types. Present study provides a base line data about avian community composition in urbanized and natural habitats along altitudinal gradient in the study area. This information may be useful to the conservation biologists for the better management and conservation of the avifauna in the Western Himalaya, a part of one of the hot biodiversity spots of the world.

Key words: bird community structure; avian diversity; altitudinal gradient; western Himalaya

Introduction

Biodiversity has become a matter of worldwide concern in mega-biodiversity countries. India is one of the 12 mega-biodiversity countries (McNeely et al. 1990) that is well known for its rich flora and fauna especially in the Himalayan States (http://www.nbaindia.org/faq.htm). BirdLife International has identified four Endemic Bird Areas (EBAs) that overlap partially or fully with the Himalaya hotspot. Of the biodiversity components, birds are proven bio-indicators of environmental quality change and are ecologically and economically important (oldwww.wii.gov.in/envis/rain_forest/chapter12). But most of the information which is available so far about bird fauna of this area is based on checklist that dates about 23 years back (Ali & Ripely 1983). Some recent studies have documented the bird communities of the Himalayan region, mostly in the Kumaon region (Price et al. 2003; Safiq et al. 1997; Sultana & Khan 1999, 2000; Sultana et al. 2007) and a few in the eastern region (Raman et al. 1998; Acharya 2008; Chettri et al. 2001, 2005; Acharya et al. 2011). However, the middle part of Garhwal Himalaya including Pauri district remained mostly neglected from avian biodiversity study point of view, with the exception of few studies on population dynamics and behaviour ecology of some pheasants (Bisht et al. 1986, 1990). Thus there is a gap of knowledge about avian fauna in terms of richness, abundance and distribution in the study area.

Many studies have been conducted on the associations of particular bird species, with habitats along environmental gradients (e.g., Bond 1957; James 1971; Cody 1974; Able & Noon 1976; Smith 1977) and in habitats with either similar or contrasting physical characteristics (e.g., Maurer & Whitmore 1981; Sabo & Holmes 1983; Landers & Macmohan 1983; Adamik et al. 2003). However, almost all these studies have been conducted in the temperate area. In the Indian subcontinent there is hardly any study that compares the bird community structure of urban/ suburban areas with those of forest habitat. Recent studies comparing bird communities across rural-urban gradient found that both, species richness and avian abundance peaked at moderate levels of urban development in temperate areas (Blair 1996, 2001; Mckinney & Lockwood 2001) and the number of low-height nesting species and of species with multiple broods increased with urbanization (Blair 2004). Several other studies have also demonstrated increase in avian diversity at intermediate levels of urban development (Nuorteva

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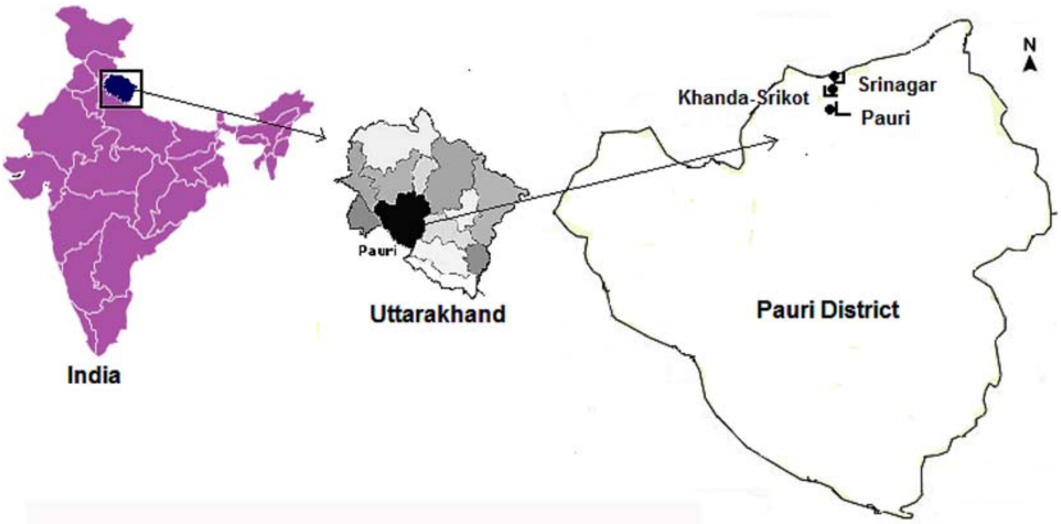

Fig. 1. Map of the study area (www.mapsofindia.com).

1971; Lancaster & Rees 1979; Jokimaki & Suhonen 1993).

In light of the above, the present study was conducted to (a) compare the structure of avian communities in the forest and urbanized habitats along different sections of the altitudinal gradient; (b) know to what extent the communities are different between habitat types and along different sections of the altitudinal gradient in Pauri district, Uttarakhand, western Himalaya.

Methods

Study area

The present study was conducted in forest and urbanized habitats from the elevation of 500 m to 2100 m a.s.l. in three different areas of the Pauri district (Fig. 1). The district Pauri Garhwal, as part of the Western Himalaya, represents a unique set of ecological characteristics over a complex landscape that incorporates forests, meadows, grasslands, marshes and rivers as well as wildlife and several other phytogeographically distinctive peculiarities. The occurrence of diverse topography and climatic factors has resulted in the remarkable biodiversity of the district (www://pauri.nic.in/land.htm). In general, the natural vegetation of the area includes dominance of *Pinus roxburghii* forest at lower altitudes to mixed conifer species like *Quercus leucotrichophora* and Pine mixed broadleaf forests *Cedrus deodara* and *Cupressus torulosa* at the higher altitudes (Tiwari et al. 2005).

High Elevation (1600–2100 m a.s.l., 30° 08′ 52.21″ N, 78° 46′ 23.58″ E). In this zone a hill station (Pauri town, area: 5 km^2) is located. It includes residential and commercial buildings, roads and other paved surfaces, and ornamental plants. There is a reserve forest area named as Nagdev reserve forest adjacent to Pauri town. The distance between forest and town varies (100–1000 m) between places.

