

ECOLOGICAL STATUS OF THREE MICRO WATERSHEDS IN WESTERN HIMALAYA

T.V. RAMACHANDRA, N.V. JOSHI, G.R. RAO, G. DHANPAL, K.V. GURURAJA AND AMIT S. YADAV

Energy and Wetlands Research Group, Centre for Ecological Sciences
Indian Institute of Science, Bangalore – 560 012, INDIA
E mail: cestvr@ces.iisc.ernet.in, energy@ces.iisc.ernet.in

ABSTRACT

Ecological status of a particular region is determined by assessing its biodiversity, prevailing conditions of the environment and their interactions. Biodiversity assessments in micro watershed across altitudinal gradients of Western Himalaya reveal that phytodiversity includes a total of 2276 individuals from 75 woody species belonging to 38 families. Among the three micro watersheds, Mandhala was species rich with 43 species followed by Moolbari (39) and MeGad (9). In Mandhala most of the species are thorny shrubs and rarely attain tree forms due to severe anthropogenic disturbances, which also yielded very low basal area. Moolbari had the highest basal area, which had dominant species *Quercus leucotricophora* and *Q. glauca*. MeGad, a high altitude area was mostly dominated by *Abies pindrow*, *Picea smithiana* and *Pinus wallichiana*.

Faunal investigations enumerated 115 butterfly species, 14 amphibian and 136 bird species. Butterflies in the region were oriental and palaearctic in origin representing nine families. Similarly, 14 species amphibians belonging to 5 families were sighted during the field investigations. *Paa minica* is vulnerable and *Amolops chakrataensis* is data deficient according to IUCN status and these two are endemics of Himalayan foot hills. Among the three watersheds, Mandhala, lying in Shivaliks has higher faunal diversity followed by Moolbari. Amphibians were not encountered in MeGad microwatershed during Aug-Sept 07. In total 136 bird species were recorded from three watersheds, the maximum number of bird species occurred in Mandhala region (104) followed by Moolbari (57) and Me Gad (35).

Key words: Biodiversity, Ecological status, Floral and faunal diversity, Watershed, Altitudinal gradients, Western Himalaya

Introduction

Three watersheds viz., Mandhala, Moolbari and Me Gad representing lower, middle and upper Himalayas respectively in the state of Himachal Pradesh were chosen by the Ministry of Science and Technology, Government of India for implementing a coordinated, multi disciplinary and multi institutional programme "Bio-geo database and ecological modeling for Western Himalayas". The Himalayas are rich in natural resources; however over the years, Himalayan environment is increasingly being threatened due to various unplanned human activities with excessive exploitation of natural resources. It is imperative to develop strategies for sustainable management to commensurate with the increasing human pressure on the natural resources.

Himachal Pradesh is an important part of Western Himalaya covering about 11% of total Himalayan land mass. Mountain ranges in the state include Shivaliks and Trans-Himalayas with altitudes ranging from 350 to 7000 m amsl. Winter (December–February), pre-monsoon (March–June), monsoon (July–September) and post-monsoon (October–November) are major seasons in the region. Precipitation varies from snowfall to rainfall that ranges from 1000 to 2500 mm. Temperature varies

from sub-zero ranges of -30° to -40°C (in winter) at higher altitudes, whereas in the plains it ranges between 8° to 40°C. Many rivers like Beas, Sutlej, Chenab, Ravi and Yamuna originate from this region. The climate is distinguished in three axes: (i) a vertical axis determined by the effect of altitude on temperature; (ii) a transverse axis determined by topography along which rain shadow effects cause decreasing precipitation and increasingly extreme (continental) temperature fluctuations from SW to NE across the main ranges; (iii) a longitudinal axis determined by a geographical trend of decreasing monsoon precipitation (June–September) and increasing winter snowfall (December–April) from SW to NW along all the ranges. The third axis is important in determining major ecological trends over the entire length of the Himalayan chain, but it is less important than the other two axes in determining the ecology of localities within Western Himalaya (Gaston *et al.*, 1983).

The vegetation of Himachal Pradesh can be broadly classified into (i) tropical-below 1000 m, (ii) sub-tropical- between 1800-2000 m, (iii) temperate-between 1800-3500 m, (iv) subalpine- between 3500-4000 m, and (v) alpine- above 4000 m. However, these may overlap depending upon the location, topography

Biodiversity in three micro watersheds across altitudinal gradients of Western Himalaya confirm the ecological distinctness and highlight the need for conservation

and climatic conditions. The enormous variations in the altitude, latitude and longitude of the Himalayas have added to the multiplicity of habitats and provide diverse microclimates and ecological niches for all the living beings. Also, the Western Himalayan flora is species deficient whereas, the eastern Himalayan flora is species rich (Chowdhery, 1999). The Western Himalayan region which includes Jammu and Kashmir, Himachal Pradesh and hilly regions of Uttar Pradesh receives very less rain compared to its eastern counterpart, the Eastern Himalaya. As a result the Western Himalayan flora in due course of time has evolved and established itself as drought resistant and cold loving while the Eastern Himalayan flora has developed into moist evergreen type. The focus of the current communication is to assess the diversity and distribution of flora and fauna in select watersheds of Western Himalaya.

Objectives

The major objectives of this study are to assess:

- Diversity and distribution of flora in the three micro watersheds;
- Diversity and distribution of selected fauna, namely butterfly, amphibians and birds in the region.

Material and Methods

Study area

The location of three micro watersheds, which form a part of Chandrabagha, Sutlej and Yamuna river basins is given in Fig. 1. Details of the geography of the study area are given in Table 1. Plate 1 depicts the panoramic view of the studied watersheds.

Mandhala: This area has mixed deciduous forests in an altitude below 1100 m. The prominent trees and shrubs found here are *Flacourtia montana*, *Acacia catechu*, *Grewia optiva*, *Toona ciliata*, *Albizia procera*, *Haldina cordifolia*, *Acacia* sp., *Lannea coramandelica*, *Mitragyna parviflora*, along with *Nyctanthus arbor-tristis*, *Carissa apaca*, *Dodonaea viscosa* and *Woodfordia fruticosa*. Most of the forests here have been deforested and hill ranges are completely covered with *Lantana camera* an exotic invasive weed. Also scattered trees of *Holoptelia integrifolia*, *Dalbergia sisoo*, *Morus nigra*, etc. occur along the field bunds and other open lands. Figure 1

depicts the drainage network in Mandhala watershed.

Moolbari : Vegetation in this watershed consists of mixed deciduous (till an altitude of 1500 m) and sub-tropical pine forest (beyond 1500 m). Apart from *Pinus*, other species are *Pyrus pashia*, *Rubus ellipticus*, *Berberis* sp, and in moist localities species of *Quercus leucotrichophora* and *Q. glauca* and *Rhododendron arboretum*. Exposed hill slopes in pine forests have *Euphorbia royleana*. Between 1800-2300 m, oak forests species such as *Quercus leucotrichophora*, *Q. glauca* dominate along with *Rhododendron arboretum*, *Lyonia ovalifolia*, *Persia* sp., *Myrica esculenta*, *Acer oblongum*, *Cedrus deodar*, etc.

MeGad : This watershed lies in cold desert and comprises of temperate, sub-alpine and alpine vegetation. *Temperate vegetation* consists of woody trees at an altitude of 2500-3200 m such as *Pinus wallichiana*, *Juniperus recurva*, *Picea smithiana*, *Abies pindrow*, *Cedrus deodara*. Along the streams and irrigated canals are planted trees of *Salix* and *Populus* sp. Sub-alpine vegetation include stunted, scattered bushes of *Juniperus communis*, *Berberis* sp., etc along with herbaceous species such as *Ranunculus*, *Pedicularis*, *Potentilla*, *Polygonum*, *Geranium*, *Anemone*, *Corydalis*, etc. Up to 4000 m consists Alpine vegetation of herbaceous species such as *Swertia*, *Silene*, *Potentilla*, *Cordalis*, *Taraxacum*, *Astragalus*, *Rheum*, *Polygonum*, *Artimisia*, *Primula* etc., occur. Alpine meadows provide one of the most spectacular and colourful view. Majority of the alpine meadows are perennial in nature and perenate through rhizomes, root stocks, runners, suckers, bulbs, tubers or bulbils. Common herbaceous species here are *Saxifraga*, *Arenaria*, *Aster*, *Polygonum*, *Primula*, *Potentilla*, *Selinum*, *Taraxicum*, *Astragalus*, *Geranium*, *Senecio*, *Saussurea*, *Swertia*, *Erigeron*, *Corydalis*, *Rheum*, etc. Terrestrial orchids such as *Goodyera*, *Malaxis*, etc. are also seen here (Murti, 2001; Aswal and Mehrotra, 1994).

Methods

Vegetation Sampling : Systematic sampling was carried out in all three micro watersheds (Moolbari, Mandhala, and MeGad) with belt transects of 250 x 4 m. In each transect, for each tree GBH in cm (Girth at Breast Height, approximately at 130 cm above ground) and height in

Table 1: Geographical details of studied micro watersheds

Micro watersheds	District	Main watershed	Latitude (°N)	Longitude (°E)	Altitude (m amsl)	Area (km ²)
Mandhala	Solan	Yamuna	30.87-30.97	76.82-76.92	400-1100	14.5
Moolbari	Shimla	Sutlej	31.07-31.17	77.05-77.15	1400-2000	10.0
MeGad	Lahaul and Spiti	Chandrabhaga	32.64-32.74	76.46-76.74	2900-4500	45.0

metre is noted along with its identification. Unidentified plants were labelled and pressed in herbaria for later identification. Coordinates were marked using GPS (Global Positioning System) at every 100 metres interval and at the start and end points in each transect. Litter

weight is measured in four 1 m X 1 m quadrat within each transect. Using densiometer, canopy cover is measured at start, end point and at 100 metre intervals in each transect. Also, relative humidity and air temperature was taken at every 100 m and at the start and end of the transect.