The forest is of mixed types. *Quercus leucotricophora, Rhododendron arboretum*, *Pinus roxburghii, Cupressus torulosa, Cedrus deodara* etc. are the major tree species with abundant mosses, selaginelles and ferns in the underfloor, as well as climbing on trees with numerous bushes of *Berberis asiatica* and a large young patch of *Q. leucotrichophora* growing from abandoned crop terraces.

Mid Elevation (900–1300 m a.s.l.; 30° 11′ 11.64″ N, 78° 47′ 01.00″ E). Srikot-Khanda – a small town covering about 300 km^2 area is situated at this elevation. It has mixed vegetation including some agricultural terraces. The forest lies adjacent to the urbanized habitat at a distance of about 100–200 m. The area is dominated by Pine (*Pinus roxburghii*) with bushes of Lantana (*Lantana camara*) and a patch of Khair (*Celtis australis*) trees.

Low Elevation (500–900 m a.s.l.; 30° 13′ 14.24″ N, 78° 46′ 44.52″ E). The town called Srinagar is situated along the bank of the river Alaknanda. The town area is about 9.659 km^2. The town has commercial and residential buildings, roads and paved surfaces. The forest lies about 1–2 km away from the town and mostly covered by Pine trees with scattered bushes of Lantana.

Field procedure

Field studies were carried out for three years during Jan. 2005 to Dec. 2007 using line transect method (Verner 1985). Depending upon the accessibility, four transects were laid in each habitat types at each altitudinal zone and each transect was visited once a month. The same transects were used repeatedly during the three years. Each transect was 1 km in length and about 30 m in width to each side. Birds seen outside 30 m width to each side of the transect were not included in the study. The distance between any two transects varied from 400–1000 m. Altogether 864 transect visits [36 months × 4 transects per habitat types × 2 habitat types (forest and urbanized) × 3 altitudinal zones] were made during the study period. Birds were sampled while walking over these line-transects. The number of individuals of each bird species has also been recorded. The whole sampling was done during 06:00 AM to 11:00 AM and 16:00 PM to 19:00 PM in April to September and during 07:00 AM to 11:30 AM and 15:30 PM to 17:30 PM in October to March. The bird identification in the field was based on Grimmett et al. (2001).

Bird species diversity (BSD) and bird species richness (BSR) were measured using Shannon's index (H') and Margalef's index, respectively (MacArthur & MacArthur 1961; Magurran 2004). Sorensen's quantitative index (see Magurran 2004) was used to know the similarity among species composition at different altitudinal zones. To know extent of variation between habitat types, Beta diversity [($\beta = S/a$), where S is the total number of species recorded and a is the average sample diversity; scale 0 (minimum β diversity) to 1 (maximum β diversity) (Whittaker 1960)] value was obtained between habitats of each study area (low, mid and high altitudinal zones).

In the present study the species found restricted to a single habitat were termed as exclusive species and those observed less than 10 sightings per year were ranked as rare. The categorization of rare species was based on the criteria used to define rarity (Gaston 1994).

We compared species richness between habitats and elevations using individual based rarefaction curves (Colwell et al. 2004). We used BioDiversity Pro software (McAleece et al. 1997) to generate rarefaction curves in order to determine whether the sampling effort was adequate.

Data were pooled from all altitudinal zones to calculate the relative abundance. A two-way ANOVA (between habitats and among elevations) was applied to know the species difference between forest and urban habitats along altitudinal zones and to compare species richness, species diversity, number of individuals and relative abundance of individuals between habitats and among study areas (Zar 1984). Two-way ANOVA was also used to test for inter-seasonal differences in BSR and BSD values across study areas. Software such as Past.exe (www.nhm.ac.uk) was used for statistical analysis.

Results

Altogether 125 species of birds belonging to 40 families were recorded in both habitat types among three altitudinal zones. The total number of species was highest for the family Muscicapidae (32 species) followed by Accipitridae (nine species) and Picidae (nine species), while the two least counts [the species kalij *Lophura leucomelanos* (Latham, 1790) and koklass *Pucracia macrolopha* Lesson, 1829] belonged to the Phasianidae. The number of bird species observed at high elevation (Pauri forest and urban), mid elevation (Srikot-Khanda forest and urban) and low elevation (Srinagar forest and urban) were 111 (88%), 79 (63.2%) and 73 (58.4%), respectively. Out of 111 species observed at high elevation, 66 (59.45%) were common to both habitat types, whereas 28 (25.22%) were found exclusively in the forest and the remaining 17 (15.31%) were observed in the urbanized area only. Thus, altogether 94 and 83 species were observed in forest and urban habitats of high elevation respectively. At mid elevation a total of 79 species were observed. Out of them 45 (56.96%) shared both habitats whereas 18 (22.78%) were exclusive to forest and 16 (20.25%) were exclusive to urban. Out of 73 species recorded at low elevation, 34 (46.57%) were common to both habitat types while 21 (29.05%) were exclusive to forest and 18 (24.65%) were exclusive to urbanized area.

Forest bird community was more diverse than the bird community of urbanized habitat in terms of BSD (two-way ANOVA: 3.74 vs 3.12; $F = 2.89$, df = 5, 35, $P < 0.01$) and BSR (two-way ANOVA: 12.3 vs 10.16; $F = 2.35$; df = 5, 35, $P < 0.01$). On comparing among altitudinal zones a significant higher BSD was obtained at high elevation (two-way ANOVA; 3.45 (forest) and 2.93 (urban); $F = 68.36$; df = 5, 35; $P < 0.05$) compared to mid (3.01 in forest and 2.74 in urban) and low (2.80 in forest and 2.68 in urban) elevations. Similarly the comparative analysis of BSR among altitudinal zones gave significantly higher value at high elevation (two-way ANOVA; 8.89 (forest) and 7.15 (urban); $F = 139.86$; df = 5, 35; $P < 0.05$) compared to mid (5.96 in forest and 6.11 in urban) and low (4.98 in forest and 5.66 in urban). In the present study 39 rare species were observed maximum (39) at high elevation followed by 30 at mid and 24 at low elevation.

The Shannon's diversity index showed a gradient from high to low elevation in respect to both habitat types. This gradient was also examined by observing number of species and other measure of richness (i.e., rarefaction) at each elevation. The rarefaction curves (Fig. 2) reveal that the highest elevations have the highest BSR in both forest and urbanized habitats as compared to mid and low elevations. The comparison between habitats shows the rarefaction curves of forest habitats upper than the one of urbanized habitats, indicating a higher BSR, among all altitudinal zones.

A comparison of bird communities between forest and urbanized habitats revealed a great overlap/similarity in each study area (high elevation 0.74; mid elevation 0.72; low elevation 0.72). However, when bird communities were compared among altitudinal zones, the similarity index was observed higher between mid and low altitudinal zones (0.74 for forest and 0.74 for urban) rather than between high and mid (0.71 for forest and 0.73 for urban) or between high and low (0.66 and 0.65) elevations.

Relatively high beta diversity values (0.38 for forest and 0.57 for urban) were observed between high and low altitudinal zones (showing greater species variation between these two study areas) compared to between high and mid (0.28 for forest and 0.46 for urban) or between mid and low altitudinal zones (0.25 for forest and 0.23 for urban).

The three dominant species of the forest at high elevation were russet sparrow *Passer rutilans* Temminck, 1835, slaty headed parakeet *Psittacula himalayana* (Lesson, 1832) and red headed tit *Aegithalos concinninus* (Gould, 1855) whereas Himalayan bulbul *Pycnonotus leucogenys* (Gray, 1835), jungle babbler *Turdoides striatus* (Dumont, 1823) and streaked laughing thrush *Garrulax lineatus* (Vigors, 1831) were found as the most dominant species at mid and low elevation forests. In urbanized habitat, the house sparrow *Passer domesticus* (L., 1758) was observed as the most dominating species at all altitudinal zones. Indian myna *Acridotheres tristis* (L., 1766) was the second dominating species at high and low elevations but Oriental white-eye *Zosterops palpebrosus* (Temminck, 1824) was the second dominant species at mid elevation. Jungle babbler was the third dominant species at high elevation while it was the house crow *Corvus splendens* Vieillot, 1817 at mid and low elevations (Table 1).

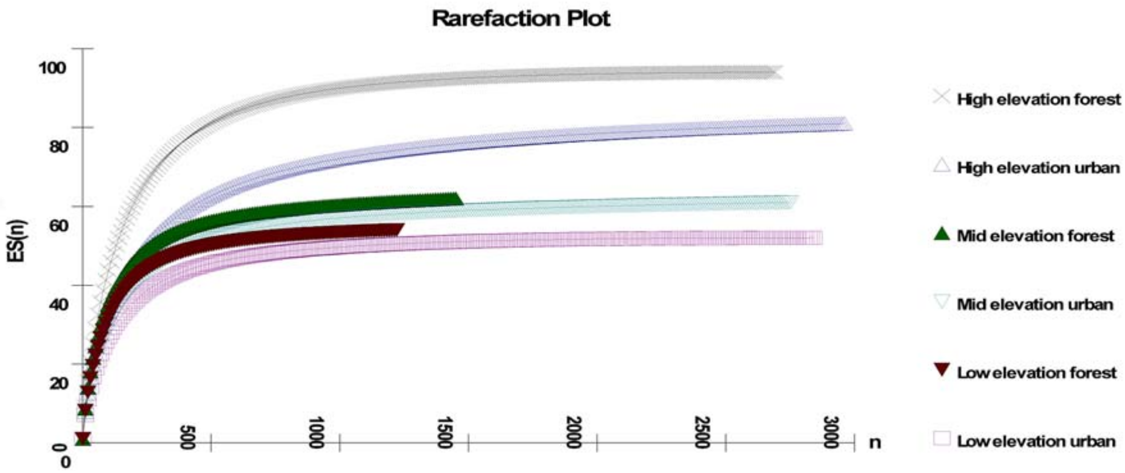

Fig. 2. Rarefaction curves for bird species richness estimated from forest and urban habitats for Pauri (high elevation), Khanda-Srikot (mid elevation) and Srinagar (low elevation).

Table 1. Relative abundance (RA) of top 10 dominant species across habitat and altitude in Garhwal Himalaya.

High Elevation				Mid Elevation				Low Elevation			
Forest Sp.	RA (%)	Urban Sp.	RA (%)	Forest Sp.	RA (%)	Urban Sp.	RA (%)	Forest Sp.	RA (%)	Urban Sp.	RA (%)
Passer rutilans	0.128	*Passer domesticus*	0.285	*Pycnonotus leucogenys*	0.137	*Passer domesticus*	0.326	*Pycnonotus leucogenys*	0.159	*Passer domesticus*	0.338
Psittacula himalayana	0.065	*Acridotheres tristis*	0.061	*Turdoides striatus*	0.109	*Zosterops palpebrosus*	0.065	*Turdoides striatus*	0.114	*Acridotheres tristis*	0.109
Aegithalos concinninus	0.058	*Turdoides striatus*	0.060	*Garrulax lineatus*	0.087	*Corvus splendens*	0.061	*Garrulax lineatus*	0.103	*Corvus splendens*	0.056
Turdoides striatus	0.056	*Corvus splendens*	0.056	*Passer rutilans*	0.062	*Turdoides striatus*	0.058	*Pycnonotus cafer*	0.098	*Columba livia*	0.049
Pycnonotus leucogenys	0.053	*Columba livia* Gmelin, 1789	0.046	*Psittacula himalayana*	0.054	*Garrulax lineatus*	0.043	*Corvus macrorhynchos*	0.043	*Zosterops palpebrosus*	0.048
Garrulax lineatus	0.037	*Pycnonotus cafer* (Linnaeus, 1766)	0.033	*Corvus macrorhynchos*	0.040	*Acridotheres tristis*	0.039	*Psittacula himalayana*	0.042	*Pycnonotus cafer*	0.038
Garrulax albogularis (Gould, 1836)	0.033	*Garrulax lineatus*	0.033	*Aegithalos concinninus*	0.037	*Lonchura striata* (L., 1766)	0.026	*Zosterops palpebrosus*	0.037	*Turdoides striatus*	0.033
Corvus macrorhynchos	0.032	*Zosterops palpebrosus*	0.033	*Pycnonotus cafer*	0.030	*Psittacula himalayana*	0.025	*Passer rutilans*	0.023	*Pycnonotus leucogenys*	0.031
Hypsipetes leucocephalus (P.L.S. Muller, 1776)	0.022	*Apus affinis* (J.E. Gray, 1830)	0.027	*Hypsipetes leucocephalus*	0.026	*Columba livia*	0.023	*Myiophonus caeruleus* (Scopoli, 1786)	0.019	*Garrulax lineatus*	0.030
Zosterops palpebrosus	0.017	*Pycnonotus leucogenys*	0.026	*Garrulus glandarius* (L., 1758)	0.021	*Pycnonotus cafer*	0.020	*Parus monticolus* Vigors, 1831	0.018	*Parus major*	0.022