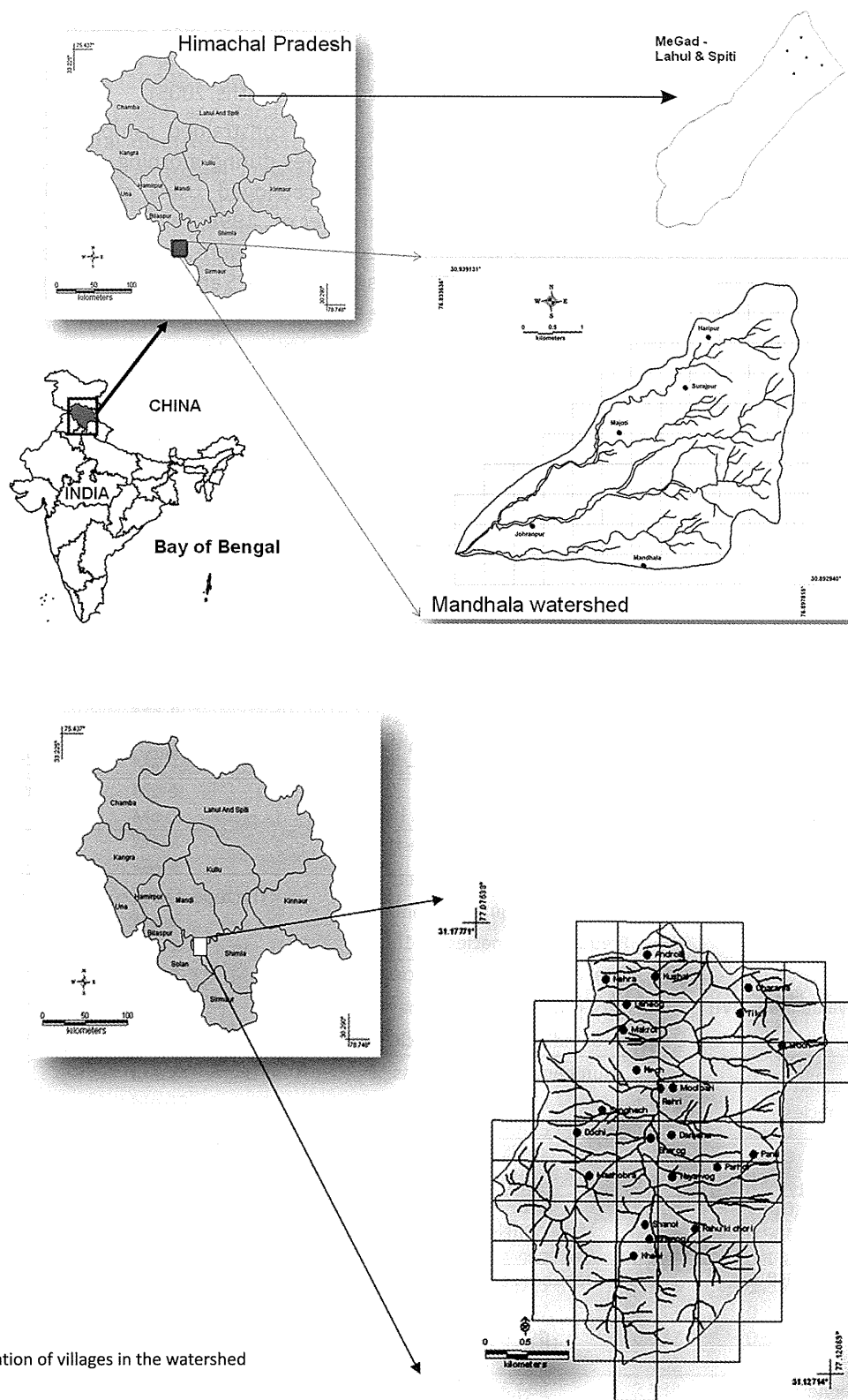


Fig. 1: Moolberi, Mandhala and Me Gad-Lahul and Spiti watersheds, Himachal Pradesh

Faunal Sampling : Focus of faunal studies are on bioindicator taxa such as butterflies, amphibians and birds.

Butterflies : In selected localities, transect based sampling (250x4 m) as well as opportunistic sampling of butterflies was carried out. Most of the butterflies were identified in the field and others were photographed and identified later with the available keys (Evans, 1932; Wynter-Blyth, 1940-1946, 1957; Erhardt, 1985; Thomas and Malorie, 1985; Mani, 1986; Leps and Spitzer, 1990; New, 1991; Scoble, 1992; Wood and Samways, 1992; Kim, 1993; Pollard and Yates, 1993; Samways, 1994; New *et al.*, 1995; Molina and Palma, 1996; Parmesan, 1996; Swengel, 1996; Blair and Launer, 1997; Spitzer *et al.*, 1997; Manel, *et al.*, 1999; Stork *et al.*, 2003; Arora *et al.*, 2005). The data was analyzed (Table 2) to calculate species diversity (using Shannon-Weiner diversity index), importance value index (IVI), etc. (Ramachandra *et al.*, 2007)

Amphibian: Amphibians are highly seasonal and majority of them breed during monsoon. Hence, field

work was carried out and identified amphibians during July-August 2007 in major land-use categories like waterbodies (streams of 1° and 2°), forests, agriculture fields, and open area between 19:00-21:00 h. We have invested 2 man-hour searches on each night. Number of individuals, sampling co-ordinates and habitat characteristics were also noted (Gaston *et al.*, 1983; Kremen, 1992; Manel *et al.*, 1999; Mehta, 2005a,b; Beebee and Griffiths, 2005).

Birds: Time constrained sampling of 1 hour in each habitat types during morning and evening was carried out and cataloged using standard keys (Ali, 1989; Grimmet *et al.*, 1998; Laiolo, 2003; Manel *et al.*, 1999). The co-ordinates were taken at the start and end point of transects using GPS and species alongwith their numbers were also recorded.

Results and Discussion

Vegetation: Vegetation studies in the Himalyan region dates back to the early 19th century by Troup (1921); Champion (1921); Osmaston (1923); Schweinfurth

Table 2: Indices computed to assess the biodiversity status

Index	Equation	Remarks
Density	$\frac{\text{Number of species A}}{\text{Area sampled (m}^2\text{)}}$	Compactness with which a species exists in an area.
Relative Density	$\frac{\text{Density of species A} \times 100}{\text{Total density of all species}}$	
Dominance	$\frac{\text{Basal area of species A}}{\text{Area sampled (m}^2\text{)}}$	The occupancy of a species over an area
Relative dominance	$\frac{\text{Dominance of species A} \times 100}{\text{Total dominance of all species}}$	
Frequency	$\frac{\text{Number of quadrats with species A}}{\text{Total number of quadrats sampled}}$	The repeated occurrence of a species
Relative Frequency	$\frac{\text{Frequency of species A} \times 100}{\text{Total frequency of all species}}$	
Important Value Index (IVI)	R. density + R. frequency + R. basal area	
Abundance	$\frac{\text{Number of individuals of a species} \times 100}{\text{Number of sampling units}}$	
Numerical species	S-1	S= Number of species
Richness	log N	N= Number of Individuals
Simpson Diversity index	$\frac{\sum n_i (n_i - 1)}{N(N-1)}$	N _i = Number of individuals in each species N= Total number of individuals
Simpson dominance index	Dominance = $\sum (n_i/N)^2$	
Shannon Weiner's Index	$H' = -\sum P_i \ln P_i$	P _i = n _i /N
Pielou's evenness measure	E=H'/log S	H'= Shannon-Weiner's index S= Number of species

(1957); Puri (1960) and Champion and Seth (1968). Quantitative assessments of vegetation in western and central Himlaya were carried out by Saxena (1979); Negi (1979); Ralhan *et al.* (1982); Saxena and Singh (1982a,b); Tewari (1982); Tewari and Singh (1985); Upreti *et al.* (1985); Singh and Singh (1984 a, b and c); Singh *et al.* (1985). Singh and Singh (1987); Rikhari *et al.* (1989); Tewari *et al.* (1989); Reddy (1989); Lodhiyal (1990); Rawal (1991); Singh and Rawat (1999) and Rana *et al.* (2010). Plate 2 depicts the floral diversity across watersheds (high altitude, mid and low altitudes). Ecological studies in the Kumaun region in the eastern part of Western Himalaya has been done by Adhikari (1992, 1995). In this backdrop, this study was undertaken to assess the floral diversity in the study areas which are ecologically distinct and hitherto least studied region. Quantitative assessment of woody species in the three micro watersheds is detailed in Table 3. Transects are named

with first two letters of the microwatershed (abbreviations Ma: Mandhala, Mo-Moolbari and Me: Me Gad). Transect wise analysis in each of the micro watershed is discussed below.

Moolbari: Total number of species (15 species) and number of individuals (188) was high in Mo-15, which is *Rhododendron arboreum* and *Quercus* mixed forest. Mo-4 was species deficient (5 species) as these forests were dominated by *Quercus glauca*. Mo-1 had the highest basal area contributed mainly by *Quercus glauca* followed by *Quercus leuchotrichophora*. Mo-15 showed highest Pielou species richness value of 2.67, while it was lowest in Mo-4 with 0.92. Shannon diversity was highest in Mo-15 (1.72). This is due to the presence of several evergreen species such as *Persea*, *Euonymous*, *Myrica* sp. etc., in the valleys. The higher slopes generally has *Quercus* species, mixed with *Rhododendron*. With dominance value of 0.73, Mo-11 showed the highest

Table 3 : Micro watershed wise Vegetation analysis

Watershed	Transect	Species	Individuals	Basal area (m ²)	Shannon's	sim-div	Pielou
Mandala	Ma-1	16	66	0.597	2.113	0.79	0.762
	Ma-2	21	77	1.242	2.655	0.901	0.872
	Ma-3	16	43	0.899	2.403	0.872	0.867
	Ma-4	13	29	0.406	2.240	0.861	0.873
	Ma-5	5	9	0.538	1.465	0.741	0.910
	Ma-6	12	84	0.569	1.454	0.572	0.585
	Ma-7	5	11	0.071	1.160	0.562	0.720
	Ma-8	6	76	0.432	0.637	0.264	0.356
	Ma-9	3	27	0.553	0.727	0.412	0.662
	Ma-10	6	9	0.261	1.677	0.790	0.936
	Ma-11	8	16	0.210	1.890	0.820	0.909
Moolbari	Mo-1	10	158	3.471	1.564	0.707	0.679
	Mo-2	11	129	3.137	1.428	0.658	0.595
	Mo-3	7	89	3.059	1.095	0.593	0.563
	Mo-4	5	75	2.198	0.694	0.354	0.431
	Mo-5	9	85	2.388	1.256	0.563	0.572
	Mo-6	6	83	2.335	1.057	0.577	0.590
	Mo-7	6	101	2.407	1.107	0.552	0.618
	Mo-8	6	66	2.509	1.325	0.652	0.740
	Mo-9	11	64	1.668	1.330	0.563	0.555
	Mo-10	8	79	1.458	1.454	0.682	0.699
	Mo-11	6	108	1.131	0.626	0.268	0.349
	Mo-12	8	62	1.351	1.298	0.621	0.624
	Mo-13	12	131	3.235	1.002	0.405	0.403
	Mo-14	13	102	2.695	1.480	0.631	0.577
	Mo-15	15	188	2.893	1.727	0.759	0.638
	Mo-16	7	58	0.730	1.301	0.626	0.669
MeGad	Me-1	4	39	2.050	0.908	0.523	0.655
	Me-2	3	31	2.361	0.923	0.564	0.840
	Me-3	3	31	3.507	0.668	0.398	0.608
	Me-4	3	18	1.995	0.426	0.204	0.388
	Me-5	1	1	0.207	0	0	0
	Me-6	3	22	2.520	0.937	0.558	0.853
	Me-7	2	30	4.056	0.637	0.444	0.918
All	Mandhala	446	43	6.664	2.688	0.842	0.706
	Moolbari	1649	39	39.94	1.805	0.695	0.493
	MeGad	177	9	16.70	1.428	0.720	0.650

species dominance and had low Simpson value (0.34). This higher dominance is mainly due to *Quercus leucotrichophora*, which has 92 individuals and only 16 individuals of all other species.

The higher dominance of *Quercus leucotrichophora* is reflected in the IVI value of 109.40, which is the highest for Moolbari water shed (Table 4). This is followed by *Quercus glauca* with 62.18. *Pinus roxburghii* is found extensively covering some of the slopes and has an IVI of 16.49. Mixed with these dominant species are species of *Acer oblongum* with IVI of 13.39, *Myrica esculenta* with

13.01. *Rhododendron arboreum* with IVI of 9.08 mostly occurred in Mo-15, which is relatively wetter compared to other transects. Other species such as *Cedrus deodara* with IVI of 8.01 occurred in valleys and *Pyrus pashia* with 6.98 is scattered throughout the watershed.

Mandhala: Eleven transects were laid in Mandhala water shed area. Total individuals recorded in these transects were 447 with the highest number of individuals (84) recorded in Ma-6. *Acacia catechu* with higher number of individuals constitutes a dominant species. This species was planted earlier by forest department under

Table 4: IVI for woody species in Mandhala, Moolbari and Me Gad watersheds

Mandhala watershed			Moolbari watershed			MeGad watershed		
Sl	Species	IVI	Sl	Species	IVI	Sl	Species	IVI
1	<i>Acacia catechu</i>	61.19	1	<i>Quercus leucotrichophora</i>	109.4	1	<i>Abies pindrow</i>	94.61
2	<i>Flacourtia indica</i>	28.51	2	<i>Quercus glauca</i>	62.18	2	<i>Pinus wallichiana</i>	83.30
3	<i>Mangifera indica</i>	26.04	3	<i>Pinus roxburghii</i>	16.49	3	<i>Picea smithiana</i>	58.58
4	<i>Lannea coromandelica</i>	19.07	4	<i>Acer oblongum</i>	13.39	4	<i>Salix denticulate</i>	27.34
5	<i>Anogeissus latifolia</i>	15.35	5	<i>Myrica esculenta</i>	13.01	5	<i>Juglans regia</i>	9.70
6	<i>Dalbergia sissoo</i>	9.45	6	<i>Rhododendron arboreum</i>	9.08	6	<i>Malus baccata</i>	7.72
7	<i>Mitragyna parviflora</i>	9.39	7	<i>Cedrus deodara</i>	8.01	7	<i>ui-Krown</i>	7.07
8	<i>Grewia optiva</i>	8.58	8	<i>Pyrus pashia</i>	6.98	8	<i>Cassia sp</i>	5.85
9	<i>Cassia fistula</i>	7.99	9	<i>Grewia sp</i>	6.04	9	<i>Juniperus macropoda</i>	5.83
10	<i>Woodfordia fruticosa</i>	7.88	10	<i>Pistachia integrima</i>	5.74			
11	<i>Azadirachta indica</i>	7.42	11	<i>Lyonia ovalifolia</i>	5.32			
12	<i>Eucalyptus</i>	7.18	12	<i>Species A</i>	4.57			
13	<i>Butea monosperma</i>	6.28	13	<i>Euonymus tingens</i>	3.51			
14	<i>Dodonea viscosa</i>	6.24	14	<i>Punica granatum</i>	3.23			
15	<i>Murraya koenigii</i>	4.96	15	<i>Euphorbia royleana</i>	2.72			
16	<i>Carissa spinarium</i>	4.78	16	<i>Species B</i>	2.53			
17	<i>Syzygium cumini</i>	4.74	17	<i>Ficus nemoralis</i>	2.02			
18	<i>Phoenix sylvestris</i>	4.73	18	<i>Berberis aristata</i>	1.78			
19	<i>Adina cordifolia</i>	4.68	19	<i>Euonymus hamiltonia</i>	1.78			
20	<i>Species 1</i>	4.54	20	<i>Bauhinia variegata</i>	1.74			
21	<i>Acacia nilotica</i>	3.84	21	<i>Prunus cerasoides</i>	1.73			
22	<i>Ficus racemosa</i>	3.72	22	<i>Celtis australis</i>	1.69			
23	<i>Pinus roxburghii</i>	3.50	23	<i>Persea sp</i>	1.65			
24	<i>Randia sp</i>	2.99	24	<i>Grewia optiva</i>	1.59			
25	<i>Acacia leucophloea</i>	2.97	25	<i>Cupressus torulosa</i>	1.29			
26	<i>Zanthoxylum alatum</i>	2.81	26	<i>Euonymus sp</i>	1.17			
27	<i>Holoptilia integrifolia</i>	2.64	27	<i>Tiliaceae</i>	1.17			
28	<i>Morus nigra</i>	2.54	28	<i>Toona ciliata</i>	1.12			
29	<i>Albizia lebbbeck</i>	2.51	29	<i>Species C</i>	0.89			
30	<i>Bambusa sp</i>	2.14	30	<i>Species D</i>	0.87			
31	<i>Species 4</i>	2.09	31	<i>Hypericum</i>	0.86			
32	<i>Species 2</i>	2.09	32	<i>Ficus pumila</i>	0.85			
33	<i>Leucena leucocephala</i>	1.92	33	<i>Species E</i>	0.83			
34	<i>Diospyros montana</i>	1.71	34	<i>Species F</i>	0.82			
35	<i>Jasminum multiflora</i>	1.64	35	<i>Ficus sp</i>	0.80			
36	<i>Pyrus pashia</i>	1.44	36	<i>Cornus capitata</i>	0.79			
37	<i>Hamiltonia suaveolens</i>	1.42	37	<i>Vitis vinifera</i>	0.79			
38	<i>Zizypus mauritiana</i>	1.42	38	<i>Rhamnus sp</i>	0.79			
39	<i>Punica granatum</i>	1.41	39	<i>Rubus ellipticus</i>	0.78			
40	<i>Species 5</i>	1.27						
41	<i>Nyctanthus arbor-tristis</i>	1.18						
42	<i>Ipomea carnea</i>	1.18						
43	<i>Lantana camara</i>	1.16						

afforestation programme. Lower number of individuals was recorded in Ma-5 and Ma-10 with severe degradation. Species richness was more in Ma-2 with 21 species and lowest in Ma-9 with 3 species. Basal area was highest in Ma-2 and lowest in Ma-7. Table 3 details transect-wise data for all three micro watersheds. The higher species diversity and basal area in Ma-2 can be attributed to the fenced protection provided by the farmers residing in the region that has ensured the survival of saplings. Hills adjoining this transect without fencing were totally barren, filled with impenetrable thickets of *Lantana* shrubs. The highest diversity was in Ma-2, which also has highest Shannon value of 2.6, Simpson diversity of 0.9 and dominance value of 0.09. The least diversity was in Ma-8 dominated by *Acacia catechu* with Shannon value of 0.63 and dominance of 0.73. *Acacia catechu* had the highest IVI of 61.19, followed by *Flacourtia indica* (28.51), *Mangifera indica*, (26.04), *Odina* (19.07), and *Anogeissus latifolia* (15.35) as listed in Table 4. Dominating deciduous trees in the region are *Acacia catechu*, *Flacourtia indica*, *Anogeissus latifolia* and *Odina wodiya*.

MeGad: This micro watershed is relatively species poor. However, basal area was highest in Me-7 with 4.05 contributed by *Abies pindrow* and *Pinus wallichiana*. The lowest basal area was in Me-5 with 0.27, predominantly sub-alpine grasslands with scattered trees. The overall species diversity in MeGad was very low with Shannon diversity of 0.9 in Me-1, with only 4 species in entire transect. Me-5 is a alpine grassland and cultivated in some areas had only one species with lowest diversity.