Of 125 species, 26 shared both habitat types across all study areas (Table 2). Among them, nine species was found to be significantly more abundant in high altitudinal zone, two at mid and two at low altitudinal zones. The remaining 13 species did not differ in abundance between habitat types or across altitudinal zones. However, seven species namely spotted dove *Streptopelia chinensis* (Scopoli, 1786), grey treepie *Dendrocitta formosae* Swinhoe, 1863, green bee-eater *Merops orientalis* Latham, 1801, purple sunbird *Nectarinia asiatica* (Latham, 1790), great tit *Parus major* L., 1758, pied bush chat *Saxicola caprata* (L., 1766), and Oriental white-eye were found more abundant in urbanized area than in forest and the abundance of the five species Himalayan tree-creeper *Certhia himalayana* Vigors, 1832, Oriental turtle-dove *Strep-*

Table 2. Mean abundance of bird species per habitat type and 95% confidence Interval (CI) for 26 species that shared both habitat types across altitude.

Species	Forest			Urban		
	Mean	±SD	95 % CI	Mean	±SD	95 % CI
Black Kite *Milvus migrans* (Boddaert, 1783)	15.33	±4.41	4.99	16.44	±1.07	1.21
Great Barbet *Megalaima virens* (Boddaert, 1783)	16.67	±4.37	4.95	16.67	±3.76	4.25
Himalayan Tree Creeper *Certhia himalayana*	13.00	±5.81	6.58	7.56	±8.53	9.65
Oriental Turtle Dove *Streptopelia orientalis*	17.56	±6.87	7.77	11.78	±4.68	5.30
Spotted Dove *Streptopelia chinensis*	17.33	±2.33	2.64	40.44	±14.63	16.56
Jungle Crow *Corvus macrorhynchos*	65.67	±17.52	19.83	40.67	±7.13	8.06
Grey Tree Pie *Dendrocitta formosae*	10.00	±1.33	1.51	27.78	±19.35	21.89
Indian Treepie *Dendrocitta vagabunda*	11.67	±1.15	1.31	17.56	±2.67	3.03
Red Billed Blue Magpie *Urocissa erythrorhyncha* (Boddaert, 1783)	27.00	±9.28	10.50	32.56	±12.95	14.65
Yellow Bellied Flower Pecker *Dicaeum melanoxanthum* (Blyth, 1843)	13.89	±9.00	10.19	18.56	±2.12	2.40
Black Drongo *Dicrurus macrocercus*	13.44	±2.04	2.30	13.89	±4.68	5.30
Common Iora *Aegithina tiphia* (L., 1758)	11.78	±5.97	6.75	11.67	±3.53	3.99
Rufous Backed Shrike *Lanius isabellinus* Hemprich & Ehrenberg, 1833	14.44	±0.19	0.22	14.44	±4.40	4.98
Green Bee Eater *Merops orientalis*	10.67	±4.91	5.56	20.89	±3.02	3.42
Purple Sunbird *Nectarinia asiatica*	14.22	±14.73	16.67	39.22	±8.00	9.06
Great Tit *Parus major*	26.00	±14.15	16.01	47.89	±19.66	22.24
Black Lored Yellow Tit *Parus xanthogenys* Vigors, 1831	13.67	±4.98	5.63	12.33	±8.74	9.89
Slaty Headed Parakeet *Psittacula himalayana*	101.22	±64.53	73.02	54.11	±17.84	20.19
Red Vented Bulbul *Pycnonotus cafer*	69.67	±43.59	49.33	87.22	±27.05	30.61
Himalayan Bulbul *Pycnonotus leucogenys*	179.22	±30.53	34.54	69.67	±24.42	27.63
Streaked Laughing Thrush *Garrulax lineatus*	117.67	±14.73	16.67	100.89	±16.32	18.46
Jungle Babbler *Turdoides striatus*	149.78	±9.10	10.30	143.11	±43.91	49.68
Pied Bush Chat *Saxicola caprata*	18.78	±12.41	14.04	40.00	±10.41	11.78
Blue Whistling Thrush *Myiophonus caeruleus*	28.33	±8.95	10.13	23.78	±3.02	3.42
Oriental White Eye *Zosterops palpebrosus*	31.67	±23.67	26.79	138.00	±40.68	46.04
Grey Breasted Prinia *Prinia crinigera* Hodgson, 1836	16.11	±2.83	3.21	20.00	±12.91	14.61

Table 3. Seasonal variation in BSD and BSR along altitude.

Elevational zones	Bird species diversity						Bird species richness					
	Forest habitat			Urbanized habitat			Forest habitat			Urbanized habitat		
	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter
High elevation	3.92	3.79	3.60	3.30	3.15	3.08	11.10	10.93	10.35	9.39	9.29	9.03
Mid elevation	3.43	3.20	3.43	3.02	2.79	2.97	6.96	6.74	7.64	6.93	6.33	6.83
Low elevation	3.19	2.97	3.23	2.84	2.71	3.05	6.24	6.07	6.90	5.62	5.56	5.96

topelia orientalis (Latham, 1790), jungle crow *Corvus macrorhynchos* Wagler, 1827, Slaty-headed parakeet and Himalyan bulbul was higher in forest habitat. Thus, the present study reveals that avian abundance can increase with urbanization.

The abundance of the kalij (*P. leucomelana*) was highest (encounter rate = 6.5/km) at high elevation followed by mid (encounter rate = 5.56/km) and low elevations (encounter rate = 4.75/km). The other least counted species, koklass (*P. macrolopha*) was sighted only at high elevation and the overall encounter rate was 5.62/km walk. There was no significant difference between mean abundance values of these species across the year during the study period.

In forest habitat the BSD and BSR were maximum during summer and minimum during winter at high elevation. At mid elevation the BSD and BSR were high during summer and minimum during monsoon and at low elevation BSD and BSR were observed high during winter and low during monsoon. In urbanized habitat the BSD and BSR were observed high during summer and low during winter at high elevation. At mid elevation BSD and BSR were observed high during summer and low during monsoon. At low elevation the BSD and BSR were observed high during winter and low during monsoon (Table 3). Seasonal difference along altitudinal zones in terms of BSD varied significantly in forest ($F = 6.38$; df = 2, 35; $P < 0.05$) and urbanized habitats ($F = 4.13$, df = 2, 35, $P < 0.05$). The difference in terms of BSR was found significant in forest ($F = 4.93$, df = 2, 35, $P < 0.05$) only.

Altitudinal migration of some forest species, small minivet *Pericrocotus cinnamomeus* (L., 1766), Indian tree-pie *Dendrocitta vagabunda* (Latham, 1790), Indian cuckoo *Cuculus micropterus* Gould, 1838, black drongo *Dicrurus macrocercus* Vieillot, 1817, little pied flycatcher *Ficedula westermanni* (Sharpe, 1888), grey-headed flycatcher *Culicicapa ceylonensis* (Swainson, 1820), grey-backed shrike *Lanius tephronotus* (Vigors, 1831) and urbanized species *Certhia himalayana*, Rufous-backed shrike *Lanius schach* L., 1758, verditer flycatcher *Eumyias thalassina* (Swainson, 1838), red-rumped swallow *Hirundo daurica* L., 1771, *Lanius tephronotus* and the presence of two winter visitors, greater spotted eagle *Aquila clanga* Pallas, 1811 and steppe eagle *Aquila nipalensis* Hodgson, 1833, and three summer visitors Asian brown flycatcher *Muscicapa dauurica* Pallas, 1811, *Eumyias thalassina,* Asian paradise-flycatcher *Terpsiphone paradisi* (L., 1758) were noticed in the study area causing seasonal fluctuations in the abundance of birds in the study area.

Discussion

The findings of this study revealed diverse populations of birds along altitudinal gradient and habitat types in the study area. The distribution of bird species and the diversity indices were observed higher at high elevation than at mid and low elevation irrespective of habitat types. In other words, there was an increase in BSD and BSR with increasing elevation in both forest and urbanized habitats with peak values at 1600–2100 m a.s.l. (highest elevation study area). The pattern of the avian community of the present study varies from that reported by many previous studies conducted on bird species richness along altitudinal gradients mostly in temperate regions. Most such studies have found the highest species richness at low_elevation such as in rain forest of eastern Andes Peru (Terborgh 1971; Terborgh & Weske 1975) or mid elevation such as in Peruvian Andes (Rahbek 1995, 2005), Madagascan rain forest (Colwell & Lees 2000), Bolwian Andes South American Forest (Kessler et al. 2001), Columbian Andes forest (Kattan & Franco 2004), urban/subtropical to subarctic forest in Taiwan (Lee et al. 2004; Ding et al. 2005). In the present study the higher BSD and BSR observed in high altitude areas may be connected to the higher plant diversity. Contrary to low and mid elevations the forest of high elevation is of mixed types which appear to support the presence of insects and other food resources in good amount to sustain the high BSD in the forest. Terborgh (1977) suggested that habitat complexity increases microhabitat availability for insects, which in turn increases their diversity and abundance, ultimately increasing the diversity and population of birds. However, further investigations are required to understand whether these patterns of altitudinal distribution are conformed to the structural or botanical classification of vegetation variation with altitude. According to Lomolino (2001) species richness at local and regional scales in altitudinal gradients is the result of the interplay of a variety of factors. But there is no reason to expect a single pattern in the altitudinal gradient of species richness across regions, spatial scales and taxa (Rahbek 1997).

The most dominant species in forest habitat varies along altitudinal zones but it is interesting to note that house sparrow was found dominating in urbanized habitat in all altitudinal zones of the study area. *P. domesticus* was obtained as the dominant bird species in urbanized habitat in some other studies in USA and Finland (Blair 1996; Jokimaki et al. 2002) also. However, recently it has been noted that there is decline in population of *P. domesticus* in urbanized habitats of many European countries (Siriwardena et al. 1998; Summers-Smith 2003; Peach et al. 2006; Chamberlain et al. 2007). Sighting of *P. domesticus* as a dominant species in the urbanized area of the study site is a good sign. It could be argued that the availability of easier or more nesting sites in the form of old traditional houses in the study area is accountable for the high density of house sparrow while food limitation has been suggested as being responsible for decrease in house sparrow population in European big cities (Hole et al. 2002).

The comparison between habitat types has shown that the forest has higher bird diversity than urbanized area at all altitudes, which is natural and such observations have been made by a number of other workers especially in temperate zones (Karr 1976; Weins 1989; Cody 2001). In other words, lower species diversity in urbanized area may be attributed to the fact that the vegetation structure supports the bird community in the forest habitat.

The study also showed that the composition and relative abundance of species were different among altitudinal zones. Because elevation affects the condition of the physical environment and the kinds and amounts of resources available for breeding and foraging activities, the composition and structure of bird community may change accordingly (Able & Noon 1976; Cody 1981; Stevens 1992).

In most studies urbanization has been shown to cause low BSR and BSD (Emlen 1974; Aldrich & Coffin 1980; Bessinger & Osborne 1982). But in the present study it is interesting to note that although there was overall decrease in the BSR and BSD values in urbanized habitat, the relative abundance of seven bird species was higher in urbanized habitat compared to the forest habitat. Some other studies (Jokimaki et al. 1996; Huhtalo & Jarvinen 1977; Clergeau et al. 1998) conducted in European areas also demonstrated that although urbanization decreases the BSD and BSR, it can increase the abundance of some bird species. A comparative study of avifauna structures of urban and forest habitats have hardly been documented in the Indian subcontinent and old tropical countries (Bhatt & Joshi 2011) and hence comparison of present findings with other study areas may not be possible. However, the findings of the present study are interesting that despite disturbance (in the form of modification, alterations or developmental works) the urbanized habitat supports a good number of avifauna (99 species).