Abies pindrow with 94.61 and *Pinus wallichiana* with 83.30 show a very high IVI value (Table 4). These are followed by *Picea smithiana* (58.58) and *Salix denticulate* (27.34).

Discussion

Mandhala, Moolbari, and Me Gad micro watersheds had a total of 2276 individuals from 75 woody species from 34 belt transects, relatively higher than earlier reports (Singh and Rawat, 1999; Rana *et al.*, 2010). A total of 38 families were recorded, of which Fabaceae had the highest number of species (7), followed by Rosaceae, Pinaceae and Moraceae (5 each). The highest number of individuals per species was *Quercus leucotriphora* with 811 individuals followed by *Q. glauca* (394), *Acacia catechu* (157), *Myrica esculenta* (73), *Pinus roxburghii* (72), *Abies pindrow* (70) and *Flacourtia indica* (68).

Species richness was highest in Mandhala (45 species) followed by Moolbari (39) and MeGad (9). Although Mandala had the highest species diversity, it

had lowest dominance. Most of the species are thorny shrubs and rarely attain tree forms due to severe anthropogenic disturbances in this watershed, hence very low basal area is observed compared to number of other species. In Moolbari, which had the highest basal area (39.94) was mainly contributed by *Quercus leucotricophora* and *Q. glauca*. In Mandhala, the negligible basal area found was due to absence of large trees as in Moolbari or MeGad, due to the earlier deforestation and extensive encroachment of forestland by obnoxious weed *Lantana camara*. This shrub has totally covered the lower slopes in Mandhala making it an unsuitable habitat for wildlife as well as domesticated animals. Also regeneration of forest plant species has totally ceased due to the permanent cover created by this bush.

Overall *Quercus* species dominated in the Moolbari watershed area, while deciduous species such as *Acacia catechu*, *Flacourtia indica* dominated in Mandala watershed. MeGad, a high altitude area was dominated by *Abies pindrow*, *Picea smithiana* and *Pinus wallichiana*, which is reflected in the IVI values (Table 4).

Faunal diversity

Butterfly: The present study enumerated 115 butterfly species of oriental and palaearctic origin representing nine families. Nymphalidae is the dominant family (32 sp.) followed by Pieridae (19 sp.), Lycaenidae (16 sp.), Satyridae and Papilionidae (12 sp. each), Hesperidae (10 sp.), Danaidae (8 sp.), Erycidae (4 sp.) and Acraeidae (2 sp.). Table 5 details the butterflies in the three micro watersheds identified based on standard keys (Wynter-Blyth, 1940-1946, 1957; Thomas and Malorie, 1985; Mani, 1986; Leps and Spitzer, 1990; New 1991; Scoble, 1992; Wood and Samways, 1992; Kim, 1993; Pollard and Yates, 1993; Samways, 1994; New *et al.*, 1995; Molina and Palma, 1996; Parmesan, 1996; Swengel, 1996; Blair and Launer, 1997; Spitzer *et al.*, 1997; Stork *et al.*, 2003)

- The family Papilionidae is commonly known as Swallowtail family, comprising some of the larger butterflies. In the study area, this family representing two sub-families viz., Parnasiinae (Apollos) and Papilioninae. Three species of apollos namely *Parnassius hardwickii hardwickii* (Common Blue Apollo) in Moolbari watershed and *Parnassius delphi* (Banded Apollo) and *Parnassius charltonius* (Regal Apollo) in the open grassy and rocky areas of Megad watershed were seen. The sub-family Papilioninae represented by *Papilio protenor protenor* (Spangle) and *Chilasa agestor* (Tawny Mime).
- The Family Pieridae commonly known as Whites

Table 5: Butterfly species across three micro watersheds of Himachal Pradesh

Sl. No.	Family	Species	Moolbari	Mandhala	Megad
1	Papilionidae	<i>Parnassius hardwickii hardwickii</i>	+		
2		<i>Parnassius delphius</i>			+
3		<i>Parnassius charltonius</i>			+
4		<i>Papilio polyctor polyctor</i>	+	+	
5		<i>Papilio polytes romulus</i>	+	+	
6		<i>Papilio demoleus</i>	+	+	
7		<i>Papilio protenor protenor</i>	+		
8		<i>Graphium serpedon</i>	+		
9		<i>Graphium agamemnon</i>		+	
10		<i>Graphium doson</i>		+	
11		<i>Chilasa clytia clytia</i>	+		
12		<i>Chilasa agestor</i>	+		
13	Pieridae	<i>Appias lalage</i>	+		
14		<i>Appias libythea</i>	+		
15		<i>Cepora nerissa phryne</i>	+	+	
16		<i>Catopsilia pomona</i>	+	+	
17		<i>Catopsilia pyranthe pyranthe</i>	+		
18		<i>Eurema brigitta rubella</i>	+	+	
19		<i>Eurema laeta laeta</i>	+		
20		<i>Eurema hecabe</i>	+	+	
21		<i>Ixias marianne</i>	+		
22		<i>Ixias pyrene</i>	+	+	
23		<i>Pieris canidia indica</i>	+	+	+
24		<i>Pieris brassicae nepalensis</i>			+
25		<i>Delias eucharis</i>		+	
26		<i>Pareronia valeria</i>		+	
27		<i>Aporia nabellica</i>			+
28		<i>Baltia butleri</i>			+
29		<i>Colias eogene eogene</i>			+
30		<i>Colias fieldii</i>			+
31		<i>Pontia daplidice moorei</i>			+
32	Danaidae	<i>Danaus chrysippus</i>	+	+	
33		<i>Danaus genutia</i>	+	+	
34		<i>Euploea core core</i>		+	
35		<i>Euploea mulciber mulciber</i>	+		
36		<i>Parantica sita sita</i>	+		
37		<i>Tirumala limniace</i>	+	+	
38		<i>Tirumala septentrionis</i>	+	+	
39		<i>Parantica aglea</i>		+	
40	Satyridae	<i>Mycalesis francisca sanatana</i>	+		
41		<i>Mycalesis mineus mineus</i>	+		
42		<i>Mycalesis perseus</i>		+	
43		<i>Ypthima asterope</i>	+	+	
44		<i>Ypthima narenda narenda</i>	+		
45		<i>Ypthima baldus baldus</i>		+	
46		<i>Melanitis leda leda</i>		+	
47		<i>Orsotriaena medus</i>		+	
48		<i>Aulocera loha</i>			+
49		<i>Aulocera swaha swaha</i>			+
50	Nymphalidae	<i>Callerebia annada</i>			+
51		<i>Callerebia shallada</i>			+
52		<i>Nymphalis (Aglais) kashmirensis</i>	+		
53		<i>Nymphalis (Aglais) ladakensis</i>	+		+
54		<i>Argyreus hyperbius hyperbius</i>	+	+	
55		<i>Ariadne merione</i>	+	+	
56		<i>Athyma opalina</i>	+		
57		<i>Athyma perius</i>	+	+	
58		<i>Athyma asura</i>	+		
59		<i>Mimathyma ambica ambica</i>	+		

Sl. No.	Family	Species	Moolbari	Mandhala	Megad
60		<i>Cyrestis thyodamas thyodamas</i>	+		+
61		<i>Hestina persimilis</i>	+		
62		<i>Hestina</i> sp.			+
63		<i>Euthalia lubentina</i>	+		
64		<i>Euthalia aconthea garuda</i>		+	
65		<i>Hypolimnas bolina</i>	+	+	
66		<i>Hypolimnas misippus</i>	+	+	
67		<i>Junonia iphita</i>	+	+	
68		<i>Junonia hierta</i>	+	+	
69		<i>Junonia orithya</i>	+	+	
70		<i>Junonia lemonias persicaria</i>	+	+	
71		<i>Junonia almana</i>	+	+	
72		<i>Junonia atilites</i>		+	
73		<i>Kallima inachus</i>	+		
74		<i>Kaniska canace canace</i>	+		
75		<i>Neptis hylas</i>	+	+	
76		<i>Neptis</i> sp.			+
77		<i>Phalanta phalanta</i>	+	+	
78		<i>Polyura athamas athama</i>	+		
79		<i>Vanessa cardui</i>	+	+	
80		<i>Vanessa indica</i>	+		+
81		<i>Limenitis procris</i>		+	
82		<i>Childrena childreni</i>			+
83		<i>Melitaea arceisa</i>			+
84	Acraeidae	<i>Acraea terpsicore</i>	+	+	
85		<i>Acraea issoria</i>	+		
86	Erycinidae	<i>Dodona durga</i>	+		
87		<i>Lybythea celtis lepita</i>	+		
88		<i>Lybithea myrrha</i>	+		
89		<i>Abisara echerius suffusa</i>		+	
90	Lycaenidae	<i>Lycaena phlaeas</i>	+		
91		<i>Lycaena kasyapa</i>			+
92		<i>Aricia agestis nazira</i>	+		
93		<i>Castalius rosimon</i>	+	+	
94		<i>Chrysozephyrus</i> sp.	+		
95		<i>Heliophorus sena</i>	+		
96		<i>Pseudozizeeria maha</i>	+	+	
97		<i>Tajuria cippus</i>	+		
98		<i>Zizula hylax</i>	+		
99		<i>Euchrysops cnejus</i>		+	
100		<i>Jamides celeno</i>		+	
101		<i>Chilades pandava pandava</i>			+
102		UI			+
103		UI			+
104		<i>Polyommatus stoliczkanus janetae</i>			+
105		<i>Thecla</i> sp.			+
106	Hesperiidae	<i>Borbo cinnara</i>	+		
107		<i>Coladenia indrani indrani</i>	+		
108		<i>Pelopidas sinensis</i>	+		
109		<i>Pelopidas mathias mathais</i>	+		
110		<i>Polytremis eltola</i>	+		
111		<i>Spialia galba</i>	+		
112		<i>Suastus gremius</i>	+		
113		<i>Telicota pythias</i>	+		
114		<i>Sarangesa dasahara dasahara</i>		+	
115		<i>Udaspes folus</i>	+	+	

or Yellows seen in MeGad watershed are *Pieris brassicae nepalensis* (Large Cabbage White),

Aporia nabellica (Dusky Blackvein), *Pontia daplidice moorei* (Bath White) and *Colias* sp.