The BSD and BSR of the study area also showed seasonal variation along altitudinal zones. Altitudinal migration as a result of seasonal change in weather conditions was noticed as a contributing factor in seasonal fluctuation in the study area. An increased BSD was observed at mid and low elevation during winter as the birds migrate from the higher altitude towards these elevations due to extreme weather conditions during winter at high elevation. Apart from weather, the seasonal changes in BSD and BSR could also be caused by fluctuations in resource availability (Loiselle & Blake 1991; Kai & Corlett 2002; Hulbert & Haskell 2003; Norris & Marra 2007). Many observations carried out by different ornithologists showed that there is seasonal bird migration along and across the Himalaya (Grimmett et al. 1998). It has also been observed that the impact of environmental factors such as variation in temperature and intensity of rain (Karr 1976; Terborgh 1977; Vazquez & Givnish 1998) which might also cause the seasonal movements of birds within and between habitats (Perrins & Birkhead 1983; Loiselle & Blake 1991; Norirs & Marra 2007). It may therefore be argued that in the present study the seasons also contribute to cause variations in BSD and BSR along altitudinal gradient.

Our results presented here from a remote study area in the Western Himalaya are preliminary. To improve our understanding of how birds respond to urbanization we need to work further, organizing comprehensive programs to monitor biodiversity along forest-urban gradient in the Indian subcontinent in general and in the Himalayan region (identified as one of the biodiversity hotspots of the world) in particular. In addition, focusing biodiversity research on those areas where relatively little is known, but predictably large impacts of future developments are likely to occur, will make data relevant for future planning decision.

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References

Able K.P. & Noon B.R. 1976. Avian community structure along elevational gradients in the Northeastern United States. Oecologia **26 (3):** 275–294. DOI: 10.1007/BF00345296

Acharya B.K. 2008. Bird communities: their distribution pattern along the elevation gradient of Teesta Valley, Sikkim. Ph.D. Thesis. Bharathiar University, Coimbatore, India.

Acharya B.K., Sanders N.J., Vijayan L. & Chettri B. 2011. Elevational Gradients in bird diversity in the Eastern Himalaya: An evaluation of distribution patterns and their underlying mechanisms. PLoS ONE **6** (12): e29097. DOI: 10.1371/journal.pone.0029097

Adamík P., Korňan M. & Vojtek J. 2003. The effect of habitat structure on guild patterns and the foraging strategies of insectivorous birds in forests. Biologia **58 (2):** 275–285.

Aldrich J.W. & Coffin R.W. 1980. Breeding bird population from forest suburban after 37 year. American Birds **34 (1):** 3–7.

Ali S. & Ripley S.D. 1983. Handbook of the Birds of India and Pakistan. Compact ed. Oxford University Press, New Delhi, 737 pp. ISBN: 0195612450

Beissinger S.R. & Osborne D.R. 1982. Effects of urbanization on avian community organization. Condor **84:** 75–83.

Bhatt D. & Joshi K.K. 2011. Bird assemblages in natural and urbanized habitats along elevational gradient in Nainital district (western Himalaya) of Uttarakhand state, India. Current Zoology (formerly Acta Zoologica Sinica) **57 (3):** 318–329.

Bisht M., Lakehra P. & Chandola-Saklani A. 1986. Behaviour ecology of White Kaleej pheasant *Lophura leucomelanain* Garhwal Himalaya, p. 835. In: Ouellet H. (ed.), Proc. of XIX International Ornithological Congress, University of Ottawa Press, Ottawa.

Bisht M., Lakehra P. & Chandola-Saklani A. 1990. The Monal Pheasant current status and habitat utilization in Kedarnath sanctuary, Garhwal Himalaya, pp. 205–208. In: Hill D.A. et al. (eds), Pheasant in Asia 1990, World Pheasant Association, Reading, U.K. http://www.nhbs.com/pheasants_in_asia_1989_tefno_60184.html

Blair R.B. 1996. Land use and avian species diversity along an urban gradient. Ecol. Appl. **6 (2):** 506–519. DOI: 10.2307/2269387

Blair R.B. 2001. Birds and butterflies along urban gradients in two ecoregions of the United States: Is urbanization creating a homogeneous fauna?, pp. 33–56. In: Lockwood J.L. & McKinney M.L. (eds), Biotic Homogenization, The Loss of Diversity through Invasion and Extinction, Kluwer Academic Publishers, Boston, 289 pp. ISBN: 0306465426

Blair R.B. 2004. The effect of urban sprawl on birds at multiple level of biological organization. Ecol. Soc. **9 (5):** 10–11.

Bond R.R. 1957. Ecological distribution of breeding birds in the Upland Forests of Southern Wisconsin. Ecol. Monogr. **27 (4):** 351–384. DOI: 10.2307/1942269

Chamberlain D.E., Toms M.P., McHarg R.C. & Banks A.N. 2007. House sparrow (*Passer domesticus*) habitat use in urbanized landscapes. J. Ornithol. **148 (4):** 453–462. DOI: 10.1007/s10336-007-0165-x

Chettri N., Jackson R. & Sharma E. 2005. Birds of Khecheopalri and Yuksom-Dzongri trekking corridor west Sikkim. Journal of Hill Research **18 (1):** 16–25.

Chettri N., Sharma E. & Deb D.C. 2001. Bird community structure along a trekking corridor of Sikkim Himalaya a conservation perspective. Biol. Conserv. **102 (1):** 1–16. DOI: 10.1016/S0006-3207(01)00092-1

Clergeau P., Savard J.P.L., Mennechex G. & Falardeau G. 1998. Bird abundance and diversity along an urban-rural gradients: A comparative study between two cities on different continents. Condor **100 (3):** 413–425. DOI: 10.2307/1369707

Cody M.L. 1974. Competition and the Structure of Bird Communities. Monographs in Population Biology, Priceton Uni. Press, Priceton, New Jersey, 326 pp. ISBN: 0691081344

Cody M.L. 1981. Habitat selection in birds: the roles of vegetation structure, competitors, and productivity. BioScience **31 (2):** 107–113. DOI: 10.2307/1308252

Cody M.L. 2001. Bird diversity components in Australian Eucalyptus and North temperate Quercus woodlands. Auk **118 (2):** 443–456. DOI:10.1642/0004-8038(2001)118[0443:BDCIAE]2.0.CO;2

Colwell R. K. & Lees D.C. 2000. The mid-domain effect: geometric constraints on the geography of species richness. Trends Ecol. Evol. **15 (2):** 70–76. DOI: 10.1016/S0169-5347(99)01767-X

Colwell R. K., Mao C.X. & Chang J. 2004. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. Ecology **85 (10):** 2717–2727. DOI: 10.1890/03-0557

Ding T.S., Yuan H.E., Geng S., Lin Y.S. & Lee P.F. 2005. Energy flux, body size and density in relation to bird species richness along an elevational gradient in Taiwan. Global Ecol. Biogeogr. **14 (4):** 299–306. DOI: 10.1111/j.1466-822X.2005.00159.x

Emlen J.T. 1974. An urban bird community in Tucson, Arizona. Condor **76 (2):** 184–197.

Gaston K.J. 1994. Rarity, Population and Community Biology. Series 13. Chapman and Hall Ltd., London, 220 pp. ISBN: 9780412475108

Grimmett R., Inskipp C. & Inskipp T. 2002. Pocket Guide to the Birds of Indian Subcontinent. Christopher Helm Publishers Ltd, Oxford University Press, New Delhi, 384 pp. ISBN: 0713663049, 978-0713663044

Grimmett R., Inskipp C. & Inskipp T. 1998. Birds of the Indian Subcontinent. Oxford University Press, New Delhi, 888 pp. ISBN: 0195649079, 9780195649079

Hole D., Whittingham M. J., Bradbury R., Anderson G., Lee T., Wilson J. & Krebs J. 2002. Widespread local house sparrow extinctions. Nature **418 (6901):** 931–932. DOI: 10.1038/418931a

Huhtalo H. & Jarvinen O. 1977. Quantitative composition of the urban bird community in Tornio, Northern Finland. Bird Study **24 (3):** 179–185. DOI: 10.1080/00063657709476554

Hulbert A.H. & Haskell J.P. 2003. The effect of energy and seasonality in avian species richness and community composition. Am. Nat. **161 (1):** 83–**97.** DOI: 10.1086/345459

James F.C. 1971. Ordination of Habitat Relationships among Breeding Birds. Wilson Bull. **83 (3):** 215–236.

Jokimaki J., Clergeau P. & Kaisanlahti-Jokimaki M.L. 2002. Winter bird communities in urban habitats: a comparative study between central and northern Europe. J. Biogeogr. **29 (1):** 69–79. DOI: 10.1046/j.1365-2699.2002.00649.x

Jokimaki J. & Suhonen J. 1993. Effects of urbanization on the breeding bird species richness in Finland: A biogeographical comparison. Ornis Fennica **70 (2):** 71–77.

Jokimaki J., Suhonen J., Inai K. & Jokinen S. 1996. Biogeographical comparison of winter bird assemblages in urban environment in Finland. J. Biogeogr. **23 (3):** 379–386. DOI: 10.1046/j.1365-2699.1996.00033.x

Kai K.H. & Corlett R.T. 2002. Seasonality of forest in vertebrates in Hong Kong, South China. J. Trop. Ecol. **18 (part 4):** 637–644. DOI: 10.1017/S0266467402002419

Karr J.A. 1976. Within and between habitat avian diversity in Africa and Neotropical lowland habitats. Ecol. Monogr. **46 (4):** 457–481. DOI: 10.2307/1942566

Kattan G.H. & Franco P. 2004. Bird diversity along elevational gradients in the Andes of Colombia: area and mass effects. Global Ecol. Biogeogr. **13 (5):** 451–458. DOI: 10.1111/j.1466-822X.2004.00117.x

Kessler M., Herzog S.K., Fjeldsa J. & Bach K. 2001. Species richness and endemism of plant and bird communities along two gradients of elevation, humidity and land use in the Bolivian Andes. Divers. Distrib. **7 (1–2):** 61–77. DOI: 10.1046/j.1472-4642.2001.00097.x

Lancaster R.K. & Rees W.E. 1979. Bird communities and the structure of urban habitats. Can. J. Zool. **57 (12):** 2358–2368. DOI: 10.1139/z79-307

Landers P.B. & MacMahon J.A. 1983. Community organization of arboreal birds in some oak woodlands of western North America. Ecol. Monogr. **53 (2):** 183–208. DOI: 10.2307/1942494

Lee P.F., Ding T.S., Hsu F.H. & Gerg S. 2004. Breeding bird species richness in Taiwan distribution on gradients of elevation, primary productivity and urbanization. J. Biogeogr. **31 (2):** 307–314.

Loiselle B.A. & Blake J.G. 1991. Temporal variation in birds and fruits along an elevation gradient in Costa Rica. Ecology **72 (1):** 180–193. DOI: 10.2307/1938913

Lomolino M.V. 2001. Elevational gradients of species density: historical and prospective views. Global Ecol. Biogeogr. **10 (1):** 3–13. DOI: 10.1046/j.1466-822x.2001.00229.x

MacArthur R.H. & MacArthur J.W. 1961. On bird species diversity. Ecology **42 (3):** 594–598.

Magurran A.E. 2004. Measuring Biological Diversity. Blackwell Publishing, Oxford Australia, 256 pp. ISBN: 0-632-05633-9

Maurer B.A. & Whitmore R.C. 1981. Foraging of five bird species in two forests with different vegetation structure. Wilson Bull. **93 (4):** 478–490.

McAleece N., Lambshead P.J.D., Paterson G.L.J. & Gage J.D. 1997. Biodiversity Professional: Free Statistics Software for Ecology. London: The Natural History Museum, London & The Scottish Association for Marine Science, Oban, Scotland. BioDiversity Pro, 1997 NHM & SAMS

McKinney M.L. & Lockwood J.L. 2001. Biotic homogenization: A sequential and selective process, pp. 1–17. In: Lockwood J.L. & McKinneyM.L. (ed.), Biotic Homogenization. New York: Kluwer Academic, Plenum Publisher, 289 pp. ISBN: 0306465426, 9780306465420

McNeely J.A., Miller K.R., Reid W.V., Mittermeier R.A. & Werner T.B. 1990. Conserving the World's Biological Diversity. IUCN, World Resources Institute, Conservation International, WWF-US and the World Bank: Washington, DC, 193 pp. ISBN: 0915825422, 9780915825424

Norris D.R. & Marra P.P. 2007. Seasonal interactions, habitat quality and population dynamics in migratory birds. Condor **109 (3):** 535–547. DOI: http://dx.doi.org/10.1650/8350.1

Nourteva P. 1971. The synanthropy of birds as an expression of the ecological cycle disorder caused by urbanization. Ann. Zool. Fenn. **8:** 547–553.