- (Clouded yellows).
- More species of the family Satyridae and Nymphalidae were recorded during the survey. *Nymphalis* (Aglaia) *kashmirensis* (Common Tortoiseshell), *Nymphalis* (Aglaia) *ladakensis* (Ladakh Tortoiseshell), *Vanessa indica* (Red Admiral), *Kaniska canace canace* (Blue Admiral), *Aulocera* sp. (Satyrs), *Callerebia* sp. (Arguses) and *Melitaea arceisa* (Blackvein Fritillary) were recorded in Moolbari and Megad watersheds.
 - Family Erycinidae is commonly known as family of Beaks, Punches and Judies, which are represented by *Dodona durga* (Common Punch), *Lybithea* sp. (Beaks) in Moolbari and *Abisara echerius suffusa* (Plum Judy) in Mandhala watershed.
 - Lycaenidae is commonly known as family of Blues are represented by *Heliophorus sena* (Sorrel Sapphire), *Tajuria cippus* (Peacock Royal) and *Chrysozephyrus* sp. (Hairstreak) in Moolbari watershed and *Lycaena kasyapa* (Green Copper)

Table 6: Amphibian diversity in the three micro watersheds of Himachal Pradesh

Species#	Mandhala	Moolbari	Megad	IUCN status
Bufonidae				
<i>Bufo himalayanus</i>	0	1	0	Least concern
<i>Bufo</i> sp.	1	1	0	
<i>Bufo stomaticus</i> *	1	1	0	Least concern
<i>Duttaphrynus melanostictus</i>	1	1	0	Least concern
Microhylidae				
<i>Microhyla ornate</i>	1	0	0	Least concern
Dicroglossidae				
<i>Euphlyctis cyanophlyctis</i>	1	0	0	Least concern
<i>Fejervarya limnocharis</i> *	0	1	0	Least concern
<i>Fejervarya</i> sp.	1	0	0	Least concern
<i>Hoplobatrachus crassus</i>	1	0	0	Least concern
<i>Hoplobatrachus tigerinus</i> *	1	0	0	Least concern
<i>Paa minica</i>	1	1	0	Vulnerable
<i>Sphaerotheca breviceps</i>	1	0	0	Least concern
Ranidae				
<i>Amolops chakrataensis</i>	0	1	0	Data deficient
Rhacophoridae				
<i>Polypedates maculatus</i>	1	0	0	Least concern
Species richness	10	6	0	

Nomenclature based on Frost *et al.* (2006)

* Observation by Zoological Survey of India.

Table 7: Relative abundance (individuals/hour of search) of amphibians recorded during the study.

Species	Mandhala	Moolbari	MeGad
Bufonidae			
<i>Bufo himalayanus</i>	0	1	0
<i>Bufo</i> sp.	15		
<i>Duttaphrynus melanostictus</i>	1	10	0
Microhylidae			
<i>Microhyla ornate</i>	2	0	0
Dicroglossidae			
<i>Euphlyctis cyanophlyctis</i>	39	0	0
<i>Fejervarya rufescens</i>	5	0	0
<i>Hoplobatrachus crassus</i>	2	0	0
<i>Paa minica</i>	1	8	0
<i>Sphaerotheca breviceps</i>	2	0	0
Ranidae			
<i>Amolops chakrataensis</i>	0	1	0
Rhacophoridae			
<i>Polypedates maculatus</i>	4	0	0
Shannon's index	1.43	1.01	0
Simpson's index	2.8	2.41	0

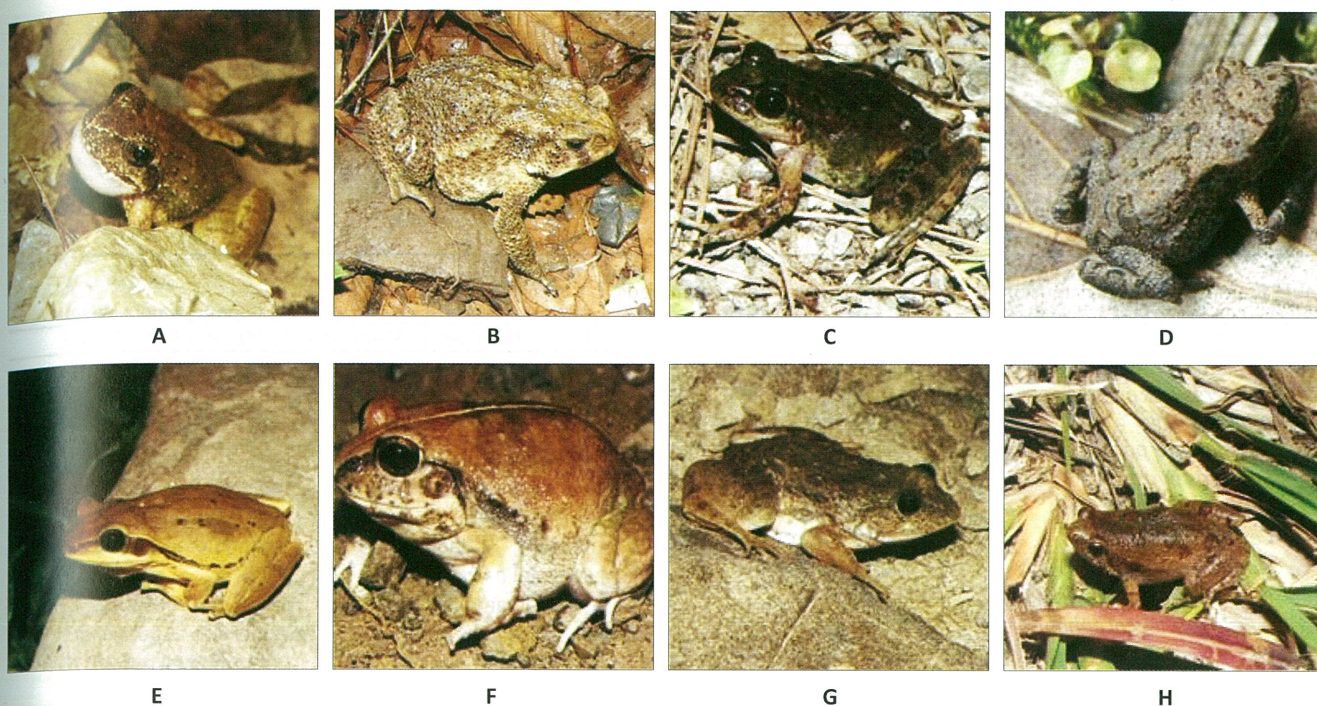


Fig. 2 : Amphibians from Moolbari and Mandhala watersheds. A. *Paa minica* B. *Bufo himalayanus* C. *Amolops chakrataensis* D. *Bufo* sp. E. *Polypedates maculatus* F. *Sphaerotheca breviceps* G. *Euphlyctis cyanophlyctis* H. *Microhyla ornata*



Plate 1: Mandhala, Moolbari and MeGad Watersheds, Himachal Pradesh



Plate 2: Vegetation profile in the watersheds

and *Polyommatus stoliczkanus janetae* (Common Meadow Blue) in Megad watershed.

Amphibians: In the present study, 14 species were observed belonging to 5 families and diversity is listed in Table 6. Of the 5 families, Dicoglossidae represents 7 species, followed by Bufonidae (4) and Microhylidae, Ranidae and Rhacophoridae (1 species each). Six species are first reported from this study.

Table 7 details the relative abundance in three watersheds comparable to the earlier reports (Mehta, 2005a, b; Beebee and Griffiths, 2005). Figure 2 depicts few amphibians recorded during this study. Mandhala watershed located in the Shivaliks is bestowed with numerous ponds, pools, streams and rivers. Most of the streams and river drain off the rainwater as soon as it rains, without any water retaining in the streams. Only ponds and pools retain water for considerable time and

Table 8: Habitat wise bird species richness in Moolbari, Mandhala and Me Gad watersheds

Habitat	Number of Species -watershed		
	Moolbari	Mandhala	Me Gad
Forest	25	65	29
Forest and Agriculture	33	42	
Riverine	35	43	
Agriculture	21	47	23
Glacier			11

Table 9: Comparative distribution of bird species in the three watersheds

Scientific names	Species	Number	Mandhala	Moolbari	MeGad
<i>Ocyrceros bipostris</i>	Indian Grey Hornbill	11	-	+	-
<i>Dicrurus leucophaeus</i>	Ashy drongo	1	-	+	-
<i>Prinia socialis</i>	ashy prinia	7	+	-	-
<i>Terpsiphone paradisi</i>	Asian paradise flycatcher	10	+	+	-
<i>Stachyris pyrrhops</i>	Black chinned babbler	2	+	-	-
<i>Francolinus francolinus</i>	Black Francolin	2	+	-	-
<i>Certhia himalayana</i>	bar tailed tree creeper	6	-	+	-
<i>Hirundo rustica</i>	Barn swallow	9	-	-	+
<i>Ploceus philippinus</i>	Baya weaver	4	+	-	-
<i>hypsipetes leucocephalus</i>	Black bulbul	31	+	+	-
<i>Dicrurus macrocercus</i>	Black drongo	83	-	+	-
<i>Ictinaetus malayensis</i>	black eagle	7	+	+	-
<i>Parus Xanthogenys</i>	Black lored tit	13	+	+	+
<i>Phoenicurus ochrurus</i>	Black redstart	2	-	+	-
<i>Elanus caeruleus</i>	black shouldered kite	1	+	-	-
<i>Psittacula roseata</i>	blossom headed parakeet	6	-	+	-
<i>Nyctornis athertoni</i>	Blue bearded bee eater	2	-	+	-
<i>Monticola cynclorhynchus</i>	Blue capped rock thrush	2	-	+	-
<i>Megalaima asiatica</i>	blue throated barbet	1	-	+	-
<i>Myophonus caeruleus</i>	Blue whistling thrush	30	-	+	+
<i>Sturnus pagodarum</i>	brahmny myna	8	+	-	-
<i>Megalaima zeylanica</i>	brown headed barbet	1	-	+	-
<i>bubulcus ibis</i>	cattle egret	13	+	-	-
<i>Motacilla citreola</i>	citrine wagtail	5	-	-	+
<i>Turdoides caudatus</i>	common babbler	6	+	-	-
<i>Falco tinnunculus</i>	common kestrel	1	-	-	+
<i>Alcedo atthis</i>	Common Kingfisher				
<i>Acridotheres tristis</i>	common myna	146	+	+	-
<i>Megalaima haemacephala</i>	coppersmith barbet	4	+	-	-
<i>Centropus sinensis</i>	Greater coucal	2	+	-	-
<i>Melophus lathami</i>	crested bunting	14	+	-	-
<i>Spilornis cheela</i>	crested serpent eagle	1	+	-	-
<i>Aethopyga siparaja</i>	crimson sunbird	1	+	-	-
<i>Phylloscopus fuscatus</i>	Dusky warbler	33	+	+	+
<i>Streptopelia decaocto</i>	eurasian collared dove	1	+	+	-
<i>Carduelis carduelis</i>	European goldfinch	2	-	-	+
<i>Rhipidura aureola</i>	White browed fantail	1	+	-	-
<i>Serinus pusillus</i>	fire fronted serin	23	-	-	+
<i>Dicaeum agile</i>	Thick billed flowerpecker	2	+	-	+
<i>Oriolus oriolus</i>	golden oriole	9	+	-	-
<i>Parus major</i>	Great tit	3	+	+	+
<i>Merops orientalis</i>	green bee eater	3	+	+	-
<i>Treron sphenura</i>	Wedge tailed green pigeon	12	+	+	-
<i>Prinia hodgsonii</i>	Grey breasted prinia	31	+	-	-
<i>Dendrocopos canicapillus</i>	grey capped pygmy woodpecker	2	-	+	-
<i>Culicicapa ceylonensis</i>	Grey headed flycatcher	3	-	+	-
<i>Seicercus xanthoschistos</i>	grey hooded warbler	19	+	+	-
<i>Saxicola ferrea</i>	Grey bushchat	1	-	+	-
<i>Lanius minor</i>	Lesser grey shrike	7	-	-	+

Scientific names	Species	Number	Mandhala	Moolbari	MeGad
<i>Dendrocitta formosae</i>	Grey tree pie	7	-	+	-
<i>Hierococcyx varius</i>	Common hawk cuckoo	8	+	-	-
<i>Megalaima virens</i>	Himalayan barbet	4	-	+	-
<i>Pycnonotus leucogenys</i>	Himalayan bulbul	151	+	+	-
<i>Dendrocopos himalayensis</i>	Himalayan woodpecker	2	-	+	-
<i>Upupa epops</i>	hoopoe	11	+	-	+
<i>corvus splendens</i>	house crow	11	+	+	+
<i>Passer domesticus</i>	house sparrow	185	+	+	+
<i>Apus affinis</i>	house swift	17	+	-	-
<i>Phylloscopus humei</i>	hume's warbler	6	-	-	+
<i>Cuculus micropterus</i>	indian cuckoo	6	+	-	-
<i>Pavo cristatus</i>	Indian peafowl	15	+	-	-
<i>Saxicoloides fulicata</i>	indian robin	64	+	-	-
<i>Aegithina tiphia</i>	iora	2	+	-	-
<i>Turdoides striatus</i>	jungle babbler	133	+	+	-
<i>Corvus macrorhynchos</i>	Jungle crow	142	+	+	+
<i>Lophura leucomelanos</i>	Kalij pheasant	15	+	+	-
<i>Eudynamis scolopacea</i>	Koel	15	+	+	-
<i>Bubo bubo</i>	Eurasian Eagle owl	2	-	-	+
<i>Streptopelia senegalensis</i>	laughing dove	1	+	-	-
<i>Phylloscopus chloronotus</i>	lemon rumped warbler	14	-	-	+
<i>Dinopium javanense</i>	lesser flameback woodpecker	3	+	-	-
<i>Sylvia curruca</i>	lesser white throat	2	-	-	+
<i>Picus chlorolophus</i>	Lesser yellow nape woodpecker	3	-	+	-
<i>Phalacrocorax niger</i>	little cormorant	3	+	-	-
<i>Egretta garzetta</i>	little egret	21	+	-	-
<i>Tachybaptus ruficollis</i>	little grebe	2	+	-	-
<i>Copsychus saularis</i>	magpie robin	5	+	+	-
<i>Spizaetus nipalensis</i>	mountain hawk eagle	1	+	-	-
<i>Treron bicincta</i>	Orange breasted green pigeon	2	+	+	-
<i>Streptopelia orientalis</i>	Oriental turtle dove	47	+	+	+
<i>Anthus rufulus</i>	paddyfield pipit	2	-	-	+
<i>Milvus migrans</i>	paraiah kite	3	+	-	-
<i>Psittacula eupatria</i>	alexandrine parakeet	6	+	-	-
<i>Francolinus pondicerianus</i>	Grey Francolin	6	+	-	-
<i>Falco peregrinus</i>	peregrine falcon	11	-	-	+
<i>Saxicola caprata</i>	pied bushchat	26	+	-	-
<i>Clamator jacobinus</i>	pied cuckoo	5	+	-	-
<i>Psittacula cyanocephala</i>	Plum headed parakeet	4	+	-	-
<i>Ardeola grayii</i>	pond heron	2	+	-	-
<i>Nectarinia zeylonica</i>	purple rumped sunbird	3	+	+	-
<i>Nectarinia asiatica</i>	Purple sunbird	39	+	+	-
<i>Urochssa erythrorhyncha</i>	Red billed blue magpie	21	-	+	-
<i>Streptopelia tranquebarica</i>	red collard dove	2	+	-	-
<i>Gallus gallus</i>	Red jungle fowl	3	+	+	-
<i>Hirundo daurica</i>	Red rumped swallow	48	+	+	-
<i>Pycnonotus cafer</i>	Red vented bulbul	73	+	+	-
<i>Vanellus indicus</i>	Red wattled lapwing	4	+	-	-
<i>Acrocephalus dumetorum</i>	Blyth's reed warbler	1	-	-	-
<i>Sterna aurantia</i>	river tern	1	+	-	-
<i>columba livia</i>	rock pigeon	201	+	+	+
<i>Psittacula krameri</i>	rose ringed parakeet	26	+	-	-
<i>Lanius schach</i>	Long tailed shrike	91	-	-	+
<i>Oenanthe pleschanka</i>	rufous tailed wheatear	13	-	-	+
<i>Tringa stagnatilis</i>	Marsh sandpiper	1	-	-	+
<i>Lophura nycthemera</i>	Silver pheasant	6	-	+	-
<i>Ficedula tricolor</i>	Slaty blue flycatcher	1	-	+	-
<i>Psittacula himalayana</i>	Slaty headed parakeet	52	-	+	-
<i>Megalaima viridis</i>	White cheeked barbet	10	+	-	-
<i>Streptopelia chinensis</i>	Spotted dove	49	+	+	-
<i>Enicurus maculatus</i>	Spotted forktail	2	-	-	+

Scientific names	Species	Number	Mandhala	Moolbari	MeGad
<i>Lonchura punctulata</i>	spotted munia	11	+	-	-
<i>Athene brama</i>	spotted owl	3	+	+	-
<i>Saxicola torquata</i>	Common stone chat	2	-	+	-
<i>Garrulax lineatus</i>	streaked laughing thrush	35	-	+	-
<i>Aethopyga gouldiae</i>	MRS Gould's Sunbird	1	+	-	-
<i>Orthohotomus sutorius</i>	tailor bird	8	-	+	-
<i>Dendrocitta vagabunda</i>	tree pie	15	+	-	-
<i>Sitta frontalis</i>	velvet fronted nuthatch	2	-	-	+
<i>Eumyias thalassina</i>	Verditer flycatcher	2	-	+	-
<i>Tichobroma muraria</i>	wallcreeper	2	-	+	-
<i>Chlidonias hybridus</i>	whiskered tern	1	-	-	+
<i>Lonchura malabarica</i>	Indian silverbill	2	+	-	-
<i>Dicrurus caerulescens</i>	white bellied drongo	4	+	-	-
<i>Halcyon smyrnensis</i>	White breasted kingfisher	12	+	+	-
<i>Chaimarrornis leucocephalus</i>	white capped redstart	5	-	-	+
<i>Zosterops palpebrosus</i>	White eye	24	+	+	-
<i>Parus nuchalis</i>	white naped tit	2	-	-	+
<i>Garrulax albogularis</i>	White throated laughing thrush	6	-	+	-
<i>Hirundo smithii</i>	wire tailed swallow	16	-	+	-
<i>Prinia flaviventris</i>	yellow bellied prinia	1	+	-	-
<i>Dendrocopos mahrattensis</i>	Yellow crowned woodpecker	1	-	+	-
<i>Chrysomma sinense</i>	yellow eyed babbler	4	+	-	-
<i>Carduelis spinoides</i>	Yellow breasted greenfinch	36	-	-	+
<i>Phoenicoptera treron</i>	Yellow footed green pigeon	4	+	-	-
<i>Motacilla flava</i>	yellow wagtail	15	-	-	+
<i>Acridotheres fuscus</i>	Jungle myna				

could be one of the reasons that majority of the amphibians observed from the regions are pool breeders dominated by *Euphlyctis cyanophlyctis*, *Microhyla ornata*, *Fejervarya* sp. and *Polypedates maculatus*. *Sphaerotheca breviceps*, a burrowing frog was observed in the dry beds of river. *Euphlyctis cyanophlyctis* was found in both streams as well as in pools. Moolbari watershed belongs to the mid Himalayan ranges and many streams originate forming a network. As it has higher elevation and more streams, frogs that breed in streams predominate the region. *Paa minica* was observed in almost all streams with water, and having canopy cover. In agriculture fields and forested areas, *Bufo himalayanus* and *Duttaphrynus melanostictus* were recorded. Altitude and extreme temperature in MeGad watershed appears inhospitable to amphibians as it is evident from their absence while recordings during this fieldwork.