Peach W., Vincent K., Ockendon N., Orsman C. & Noble D. 2006. Environmental causes of the decline of house sparrow: a review of the evidence. J. Ornithol. **147 (5) Suppl. 1:** 19.

Perrins C.M. & Birkhead T.R. 1983. Avian Ecology. New York: Blackie and Son Ltd., 221 pp. ISBN: 0216914779, 9780216914773

Price T., Jennifer Z., Kartika J. & Nitin J. 2003. Bird species diversity along Himalaya: a comparison of Himachal Pradesh and Kashmir. J. Bombay Nat. Hist. Soc. **100:** 394–408.

Rahbek C. 1995. The elevational gradient of species richness: a uniform pattern? Ecography **18 (2):** 200–205. DOI: 10.1111/j.1600-0587.1995.tb00341.x

Rahbek C. 1997. The relationship among area, elevation and regional species richness in Neotropical birds. Am. Nat. **149 (5):** 875–902. DOI: 10.1086/286028

Rahbek C. 2005. The role of spatial scale and the perception of large-scale species-richness patterns. Ecol. Lett. **8 (2):** 224–239. DOI: 10.1111/j.1461-0248.2004.00701.x

Raman T.R.S. 2006. Effects of habitat structure and adjacent habitats on birds in tropical rainforest fragments and shaded plantations in the Western Ghats, India. Biodiver.Conserv. **15 (4):** 1577–1607. DOI: 10.1007/s10531-005-2352-5

Raman T.R.S., Rawat G.S. & Johnsingh A.J.T. 1998. Recovery of tropical rainforest avifauna in relation to vegetation succession following shifting cultivation in Mizoram, Northeast India. J. Appl. Ecol. **35 (2):** 214–231. DOI: 10.1046/j.1365-2664.1998.00297.x

Sabo S. R. & Holmes R. T. 1983. Foraging niches and the structure of forest bird communities in contrasting montane habitats. Condor **85 (2):** 121–138.

Safiq T., Javed S. & Khan J.A. 1997. Bird community structure of middle altitude oak forest in Kumaon Himalayas, India a preliminary investigation. Int. J. Ecol. Environ. Sci. **23 (4):** 389–400.

Siriwardena G.M., Baillie S.R., Buckland S.T., Fewster R.M., Marchant J.H. &Wilson J.D. 1998. Trends in the abundance of farmland birds: A quantative comparision of smmothed Common Birds Census indices. J. Appl. Ecol. **35 (1):** 24–43. DOI: 10.1046/j.1365-2664.1998.00275.x

Smith W.J. 1977. The Behaviour of Communication. Havard University Press, Cambridge, MA, 545 pp. ISBN: 0674064658, 9780674064652

Stevens G.C. 1992. The elevational gradient in altitudinal range: an extension of Rapoport's latitudinal rule to altitude. Am. Nat. **140 (6):** 893–911. PMID: 19426029

Sultana A., Hussain M.S. & Khan J. A. 2007. Bird communities of the proposed Naina and Pindari wildlife sanctuary in the Kumaon Himalaya, Uttarakhand, India. J. Bombay Nat. Hist. Soc. **104 (1):** 19–29.

Sultana A. & Khan J.A. 1999. Avian community in the Kumaon Himalaya, India – a preliminary study. Int. J. Ecol. Environ. Sci. **25 (2):** 167–176.

Sultana A. & Khan J.A. 2000. Birds of oak forests in the Kumaon Himalaya, Uttar Pradesh, India. Forktail **16:** 131–146.

Summers-Smith J.D. 2003. Decline of the House Sparrow: A Review. Br. Birds **96:** 439–446.

Terborgh J. 1971. Distribution on environmental gradients theory and a preliminary interpretation of distributional patterns in the avifauna of the Cordillera Vilcabamba, Peru. Ecology **52 (1):** 23–40. DOI: 10.2307/1934735

Terborgh J. & Weske J.S. 1975. The role of competition in the distribution of Andean birds. Ecology **56 (3):** 562–576. DOI: 10.2307/1935491

Terborgh J. 1977. Bird species diversity on an Andean elevational gradient. Ecology **58 (5):** 1007–1019. DOI: 10.2307/1936921

Tiwari A.K., Agarwal A., Kumar S. & Tiwari S.C. 2005. Analysis of land use and biomass in Khanda watershed, Garhwal Himalaya, using satellite remote sensing data. Trop. Ecol. **46 (2):** 253–263.

Vazquez G.J.A. & Givnish T.J. 1998. Altitudinal gradients in tropical forest composition, structure and avian diversity in the Sierra de Manantlan. J. Ecol. **86 (6):** 999–1020. DOI: 10.1046/j.1365-2745.1998.00325.x

Verner J. 1985. Assessment of counting techniques. Curr. Ornithol. **2:** 247–302.

Whittaker R.H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecol. Monogr. **30 (3):** 279–338. DOI: 10.2307/1943563

Wiens J.A. 1989. The Ecology of Bird Communities. Foundations and Patterns. Vol. 1, Cambridge University Press, Cambridge, 539 pp. ISBN:0521260302, 0521426340 e-book: http://www.amazon.com/Ecology-Communities-Foundations-Patterns-Cambridge/dp/052 1426340#reader_0521426340

Zar J.H. 1984. Biostatistical Analysis. Prentice-Hall, New Jersey, 718 pp. ISBN: 0130779253/0-13-077925-3.

www.nbaindia.org/faq.htm (accessed 15.05.2010)

www://pauri.nic.in/land.htm (accessed 15.05.2010)

oldwww.wii.gov.in/envis/rain_forest/chapter12 (accessed 15.05. 2010)

www.mapsofindia.com (accessed 15.05.2010)

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