Avifauna diversity and richness : Sampling was done following the standard protocol (Ali, 1989; Grimmet *et al.*, 1998; Laiolo, 2003) in different habitat types: forests, glacier, agriculture and forests, riverine, and agriculture. Habitatwise species richness is given in Table 8 for Moolbari, MeGad and Mandhala watersheds respectively. The distribution of bird species in the three watersheds is summarised in Table 9. Eight species of birds common to all three watersheds, in an altitude of 400 to 4000 m. 31 species common to Mandhala and

Moolbari watershed, in the altitudinal range of 400 to 2000 m. Nine species common to Moolbari and Me Gad Watersheds. The habitat wise study revealed that bird species richness is more in forest patches of Mandhala and MeGad Watersheds, whereas, forest and agriculture mixed habitats in Moolbari had more species. In total, 136 bird species were recorded in three watersheds. Mandhala watershed records highest number of species (105) followed by Moolbari (57) and Megad (35).

Conclusion

Mandhala, Moolbari, and Me Gad micro watersheds had a total of 2276 tree individuals from 75 woody species from 34 belt transects. A total of 38 families were recorded, of which Fabaceae had the highest number of species (7), followed by Rosaceae, Pinaceae and Moraceae (5 each). The highest number of individuals per species was *Quercus leucotriphora* with 811 individuals followed by *Q. glauca* (394), *Acacia catechu* (157), *Myrica esculenta* (73), *Pinus roxburghii* (72), *Abies pindrow* (70) and *Flacourtia indica* (68). Species richness was highest in Mandhala (45 species) followed by Moolbari (39) and MeGad (9). *Quercus* species dominated in the Moolbari watershed area, while deciduous species such as *Acacia catechu*, *Flacourtia indica* dominated in Mandala watershed. MeGad, a high altitude area was dominated by *Abies*

pinus, *Picea smithiana*, and *Pinus wallichiana*, which is reflected in the IVI values. Occurrence of perennial streams in the watershed dominated by native vegetation compared to the seasonal streams in monoculture plantations, highlight the need for appropriate watershed management strategies to ensure the sustenance of water.

115 butterfly species of oriental and palaearctic origin representing nine families. Nymphalidae is the dominant family (32 sp.) followed by Pieridae (19 sp.), Lycaenidae (16 sp.), Satyridae and Papilionidae (12 sp.

each), Hesperridae (10 sp.), Danaidae (8 sp.), Erycidae (4 sp.) and Acraeidae (2 sp.). 14 amphibian species were observed belonging to 5 families. Of the 5 families, Dicroglossidae represents 7 species, followed by Bufonidae (4) and Microhylidae, Ranidae and Rhacophoridae (1 species each). Six species are first reported from this study. Regarding bird diversity, 136 bird species were recorded in three watersheds. Mandhala watershed records highest number of species (105) followed by Moolbari (57) and Megad (35).

Acknowledgements

We are grateful to NRDMS Division, Ministry of Science and Technology (DST), Government of India for funding this project. We thank Dr. J.C.Rana, Dr. Pradeep, Dr. V.L. Verma, Dr. Archana Singh and Prashanth Bhasim of NBPGR for their immense helps as and when required. We thank the Director, Himachal Pradesh remote sensing agency and Mr.Thapa and other staff for providing us with valuable data. We also thank Dr. J.C.Sharma for providing us with a report on Mandhala soil types. We thank Mr.Rajesh Sharma, Block Development Officer at panchayat office, who took the trouble for us in procuring information related to people living below poverty line. Mr. R.S. Rathore and Mr.S.S. Thakur are acknowledged for their help in data collection at the Directorate of Agriculture, Shimla. D.F.O., Shimla Mr.Naresh Kumar, R.F.O. Mr. Dharmi and other staff for arranging visit to the forest areas and also for providing us with working plans and compartment history data.

पश्चिमी हिमालय के तीन सूक्ष्म जल संभरों की पारितंत्रीय स्थिति

टी.वी. रामचंद्र, एन.वी. जोशी, जी.आर. राव, जी. धनपाल, के.वी. गुरुराजा तथा अमित एस. यादव

सारांश

किसी भी क्षेत्र की पारितंत्रीय स्थिति का निर्धारण वहां की जैवविविधता और पर्यावरणीय स्थितियों की अन्तःक्रिया के आधार पर किया जाता है। पश्चिमी हिमालय के तुंगीय घटकों के सूक्ष्म जलसंभरों के जैवविविधता आकलन से पता चलता है कि पादप वैविध्य में 38 कुलों की 75 काष्ठीय प्रजातियों के 2276 एकल शामिल हैं। प्रजाति समृद्धि के मामले में तीन सूक्ष्म जलसंभरों में से मंधाला का स्थान प्रथम (43 प्रजातियां), मूलबाड़ी का स्थान द्वितीय (39 प्रजातियां) तथा मेगाड का स्थान तृतीय (9) है। मंधाला में अधिकांश प्रजातियां कंटीली झाड़ियां हैं। जो मानवीय क्रिया-कलापों के कारण वृक्ष का रूप कम ही ले पाती है। इनका आधार क्षेत्र भी कम रहता है। मूलबाड़ी का आधार क्षेत्र सर्वोच्च है। जिसमें मुख्यतः क्वेरकस ल्यूकोट्रिकोफोरा तथा क्वे. ग्लायुका पाये जाते हैं। मेलगड के उच्च तुंगीय भागों में मुख्यतः एबीस पिंडरो, पीसिया स्मिथियाना तथा पाइनस वाल्कियाना पाये जाते हैं।

जीव जन्तुओं में तितलियों की 115, उभयचरों की 14 तथा पक्षियों की 136 प्रजातियां पाई जाती हैं। इस क्षेत्र में पूर्वी और पुराजीवी तितलियों के नौ कुलों का प्रतिनिधित्व है। इसी प्रकार कार्यक्षेत्रीय खोजों के समय पांच कुलों के 14 उभरचर देखे गये। आई यू सी एन की स्थिति के अनुसार पा-माइनिका संवेदनशील है, अमोलोपस चक्राटेनिसिस का डाटा अपूर्ण है और ये दोनों हिमालय की तलहटियों में देशज हैं। तीन जलसंभरों में मंधाला (शिवालिक) में जीव-जन्तु वैविध्य सर्वाधिक है। जिसके बाद मूलबाड़ी का स्थान है। अगस्त-सितम्बर 2007 में मीगाड सूक्ष्म जल संभर में उभयचर नहीं देखे गये। तीनों जल संभरों में कुल 136 पक्षी प्रजातियां रिकार्ड की गईं। जिनमें से मंधाला में सर्वाधिक 104, मूलबाड़ी में 57 तथा मीगाड में 35 पक्षी प्रजातियां शामिल हैं।

References

- Adhikari, B.S. (1992). *Biomass, productivity and nutrient cycling of kharsu-oak and silver-fir forest in Central Himalaya*. Ph.D., Thesis, Kumaun University, Nainital, India.
- Adhikari, B.S., Rawat, Y.S. and Singh, S.P. (1995). Structure and function of High altitude forest of Central Himalaya I. Dry Matter Dynamics. *Ann. of Bot.*, **75**: 237-248.
- Ali, S. (1989). *Book of Indian Birds*, Second edition, Bombay Natural History Society publication, Mumbai.
- Arora, G.S., Mehta, H.S. and Walia, V. (2005). Insecta: Lepidoptera (Butterflies). In: *Fauna of Western Himalaya (Part-2)-Himachal Pradesh* (ed. Director), Zoological Survey of India, Kolkata, pp. 157-180.
- Aswal, B.S. and Mehrotra, B.N. (1994). *Flora of Lahaul-Spiti (A cold desert in North-West Himalaya)*. Bishen Singh Mahendra Pal Singh: Dehradun.

- Beebee, T.J.C. and Griffiths, R.A. (2005). The amphibian decline crisis: A watershed for conservation biology?, *Biological Conservation*, **125**: 271-285 doi:10.1016/j.biocon.2005.04.009
- Blair, R.B. and Launer, A.E. (1997). Butterfly diversity and human land use: Species assemblages along an urban gradient. *Biological Conservation*, **80**: 113-125.
- Champion, H.G. and Seth, S.K. (1968). *A Revised Survey of Forest Types of India*. Manager of Publications, Government of India, Delhi.
- Champion, H.G. (1921). The influence of hand of man on the distribution of forest in the Kumaun Himalaya. *Indian Forester*, **49**(3).
- Chowdhery, H.J. (1999). Himachal Pradesh In: *Floristic diversity and Conservation strategies in India*, Vol-2. (V.Mudgal, P.K. Hajra etd.). Botanical survey of India, Calcutta.
- Erhardt, A. (1985). Diurnal Lepidoptera: Sensitive indicators of cultivated and abandoned grassland. *Journal of Applied Ecology*, **22**: 849-861.
- Evans, W.H. (1932). *The Identification of Indian Butterflies*, 2nd ed., 454 pp., 32 pls. Bombay Natural History Society, Bombay.
- Frost, D.R., Grant, T., Faivovich, J., Bain, R.H., Haas, A., Haddad, C.F.B., De Sá, R.A., Channing, A., Wilkinson, M., Donnellan, S.C., Raxworthy, C.J., Campbell, J.A., Blotto, B.L., Moler, P., Drewes, R.C., Nussbaum, R.A., Lynch, J.D., Green, D.M., Wheeler, W.C. (2006). The Amphibian Tree of Life. *Bull Amer Mus Nat Hist*, **297**: 1-370.
- Gaston, A.J., Garson, P.J. and Hunter, M.L. (1983). The status and conservation of forest wildlife in Himachal Pradesh, Western Himalayas, *Biological Conservation*, **29**: 291-314
- Grimmet, R., Inskipp, C. and Inskipp, T. (1998). *Birds of the Indian Subcontinent*, Oxford University Press, Oxford, UK.
- Kim, K. C. (1993). Biodiversity, conservation, and inventory: Why insects matter, *Biodiversity and Conservation*, **2**: 191-214.
- Kremen, C. (1992). Assessing the indicator properties of species assemblages for natural areas monitoring, *Ecological Applications*, **2**: 203-217.
- Laiolo, P. (2003). Diversity and structure of the bird community overwintering in the Himalayan subalpine zone: is conservation compatible with tourism?, *Biological Conservation*, **115**: 251-262
- Leps, J. and Spitzer, K. (1990). Ecological determinants of butterfly communities (Lepidoptera, Papilionidae) in the Tam Dao Mountains, Vietnam. *Acta Entomologica Bohemoslovaca*, **87**: 182-194.
- Lodhiyal, L.S. (1990). *Structure and functioning of Popular plantation in Tarai belt of Kumaun Himalaya*. Ph.D., Thesis, Kumaun University, Nainital.
- Manel, S.P., Diasx, J.M., Buckton, S.T. and Ormerod, S.J. (1999). Alternative methods for predicting species distribution: an illustration with Himalayan river birds, *Journal of Applied Ecology*, **39**: 734-747
- Mani, M.S. (1986). *Butterflies of the Himalaya*, Oxford and IBH Publishing Co. New Delhi.
- Mehta, H.S. (2005a). *Fauna of Western Himalaya* (Part 2) Himachal Pradesh, Zoological Survey of India, Kolkata. pp
- Mehta, H.S. (2005b). *Amphibia*. In: *Fauna of Western Himalaya* (Part 2) Himachal Pradesh, Zoological Survey of India, Kolkata.
- Molina, J.M. and Palma, J.M. (1996). Butterfly diversity and rarity within selected habitats of western Andalusia, Spain (Lepidoptera: Papilionoidea and Hesperioidea), *Nota Lepidopterologica*, **78**: 267-280.
- Murti, S.K. (2001). *Flora of Cold Deserts of Western Himalaya*: Vol-1, Botanical survey of India, Calcutta.
- Negi, K.S. (1979). *Species composition, biomass structure and nutrient relation of an oak forest*. Ph.D, Thesis, Kumaun University, Nainital.
- New, T.R. (1991). *Butterfly Conservation*. Oxford University Press, South Melbourne, Australia.
- New, T.R., Pyle, R.M., Thomas, J.A., Thomas, C.D. and Hammond, P.C. (1995). Butterfly Conservation Management, *Annual Review of Entomology*, **40**: 57-83.
- Osmaston, A.E. (1923). Notes on Forest Communities of Garhwal Himalaya. *J. Ecol.*, **10**: 129-167.
- Parmesan, C. (1996). Climate and species range, *Nature*, **382**: 765-766.
- Pollard, E. and Yates, T.J. (1993). *Monitoring Butterflies for Ecology and Conservation*, Chapman and Hall, London.
- Puri, G.S. (1960). *Indian Forest Ecology*. Vol. I, Oxford Book and Stationery Co., New Delhi.
- Ralhan, P.K., Saxena, A.K. and Singh, J.S. (1982). Analysis of forest vegetation at and around Nainital in Kumaun Himalaya. *Proc. Indian Nat. Sci. Acad.*, **48**: 121-137
- Ramachandra, T.V., Subash Chandran, M D., Gururaja, K. V. and Sreekantha, (2007). *Cumulative Environmental Impact Assessment*, Nova Science Publishers, New York.
- Rana, J.C., Archana singh, Yogendra Sharma, K., Pradeep and Nisha Mendiratta, (2010). Diversity of plant bioresources in Western Himalayan region of India, *Current Science*, **98**(2):192-203
- Rawal, R.S. (1991). *Woody vegetation analysis along an elevational gradient (1600-3400 m) of upper Sarju catchment, Kumaun Himalaya*. Ph.D., Thesis, Kumaun University, Nainital.
- Reddy, V.S. (1989). *Analysis of soil and vegetation of landslides damage and undamaged sites in Kumaun Himalaya*. A study on recovery of forest ecosystem. Ph.D., Thesis, Kumaun University, Nainital.

- Rikhari, H.C., Chandra, R. and Singh, S.P. (1989). Pattern of species distribution and community along a moisture gradient within an Oak zone of Kumaun Himalay. *Proc. Indian Natn. Sci. Acad.*, **55**: 876-880.
- Samways, M.J. (1994). *Insect Conservation Biology*, Chapman and Hall, London.
- Saxena, A.K. (1979). *Ecology of complete of north western catchment of the river Gola*. Ph.D., Thesis, Kumaun University, Nainital.
- Saxena, A.K. and Singh, J.S. (1982a). A phytosociological analysis of woody species in forest communities of part of Kumaun Himalaya. *Vegetatio*, **50**: 3-22.
- Saxena, A.K. and Singh, J.S. (1982b). Quantitative profile structure of certain forest in the Kumaun Himalaya. *Proc. Indian Acad. Sci.*, **91**: 529-549.
- Schweinfurth, U. (1957). Die horizontale und. vertike verbreitung der vegetation in Himalaya. *Bonner. Geogr. Abh.*, **20**: 201-372
- Scoble, M.J. (1992). *The Lepidoptera: Form, Function and Diversity*, Oxford University Press, New York.
- Singh, J.S. and Singh, S.P. (1987). Forest Vegetation of the Himalaya. *Bot. Rev.* **53** (1): 80-192.
- Singh, J.S. and Singh, S.P. (1984a). *An integrated ecological study of eastern Kumaun Himalaya with emphasis on natural ecological resources*. Vol. I. Studies with regional perspective. Final report (HCS/DST/187/76). Kumaun university, Nainital.
- Singh, J.S. and Singh, S.P. (1984b). *An integrated ecological study of eastern Kumaun Himalaya with emphasis on natural ecological resources*. Vol. II. Site specific studies. Final report (HCS/DST/187/76). Kumaun university, Nainital.
- Singh, J.S. and Singh, S.P. (1984c). *An integrated ecological study of eastern Kumaun Himalaya with emphasis on natural resources*. Vol. 3 syn. Thesis and summary. Final report (HCS/DST/187/76). Kumaun University, Nainital.
- Singh, S.K. and Rawat, G. S. (1999). *Floral diversity and vegetation structure in Great Himalayan National Park*, Wildlife Institute of India, Dehra Dun
- Singh, S.P., Khana, R. K. and Singh, J.S. (1985). Accumulation in wood: A nutrient conservation strategy of tropical forest. *Environ. Conserv.*, **12**: 170-173.
- Spitzer, K., Jaros, J., Havelka, J. and Leps, J. (1997). Effect of small-scale disturbance on butterfly communities of an Indochinese montane rainforest, *Biological Conservation*, **80**: 9-15.
- Stork, N.E., Srivastava, D.S., Watt, A.D. and Larsen, T.B. (2003). Butterfly diversity and silvicultural practice in lowland rainforests of Cameroon, *Biodiversity and. Conservation*, **12**: 387-410.
- Swengel, A.B. (1996). Effects of fire and hay management on abundance of prairie butterflies, *Biological Conservation*, **85**(2): 73-85.
- Tewari, J.C. (1982). *Vegetational analysis along altitudinal gradients around Nainital*. Ph.D., Thesis, Kumaun University, Nainital.
- Thomas, C.D. and Malorie, H.C. (1985). Rarity, species richness, and conservation: Butterflies of the Atlas Mountains in Morocco, *Biological Conservation*, **33**: 95-117.
- Tiwari, J.C. and Singh J.S. (1985). Mapping forest Biomass in India through aerial photographs and non destructive field sampling. *Appl. Geogr.*, **4**: 151-165.
- Tiwari, J.C. Rikhari, H.C. and Singh, S.P. (1989). Composition and structure feature of certain tree stands along an elevational gradient in Central Himalaya. *Vegetatio*, **85**: 117-120.
- Troup, R.S. (1921). *Silviculture of Indian Trees*. Vol. I-III. Clarendon Press, Oxford.
- Upreti, N., Tewari, J.C. and Singh, S.P. (1985). The Oak forest of the Kumaun Himalaya (India): Composition, diversity and regeneration. *Mountain Res. and Dev.*, **5**(2): 163-174.
- Wood, P.A. and Samways, M.J. (1992). Landscape element pattern and continuity of butterfly flight paths in an ecologically landscaped botanic garden, Natal, South Africa, *Biological Conservation*, **58**: 149-166.
- Wynter-Blyth, M.A. (1940-1946). A list of the butterflies of the Shimla hills, *Journal of Bombay Natural History Society.*, **41**: 716-741; 1945, **45**: 256-257; 1946, **46**: 735-736.
- Wynter-Blyth, M.A. (1957). *Butterflies of the Indian Region*, pp.523, 1-72 plates. Bombay Natural History Society, Bombay.